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IR2MA
Large Scale Irrigation Management Tools for Sustainable Water Management in Rural Areas and Protection of Receiving Aquatic Ecosystems

Subsidy Contract No: I1/2.3/27

WP5

Deliverable 5.3.3

Applied research and demonstration activities on the improvement of irrigation scheduling for open field crops

Project co-funded by
European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy

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Subsidy Contract No: I1/2.3/27

Partners

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PB5 CONSORZIO PER LA BONIFICA DELLA CAPITANATA (CBC) http://consorzio.fg.it/

Associated partners

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Project co-funded by European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy

Notes

Deliverable 5.3.3 - Applied research and demonstration activities on the improvement of irrigation scheduling for open field crops.

Involved partners:

Institute of Sciences of Food Production (ISPA) National Council of Research (CNR).

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Project Summary

The main objectives of the InterregIR2MA project are the implementation of advanced smart decision support systems (DSS) for irrigation management, the definition of optimal strategies for the reuse of treated wastewaters for the production of safe and high-quality horticultural products, as well as the dissemination of technological solutions suitable for optimizing water resource uses.
The project involves for the Italian side the Institute of Sciences of Food Production, National Council of Research (CNR-ISPA), Consorzio di Bonifica della Capitanata (CBC), the Mediterranean Agronomic Institute of Bari (CIHEAMB) and Puglia Region as Associate partner, while on the Greek side the University of Ioannina and the Region of Epirus.
Among the several ways to use water, irrigation represents the largest quantity (even up to 70% of the total used volume). Therefore, considering the problem of the climate changes and their effects on the future scenarios in agriculture, it is essential to put in place suitable strategies for optimizing the irrigation practice, avoiding water reservoir pollution and contamination and, where possible, taking advantage of unconventional water usage, for example by reusing wastewater.

Foreword

This report contains a description of the activities carried out by CNR-ISPA in the framework of IR2MA project WP5 - Specialized research actions, Deliverable 5.3.3 - Applied research and demonstration activities on the improvement of irrigation scheduling for open field crops.

The activities focused to evaluate the degree of satisfaction of the irrigation needs of the area of an irrigation district falling within the wider area of the 'Consorzio per la Bonifica della Capitanata', to undertake initiatives to make up for any water resource deficit such as the reprogramming of crops and / or the use of additional water resources such as waste water. The analysis focused on data referring to years 2016 and 2017, kindly provided by CBC (PB5).

The main results highlight the need to replan the crops to be included annually in crop rotation, taking into account that the high incidence of tree crops makes this initiative less flexible. Therefore, it would be very useful to encourage the use of additional water resources such as waste water.

1. Introduction

Population of the world is expected to substantially increase from 7 billion to 9 billion for the upcoming 30 years, in line with that the food requirements would increase about 50% in order to meet the population growth. Therefore, for the decades to come, the increase the agricultural productivity and transforming our agricultural systems to sustainable and secure will be among the main tasks.

Serious climatic change along with water scarcity are expected to soar in terms of magnitude and frequency and spatial extend as a result of climate change, in addition to that agriculture is one of the main sources of water degradation and consumption. Auditing and assessing its sustainability is very important in order to determine how the current use of water resources can affect their availability in the future and to protect their quantity and quality.

World is projected to experience warming exceeding global trends, with most climate change scenarios also resulting in reduced water availability (Chenoweth et al., 2011). Water scarcity is likely to pose severe limitations to the agricultural sector in the future, as numerous countries risk not being able to meet irrigation requirements (Fader et al., 2016). Already today, freshwater resources in the region are being extracted at unsustainable rates, not allowing for natural replenishment (FAO, 2016). However, improved irrigation efficiency and a shift to crops with lower irrigation demands could considerably lower the requirement for irrigation water withdrawal in the region (Daccache et al., 2014)

Agriculture, the dominant consumer of freshwater resources, is now a days facing a new approach, that is to protect integrity of water resources. This approach can be achieved by three strategies: (1) accurate determination of crop water requirements and development of physical and biological criteria. This will result in better control of water supply, thus, save the water resources (Katerji et al., 2008). (2) to improve the performance of the irrigation system (Pereira et al., 2002) . (3) To enhance the efficiency of water use of plant varieties and species.

High effectiveness irrigation services leads the environment toward sustainable and productive agriculture, develop a vital system for employment and income, and keep the people out of poverty. The opposite result from poorly managed irrigation. Performance assessment is the observation, documentation and interpretation of practices associated to irrigation for the purpose of improvement of efficiency (Molden et al., 2007).

In addition to pervious strategies water resources management in semi-arid areas calls for solutions able to provide responses to the decrease of available resources as effect of, among others, climate change (Vergine et al., 2015) and to ensure the sustainability of water uses, mainly in agriculture (D'Agostino et al., 2014). In this perspective, reuse of treated wastewater is recognized as a key component for its ability to satisfy the increasing demand while mitigating environmental pollution (Qadir et al., 2010). However, the worldwide amount of treated wastewater reuse is still very small (less than 1%) compared to the total withdrawal of water (Bucknall, 2007).

