# WATER FOOTPRINT OF AN ORGANIC VINEYARD IN MEDITERRANEAN REGION

**G. Tsitselis*, O. Lamnatou, G. Zagklis, S. Kavasilis, D. Dimou, M. K. Doula**

Laboratory of Non-Parasitic Diseases, Benaki Phytopathological Institute, 8 Stef. Delta, 14561 Kifissia, Greece

(g.tsitselis@bpi.gr)

## ABSTRACT

Southern European countries use the largest percentages of abstracted water for agriculture. From the average of 44% of total water abstraction in Europe which is used for agriculture, more than two-thirds is used by the southern European countries. The Common Agricultural Policy supports investments to conserve water, improve irrigation infrastructures and enable farmers to improve irrigation techniques. Targeted actions are needed to decrease overconsumption and to inform and guide farmers to implement sustainable irrigation practices. Water Footprint (WF) of cultivated crops is one step to this target to define the background status of water consumption and then setup targets for optimizing irrigation schemes. Especially for the Mediterranean region and the Greek conditions in particular, this would be a very useful tool taking into account the unequal distribution of the availability of water resources and the unequal demand for water between large areas. The present work was conducted in the framework of the LIFE project entitled "Innovative technologies for climate change mitigation by the Mediterranean agricultural sector-ClimaMED" and implemented at an organic vineyard in Heraklion, Crete, Greece, aiming to estimate WF, by calculating the three WF components, i.e. Green, Blue and Grey Water Footprint.

## KEYWORDS

Mediterranean region, Organic vineyard, Water footprint, Water scarcity

## 1. INTRODUCTION

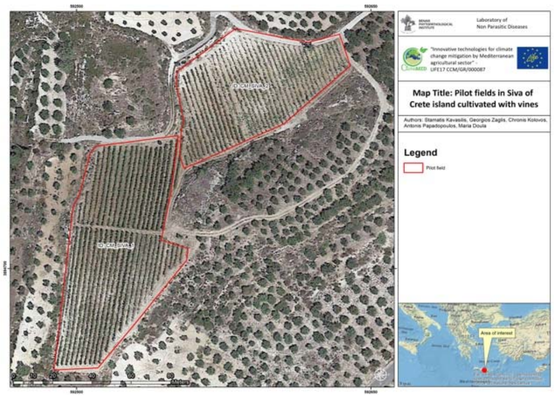
In recent years, climate change, world population growth and industrialization have placed considerable stress on the local availability of water resources. One of the indicators that is widely recognized to support better water management is Water Footprint (WF)[1]. The WF has been developed within the water resources research community as a volumetric measure of freshwater availability. The concept is used to assess water use along supply chains, sustainability of water use within river basins, efficiency of water use, equitability of water allocation and dependency on water in the supply chain[2]. Agriculture is one of the main causes of water consumption and degradation[3]. It has a strong influence on water demand and the scarcity of water, which affects the balance of entire production areas. Global water resources are widely used for food production; some areas of the Mediterranean are scarce in water and the water demand is expected to increase in the future due to population growth [3]. Assessing agriculture's sustainability is important to determine how the current use of water resources can affect their availability in the future and to safeguard their quantity and quality [4]. Among other activities, irrigation is the dominant one, leading to water stress, with environmental consequences on local, regional and global level[5]. Irrigated agriculture constitutes the largest consumer of freshwater in the Mediterranean region and provides a major source of income and employment for rural livelihoods. However, increasing droughts and water scarcity have highlighted concerns regarding the environmental sustainability of agriculture in the region[6]. Grapes are the most widely grown commercial fruit crop in the world, and also one of the most popular fruit crops for horticultural production. Grape growers constantly search for the means to maximize their profits all over the world [7].

According to studies conducted by the Greek Institute of Geology and Mineral Exploration Management (IGMEM), Greece uses the highest percentage of its water on crop irrigation (86%), compared to other Mediterranean countries such as Portugal https://greece.greekreporter.com/?s=Portugal and Spain.

The present study was conducted in the framework of the LIFE ClimaMED project [8] and aims to estimate the WF of an organic vineyard in Crete, Greece by taking into account meteorological data and data provided by the farmer.

## 2. METHODOLOGY

The study area was a 10 years old organic multivariate vineyard of 1 ha, located at Kerasia village, Heraklion, Crete (Map 1). The vines are rarely irrigated by using drilling water through a drip irrigation system. Composts and well stabilized manures are used for fertilization, while no phytoprotective means are applied.




*Map 1. The pilot vineyard in Crete*

As regards our study, a meteorological station for the measurements of air temperature, solar radiation, relative humidity, rainfall and soil moisture and temperature was installed at the field while field data was collected (i.e. quantity of irrigation water, type and amount of soil additives) during one cultivation period. Using the program STATA, the monthly minimum and maximum values of air temperature, relative humidity and solar radiation were retrieved. Additionally, the monthly rainfall totals for the cultivation period (July 2019-June 2020) were computed.

For the estimation of WF, the method of Hoekstra [9] was implemented, which is represented in the equation [1] below:

$$WF = WF_{green} + WF_{blue} + WF_{grey} \quad [1]$$

The $WF_{green}$, which is defined by the meteorological data, soil characteristics and the type of the crop, is calculated as the total volume of crop evapotranspiration (ETc) of the reporting period (Equation [2]).

$$WF_{green} = \sum ETc \quad [2]$$

For the estimation of $WF_{green}$ as crop evapotranspiration is considered the minimum volume of water between the calculated ETc and the effective precipitation. The effective precipitation of the vineyard was assumed to be the 80% of the total rainfall of the cultivation period, excluding deep filtration and surface runoff [9]. Crop evapotranspiration is determined by the following equation:

$$ETc = Kc \cdot ETo \quad [3]$$

where $ET_0$ indicates the evapotranspiration of reference (i.e. the evapotranspiration rate of a reference plant covered surface, adequately supplied with water) and Kc the crop coefficient, which incorporates crop characteristics and averaged effects of evaporation from the soil.

$ET_0$ for the cultivation period was estimated by utilizing the ETo calculator of the Food and Agriculture Organization of the United Nations - Land and Water Division (FAO) [10].

Kc incorporates all the characteristics that differentiate the cultivation of interest (grapes in this study) from the reference plant covered surface such as the height of the cultivation and its reflection coefficient (albedo). Kc is also affected by the different growth stages and was estimated for every month, using literature data [11] and empirical knowledge for grapes grown under Mediterranean climate conditions (Fig. 1).

The blue water, i.e. the difference between the crop evapotranspiration and the effective precipitation, represents the need of a crop for fresh irrigating water. This is the theoretical $WF_{blue}$ of the cultivation, meaning that under balanced irrigation practices, the farmers after considering the green water retained by the cultivation from rainfall, they have to calculate the additional water amount required (which is blue water) in order to satisfy the water demands. However, due to water shortage most of the cultivations are irrigated with less water than demanded.

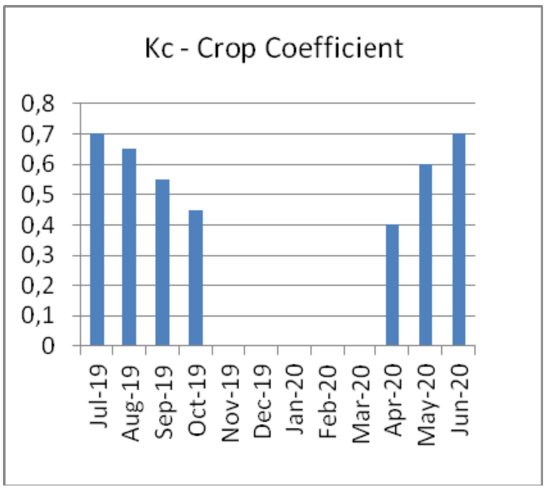



*Figure 1. Grapes crop coefficient (Kc) variation during one cultivation period*

However, the real blue water footprint is the amount of irrigation water finally applied by the farmer, which for the case of the vineyard of this study is seen in Fig. 2.

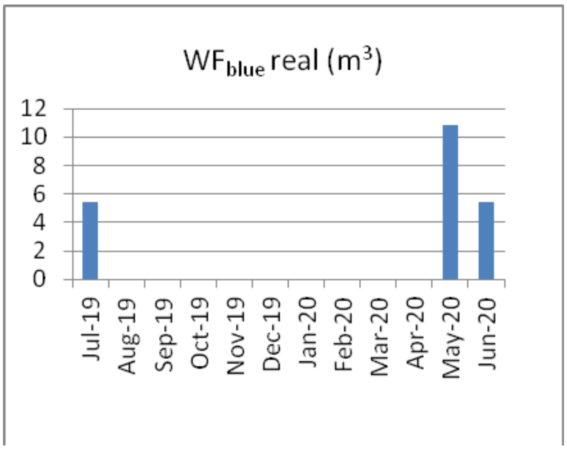



*Figure 2. The real $WF_{blue}$ during the cultivation period of the pilot vineyard in Crete.*