Wastewater has been used as a source of irrigation water for centuries. In addition to providing a low cost water source, the use of treated wastewater for irrigation in agriculture combines three advantages. First, using the fertilizing properties of the water (fertirrigation) eliminates part of the demand for synthetic fertilizers and contributes to decrease the level of nutrients in rivers. Second, the practice increases the available agricultural water resources and third, it may eliminate the need for expensive tertiary treatment (Angelakis et al., 1999).

In light of the considerations described above, the objective of this study was to evaluate for the years 2016 and 2017 the degree of satisfaction of the irrigation needs of the entire area of an irrigation district falling within the wider area of the ‘Consorzio per la Bonifica della Capitanata’, to undertake initiatives to make up for any water resource deficit such as the reprogramming of crops and / or the use of additional water resources such as waste water. The work is part of the Master's thesis in 'Land and Water Resources Management: irrigated agriculture' carried out at the CIHEAM in Bari as part of the IR2MA project, carried out in collaboration with the CNR-ISPA and the "Consorzio per la Bonifica della Capitanata" (Anas, 2019).

2. Description of the Sinistra Ofanto irrigation scheme.

The study area is district 17 of the “Consorzio per la Bonifica della Capitanata”, which is located in Sinistra Ofanto irrigation scheme.

The “Sinistra Ofanto” irrigation scheme is located in the south-eastern part of the province of Foggia, Apulia region, Southern Italy (Figure 1). The irrigation scheme extends along the left part of the river of Ofanto for a total area of 40,500 ha of which, 38,815 ha are irrigable and 28,165 ha are under irrigation. The entire irrigation scheme is supplied by the waters coming from the Ofanto River, which relates to three regions (Basilicata, Apulia and Campania). The “Sinistra Ofanto” structure is managed and controlled by “Consorzio per la Bonifica della Capitanata”, referred to as CBC, which is a local water users’ organization (WUO). This large-scale irrigation scheme was constructed in the period 1980’s, in order to be operated as on-demand delivery schedule, using the pressure generated either by pumping or gravity. Nevertheless, in dry years during peak-demand periods, these schedules had to be switched to arranged demand (Lamaddalena et al., 1995; Lamaddalena, 1996).

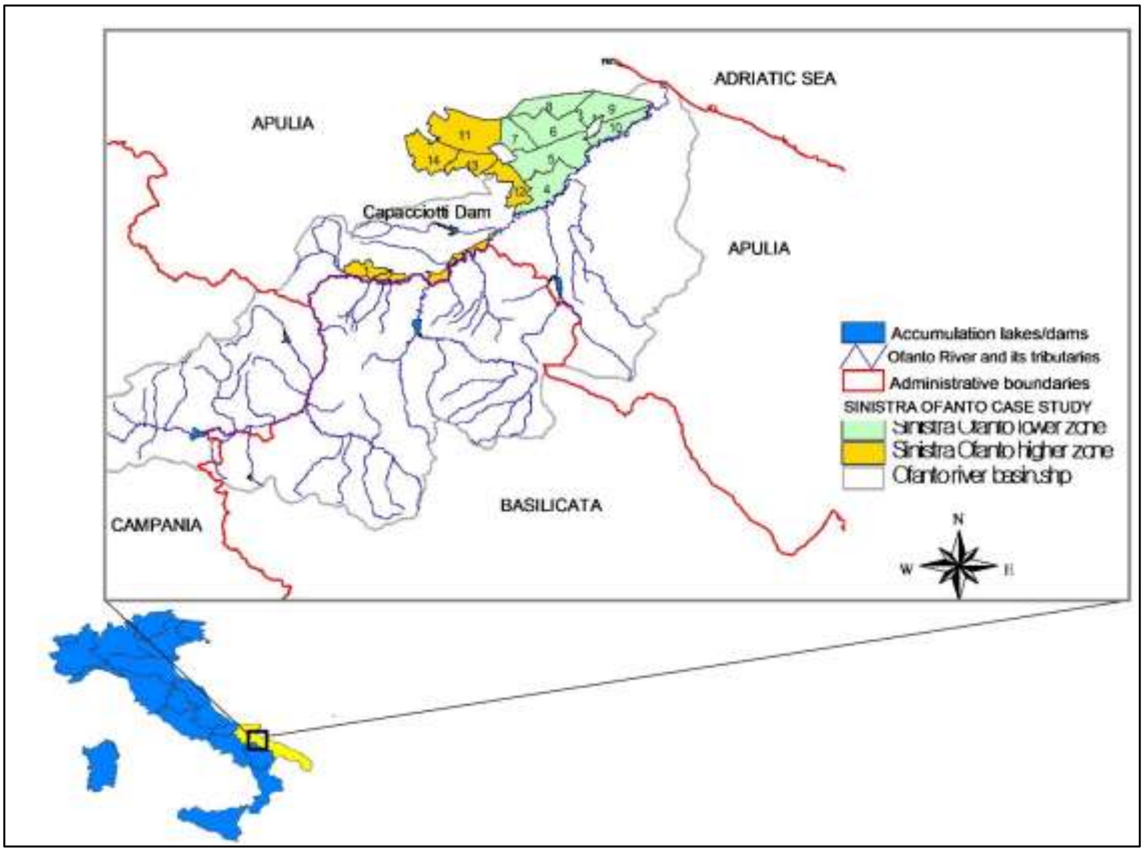

Figure 1. Location of the Sinistra Ofanto irrigation scheme within the Ofanto River Basin

The topographic features of the irrigation area are a flat plain, with two slope directions, the first one towards the Adriatic Sea (West-East), and the other towards the Ofanto River (North-South). Streams with seasonal regimes (fall-winter-spring), mainly result from rainfall intensities, compose the hydrography of the area.