The grey water footprint is the water amount needed to dilute the load of pollutants and defines the freshwater pollution. The $WF_{grey}$ is computed as the sum of two contributions: the direct and the indirect $WF_{grey}$[12]. The direct $WF_{grey}$ is defined as the virtual water needed to dilute fertilizers and treatments applied at field, while the indirect is defined as the volume needed to dilute the emission of pollutants in water during all the processes involved in the product life cycle, except the use of fertilizers and treatments. In our study we considered both direct and indirect $WF_{grey}$ as zero since no mineral fertilizers are applied on soil, practice that contributes to nitrate pollution of water. As regards organic fertilization, this is also not considered to contribute to water pollution since the mineralization rate of nitrogen contained in well stabilized organic materials is limited. Thus, pollution due to leaching processes is considered to be minimal and therefore not considered in this study. As regards the indirect grey water, this is also not the case of this study, since data collected refers only to field data, i.e. before grapes transportation to the winery, and all practices that may contribute to $WF_{grey}$ are minimal.

## 3. RESULTS AND DISCUSSION

Figure 3 presents the $WF_{green}$ and the $WF_{blue}$

(theoretical and real) as estimated for the pilot vineyard in Crete.

The total estimated $WF_{green}$ is 700.2m$^3$; the theoretically $WF_{blue}$ is 4,483m$^3$ and the real $WF_{blue}$ is 21,6m$^3$.

Therefore, the total (real) WF of the cultivation is 721.8m$^3$. Considering that fresh yield of the studied period was 8tn/ha, then the WF is 90.2 m$^3$/tn of fresh grapes. This value is very low compared to the literature and this is because the pilot vineyard is cultivated under inputs limitation, included water.

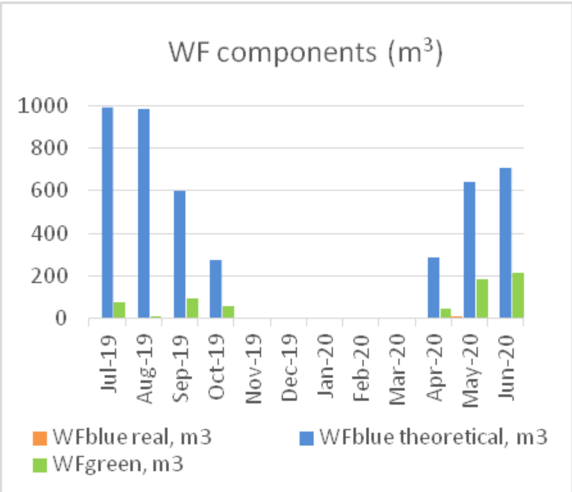



*Figure3. WF components in the organic vineyard throughout the cultivation period*

However, if we consider that the farmer irrigates the cultivation regularly and provides the required water according to the losses due to evapotranspiration, then the WF would be 5,18.2m$^3$ (i.e. the sum of $WF_{green}$ and of the theoretical $WF_{blue}$), which corresponds to approximately 648m$^3$/tn of grapes, which is close to global average of 608 m$^3$/tn according to Mekonnen and Hoekstra[13,14].

Therefore, the main WF component for the pilot vineyard is the green one due to the small amount of water applied with irrigation. This practice, although it results to lower yield (up to 20%) is a common practice in order to control the organoleptic characteristics of the grapes (e.g. increased soluble sugars) and consequently of the produced wine. Grapes cultivation in Italy is a similar case, i.e. from the 488 L water per kg of fresh fruit on average, 76% corresponds to green water, 7% corresponds to blue water, and 17% corresponds to grey water [14].

## 4. CONCLUSIONS

In the arid and semi-arid areas such as those in the island of Crete, the correct management of water is of fundamental importance for the sustainable and continuous growth of high-quality products. Taking into consideration that the predictions for effective precipitation are ominous such an indicator is valuable for sustainable water use. Water footprints (WFs) are a tool of great significance thus they are being increasingly used to indicate the impacts of water use by production systems. To this direction, the quantification of water use in the organic vineyard is valuable, not only from the environmental point of view, but also in order to monitor water needs and consumption during the cultivation stage as well as the organoleptic characteristics of the crops.

Similar as in other studies, this study demonstrates that the main component of the vineyard's water footprint is the green one. This happens due to the small amount of water applied with irrigation. However, this limited applied quantity of water does not act as an inhibitor for the qualitative and quantitative production of the vineyard. The production of 8tn/ha is only 20% decreased compared with a fully irrigated vineyard in the same region. This practice leads to the production of grapes with specific organoleptic characteristics (e.g. increased soluble sugars) and consequently of the produced wine. However, Med small producers are far from an integrated cultivation management approach, which comprises monitoring of all available resources (water, soil nutrients, other inputs) targeting to the production of grapes and wine of high quality and of low environmental profile.

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