The system is partitioned into seventeen districts (1-17), where each district subdivided into sectors each with a surface area ranging from 20 to 300 ha. A storage and daily compensating reservoirs which are fed by a conveyance pipe coming from Capacciotti dam serve the irrigation districts (Figure 1). The pressurized irrigation network in each district begins from those reservoirs and is designed for on-demand delivery schedule. The irrigation scheme of Sinistra Ofanto is dominated by Marana Capacciotti dam and the Ofanto watershed. The conveyance system is a branched one, with a small part as open channel and its vast majority is pressurized pipes supplying the reservoirs that, thus, supply water to the districts. The estimated available water resources of the Sinistra Ofanto district is 76 Mm^3, with a capability of 2,000 m^3/ha which permits to feed the water to an irrigable area of 38,000 hectares. The scheme operates using 10 accumulation reservoirs with a value of daily compensation of 20,000-40,000 m^3. Moreover, three pumping stations with a total power of 1,520 KW, convey the water to highest areas.

Pumping systems serve about 13,650 ha, while the reaming surface (24,737 ha) is being operated by gravity. The distribution network consists of roughly 2000 km either of PVC for small sections where the diameter is between 90 and 350 mm, or fiber cement pipes. The distribution pipelines within each district are buried and carry the water to the needed point. The farms among each sector is being served by the sectoral distribution network. At each sector, a control unit has been installed consisting of a gate valve, a flow regulator and a flow meter, so that a flow of 10 L/s and a pressure of 20 m are guaranteed. The irrigation season is considered to extend from 1st March to the end of November. The major crops are tree crops as vineyards (42%), olive trees (27%) and mixed orchards (5%), then vegetables (15%, mainly artichoke and asparagus) and industrial crops (6%).

2.1. Description of district number 17

2.1.1. General background

The irrigation district number 17 is in the surrounding of Trinitapoli, nearby the Bari-Foggia railway and has an area of about 900 ha. The district is located in the northern part of the lower zone of Sinistra Ofanto irrigation scheme as shown in Figure 2. Twelve sectors are included in the district that represent the divisions served by the irrigation network and the irrigation services (Figure). The area and the area percentage of each sector in the district are shown in Figure . The surface area of the sectors ranges from 32 (Sector 6) to 138 ha (Sector 1), while the mean value of the sectors area is 77 ha.

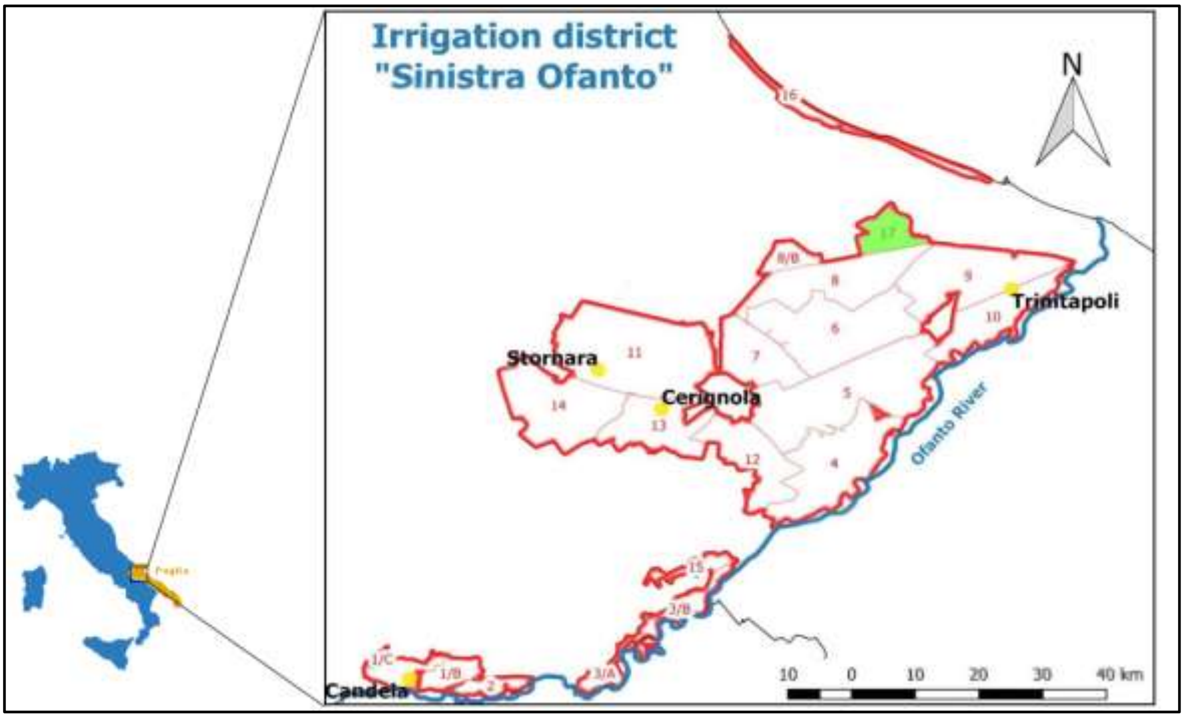

Figure 2. Location of district 17 within Sinista Ofanto irrigation scheme.

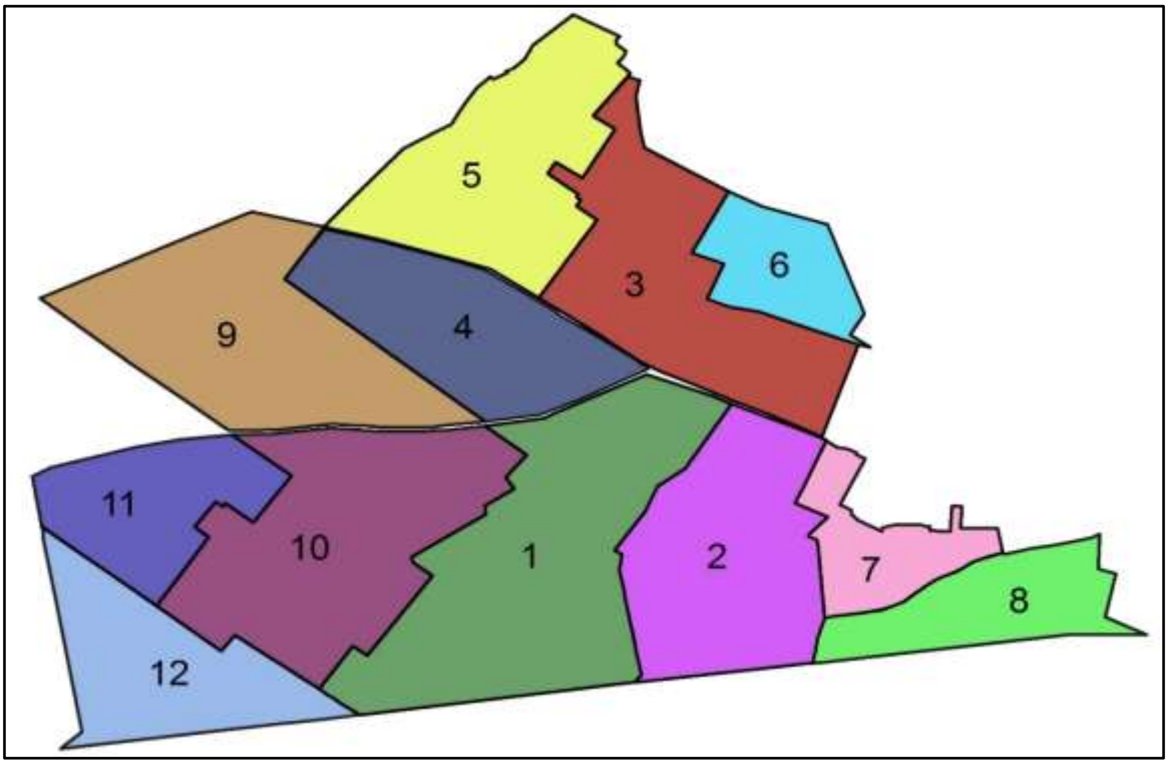

Figure 3. Sectors of district 17.

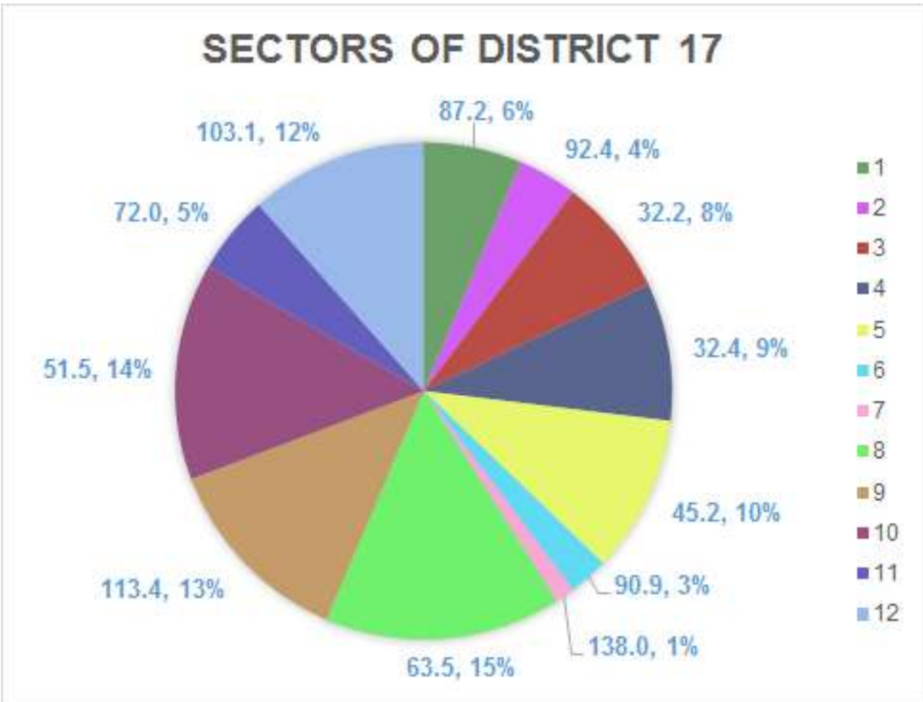

Figure 4. The area and percentage of each secor in district 17.

2.1.2 Climate

According to Caliandro et al. (2005), the climate in general is Mediterranean. In particular, the climate is characterized by a high annual water deficit (675 mm), by low annual total rainfall (526 mm) and in the summer months (<30 mm), by a wide dry period, between the second half of May and the mid-

September, with average annual minimum and maximum temperatures of 10.9 and 20.5 ° C, respectively. The peak temperature happens through July and August, and sometimes can record 40 °C. The winds those blow from the north are winter predominant winds, while those blow from south-west are fluctuating during the summer period. The approximated mean speed of wind is 1 m/s with more strength after midday. The average daily value of reference evapotranspiration is 2.5 mm, which result in an average yearly evapotranspiration of around 900 mm. Table shows monthly average climatic attributes (evaporation, rainfall, temperature, relative humidity, wind speed) for five years (2012 – 2016), obtained from "Finocchio" station (41°19'16.22'' LN; 16°07'45.25'' LE; Altitude, 16 m a.s.l.).

Table 1. Monthly average climatic attributes (Average year)

Month	Evaporation	Rainfall	Temperature (°C)			Relative Humidity (%)			Radiation	Wind
	(mm)	(mm)	max	min	Avg	max	min	Avg	cal/cm^2/d	km/d
Jan	15.8	39.1	12.5	3.1	7.3	97.1	62.0	83.4	160.0	79.7
Feb	24.9	51.2	13.2	3.7	8.1	97.4	62.8	83.7	218.0	98.2
Mar	49.1	57.6	16.1	5.7	10.7	97.0	57.4	80.5	328.4	111.1
Apr	78.7	45.0	20.3	8.7	14.3	94.7	49.7	74.5	453.1	107.8
May	110.3	40.0	24.0	11.7	17.9	93.5	45.3	70.1	543.7	110.1
Jun	136.7	31.2	28.9	16.0	22.5	89.3	42.9	66.1	622.1	95.3
Jul	151.0	10.6	32.1	18.7	25.3	88.4	39.6	64.3	618.1	91.7
Aug	131.2	29.9	31.7	18.7	24.8	92.4	43.2	69.0	548.9	92.7
Sep	77.2	75.9	26.8	15.0	20.3	97.8	52.6	79.9	397.8	76.9
Oct	40.5	41.3	22.2	11.6	16.2	99.6	65.8	88.6	259.3	60.7
Nov	20.5	89.0	18.1	8.2	12.5	98.9	68.6	88.7	177.3	74.9
Dec	13.1	33.9	13.5	3.5	7.6	98.9	66.4	88.6	152.2	80.6
Average	**849.2**	**544.5**	**21.6**	**10.4**	**15.6**	**95.4**	**54.7**	**78.1**	**373.3**	**90.0**

Figure shows the variation of maximum, minimum and average temperature values for the average years.

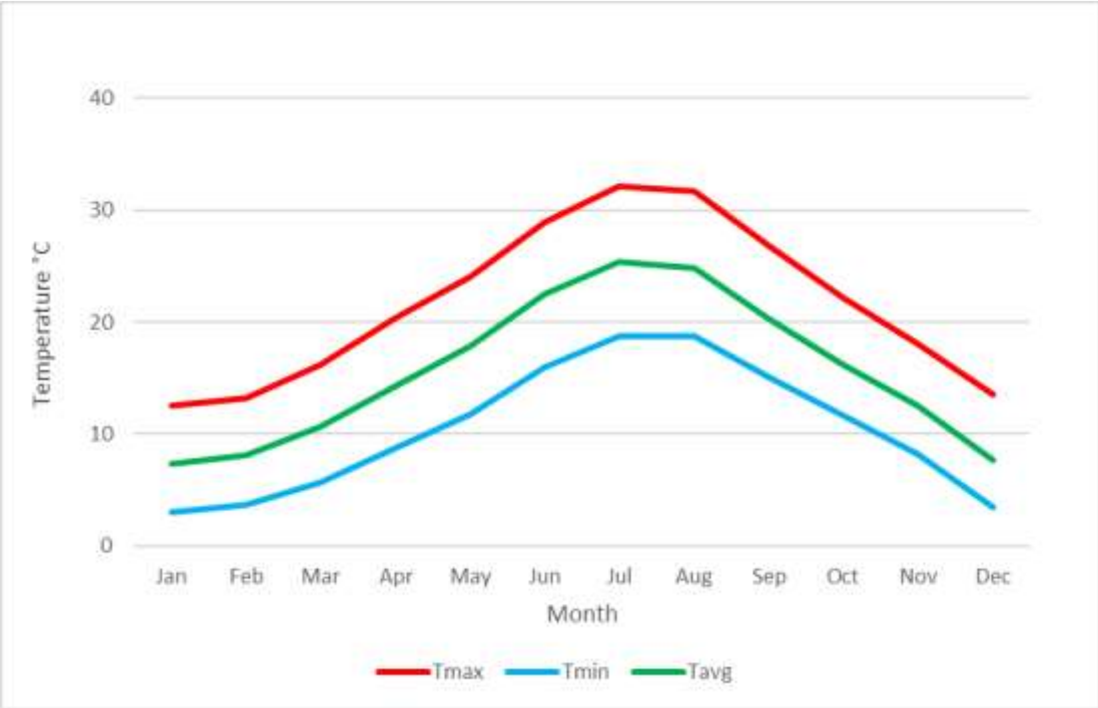

Figure 5. Temperature variation for the average year.

The distribution of monthly average values of rainfall for the years (2012-2016) is also shown in Figure.

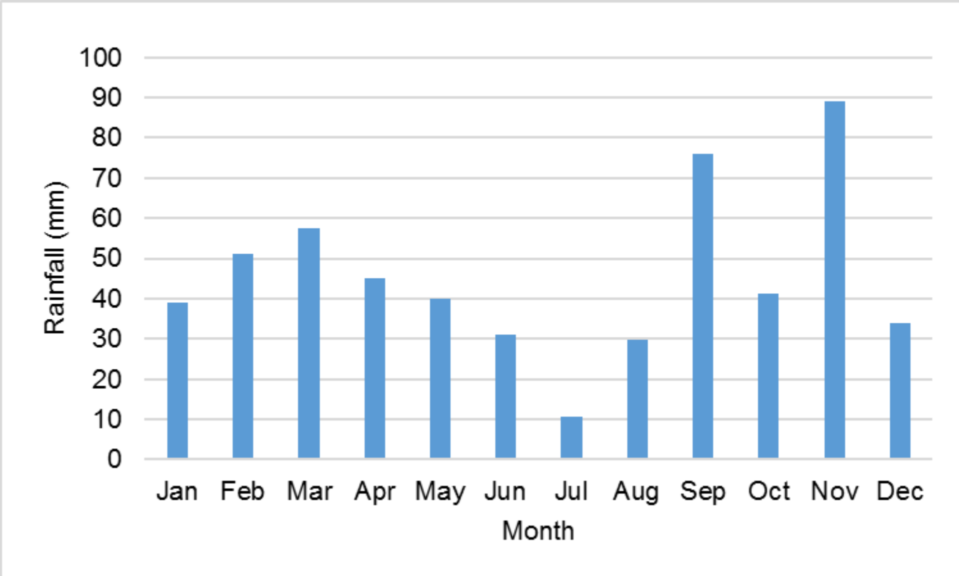

Figure 6. Monthly rainfall values for the average year

The Thermo-Pluviometric Bagnauls-Gaussen diagram in (Figure) presents the average monthly values of precipitation and the records of average temperature for the years of 2012-2016. It is noticeable that the dry season is from May until the end of August.

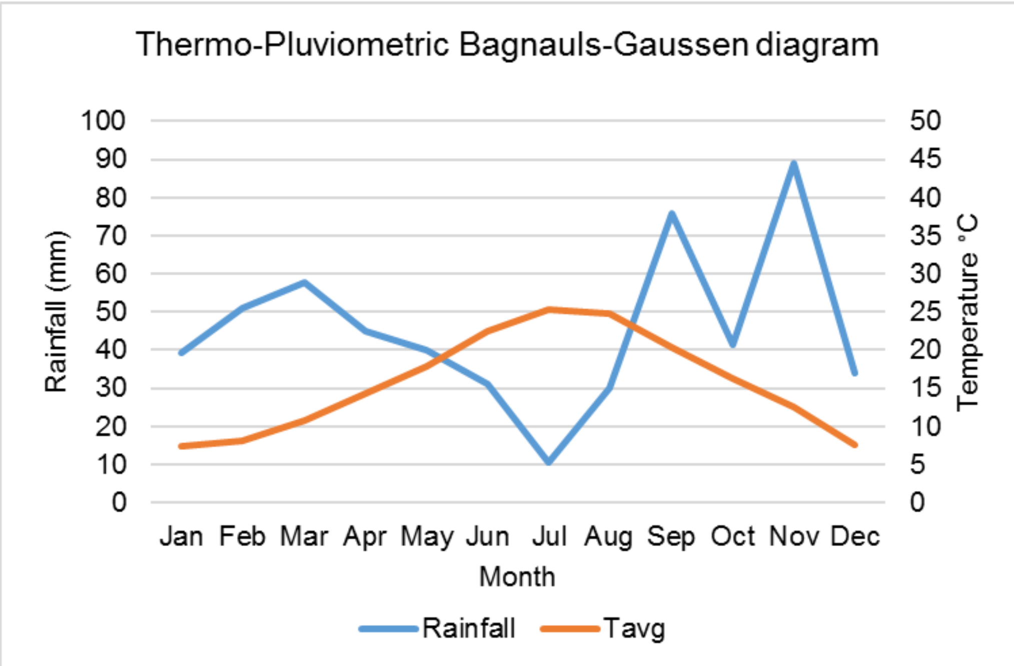

Figure 7. Thermo-Pluviometric Bagnauls-Gaussen diagram for the average year.

2.1.3 Soil properties

Twelve soil samples were collected from the district, where one sample has been taken in each sector to represent the soil features of the area. Based on laboratory analysis, the average values for sand, silt and clay are 46.1, 11.0 and 42.8% respectively. Using these value and according to U.S. Department of Agriculture classification of soil texture, the soil has loamy texture. The average depth of the soil profile is not high (less than 1 m), whereas the soil water holding capacity ranges from 130 until 170 mm/m. The prevailing soils in the area are Luvisols, Cambisols and Vertisols, featured by Cretaceous limestone, clayey and marl to sandy deposits.

2.1.4 Cropping Pattern

The area is characterized by huge number of small farms, that are mainly operating as market-oriented. Irrigation is a substantial factor in profit-based farming activities, and it depends on the restricted volume of rainfall in the peak period of crop water requirement.

In 1975 the network was designed as on- demand delivery schedule using an empirical approach (Khadra and Lamaddalena, 2010). Many changes in cropping pattern and irrigation activities have happened, which resulted in crop water requirements different from those of the design ones. The cropping pattern in the years 2017 and 2016 are shown in

Table

Table 2. The cropping pattern of district 17 during the years 2017 and 2016.

Crop	2017		2016	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Oil Olive	216.21	24.33	211.71	23.80
Wine grape	210.57	23.70	204.66	23.01
Autumn cereals	99.34	11.18	143.30	16.11
Uncultivated	91.02	10.24	117.77	13.24
Artichoke	60.56	6.82	35.67	4.01
Early peach	57.76	6.50	46.51	5.23
Table grape	46.68	5.25	45.64	5.13
Apricot	25.34	2.85	20.91	2.35
Tomato	16.75	1.88	22.86	2.57
Almond	15.68	1.76	2.80	0.31
Late peach	12.30	1.38	12.33	1.39
Vegetables	6.55	0.74	10.84	1.22
Melon	5.49	0.62	6.85	0.77

Plum	2.90	0.33	2.92	0.33
Wood /trees	2.59	0.29	2.61	0.29
Table Olive	1.01	0.11	1.01	0.11
Early potatoes	0.63	0.07	0.58	0.07
Mixed Orchard	0.57	0.06	0.58	0.07
Broccoli	1.19	0.13	-	-
Undefined	8.14	0.92		
Fennel	1.06	0.12	-	-
Parsely	0.07	0.01	-	-
Pumpkin	6.10	0.69	-	-
	888.52	**100.0**	**889.5**	**100.0**

Figure shows the percentage of dominant crops with respects to the total area of the cropping pattern in 2017. The leading crops in the year of 2017 are olive (24.5%), wine grape (24%), and autumn cereals (11.28%).

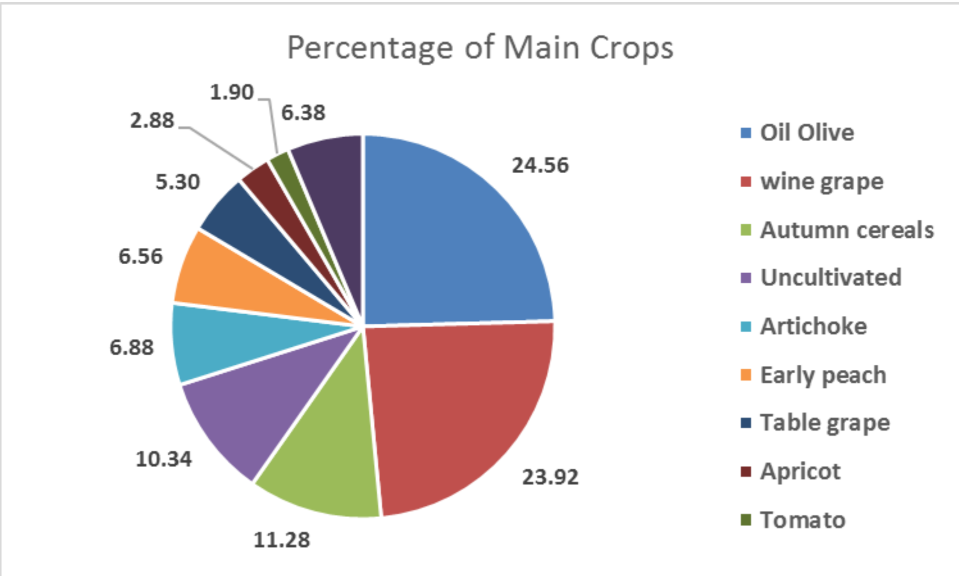

Figure 8. The percentage of dominant crops with respects to the total area of the cropping pattern in 2017

2.1.5 Crops water requirements, irrigation water availability and network characteristics.

2.1.5.1 Irrigation water demand.

The crop water requirement for each crop is defined as the overall water needed by the crop. There are many factors that affects the crop water requirements, as climatic conditions, crop species, type of soil, length of crop cycle and other factors related to irrigation management practices. The recommended net irrigation requirements, and the length of growing period for different crops, are reported in (

Table). The available volume of water is unsure, and principally determined by the stored water in the reservoir and trend of the climate. Sometimes, while the storing stage is still not finished, the water consumption of water starts. Taking into account the potential irrigation water demand shown in

Table and 4 beside the area of each crop, and if a full irrigation is applied, the probable net irrigation water requirements would be approximately 1.8 Mm^3.

Table 3. Recommended Net irrigation requirements and the length of growing period for different crops

Crop	NIR (m^3/ha)	Total growing period (days)
Autumn-winter cereals	1000 - 2000	210
Vineyard	1800 - 3000	190
Olives	2000 - 3000	270
Artichoke	2500 - 4000	270
Peach trees	3000	210
Tomato	4000-5000	135 – 180
Vegetables	4000	125
Almonds	4500	180
Early Potatoes	1000 - 1500	105 – 145

Table 4. The Net Irrigation Requirement (NIR) of each crop of district 17 during the years 2017 and 2016 calculated by CROPWAT model.

Crops	2017		2016	
	(m^3/ha)	m^3	(m^3/ha)	m^3
Oil Olive	1,893	409,286	2,021	427,866
wine grape	2,027	426,825	2,162	442,475
Autumn cereals	1,126	111,857	1,234	176,832
Uncultivated	0	0	0	0
Artichoke	3,589	217,350	3,725	132,871
Early peach	3,126	180,558	3,420	159,064
Table grape	3,159	147,462	3,325	151,753
Apricot	2,854	72,320	2,901	60,660
Tomato	3,872	64,856	4,023	91,966

Almond	3,654	57,295	3,326	9,313
Late peach	4,562	56,113	4,128	50,898
Vegetables	3,856	25,257	3,654	39,609
Melon	2,958	16,239	3,124	21,399
Plum	2,457	7,125	2,536	7,405
Wood /trees	3,658	9,474	3,365	8,783
Table Olive	5,645	5,701	5,123	5,174
Early potatoes	2,457	1,548	2,367	1,373
Mixed Orchard	3,654	2,083	3,721	2,158
Broccoli	2,448	2,913	2,664	0
Undefined	2,000	16,280	1,856	0
Fennel	2,444	2,591	2,662	0
Parsely	2,953	207	3,025	0
Pumpkin	3,658	22,314	4,009	0
		1,855,653		**1,789,600**

2.1.5.2 Water availability

The major part of water is substantially comes from rivers and other sources, and then delivered to farms by gravity. Hence, the opportunity to deliver the needed amount of water by the crops relies on the availability of these water resources. The recorded amount of irrigation water per season withdrawn by the consortium for district 17 is reported in Table . The table shows that the average water withdrawal is 975900 m^3, and the system can satisfy only about 50 % of needed water.

Table 5. Recorded amount of irrigation water per season by the consortium for district 17.

District	*Volume of water per season (m^3)*	
	Year 2017	***Year 2016***
17	1,118,269	833,531

The irrigation water is being distributed from the month of March until the end of November. The potential water supply taking into account 180-200 days of irrigation season, ranged approximately between 1,000 and 5,000 m^3/ha, according to the different crops. However, about 2,050 m^3/ha as a maximum amount of water is being supplied, this is because of the limited availability of water, and the capabilities of the irrigation system and the associated irrigation facilities.

Conclusions

A study to evaluate for two years (2016 and 2017) the degree of satisfaction of the irrigation needs of the area of an irrigation district falling within the 'Consorzio per la Bonifica della Capitanata', was carried out.

The recorded amount of irrigation water per season withdrawn by the consortium for district 17 is about 975,000 m^3, as average of 2016 and 2017, and the system can satisfy only about 50 % of needed water. Therefore, it would be useful to undertake initiatives to make up for any water resource deficit such as the reprogramming of crops and / or the use of additional water resources such as waste water.

Synopsis in English language

The objective of this study was to evaluate for the years 2016 and 2017 the degree of satisfaction of the irrigation needs of the entire area of an irrigation district falling within the wider area of the 'Consorzio per la Bonifica della Capitanata', to undertake initiatives to make up for any water resource deficit such as the reprogramming of crops and / or the use of additional water resources such as waste water.

The recorded amount of irrigation water per season withdrawn by the consortium for district 17 is about 975,000 m^3, as average of 2016 and 2017, and the system can satisfy only about 50 % of needed water.

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