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DESIGN OF LARGE SCALE ON-DEMAND IRRIGATION SYSTEM IN THE AGRICULTURAL AREA OF CORATO, APULIA, ITALY

SUMMARY

The objective of this project was to design a collective, on-demand irrigation network for an agricultural area near *Corato*, province of Bari, Apulia region, southern Italy. For this purpose, a study integrating agronomic, engineering, economic and environmental aspects has been conducted. The goal was to evaluate the ability to supply agricultural lands with irrigation water in order to cover the cropping pattern requirements in this district during the peak period of a dry year. After collecting and processing the climatic data for 30 years period, as well soil characteristics, crop water requirements have been determined. Besides that, modelling tool CROPWAT generated curves of yield response to different amounts of irrigation applied. The most optimal cropping pattern is chosen in socio-economic part through a predictive model, consisting of 3 annual (watermelon, tomato, lettuce) and 3 permanent crops (peach, grapevine, olive). Furthermore, sensitivity analysis have been done in order to avoid future risk and to predict farmers' behaviour. The irrigation network was designed based on the specific continuous discharge (0.422 $ls^{-1}ha^{-1}$) which was computed on GIR values for the peak month of the dry year. A layout of the distribution network is computed by Geographical Information System (GIS) including reservoir, main pipelines, secondary pipelines, nodes, 38 hydrants with a module of 5 ls^{-1} and 23 hydrants with a module of 10 ls^{-1}. Several tools (air and relief valves, control gates) are included in the network as well. Optimization model was used in order to calculate pipe diameter and their length (13271.7 m). In addition, storage reservoir was designed, as well as pumping station with 4 horizontal and 2 submerged pumps and pressurized regulating tank that controls opening and closure of the pumps. Cost and benefit analysis showed that the project is cost-effective on social basis and will fully recover its investment in two years, with an economic rate of return of 129%. An environmental impact assessment was conducted for the project and neighbouring area and it showed that they are not affected negatively. In addition, good management and monitoring practices to minimize the potential negative environmental impact are required and proposed for long-term sustainability of the irrigation project.

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INTRODUCTION

Agricultural sector is the most water consuming sector in the world, reaching more than 70% of the withdrawal in many areas of the world and especially in the Southern Mediterranean countries.

In many countries, particularly those situated in the arid and semi-arid regions of the world, this dependency can be expected to intensify, due to the increasing demand on agricultural products. Thus, contribution of irrigated agriculture to food production is substantial and the expansion of irrigated agriculture will surely result in higher yield and production. According to it, irrigation is required to satisfy the water demand during the driest periods of the year, especially in semi-arid Mediterranean climate.

The objective of this project is to design a collective on demand irrigation network for an agricultural area *Corato*, in the province of Bari, Apulia region (Southern Italy).

The total area of *Corato* region is 280 ha, of which 235 ha are suitable for agriculture and irrigable. Water sources for irrigation in this region are provided by two wells with discharges of Q_1=80 ls^{-1} and Q_2=50 ls^{-1}.

For this purpose, a study integrated agronomic, engineering, economic and environmental aspects have been conducted as presented in the following steps:

Climatic, soil, water source, water quality and crop characteristics data collection and elaboration;

Economic analysis through cropping pattern optimization under certain constraints and for a specific objective function;

Determination of specific continuous discharge for optimal cropping pattern;

Irrigation network design and design of storage reservoir, pumping station, pressurized tank and all the other structures and equipment of the project;

Estimation of the project's implementation, operation and maintenance costs (cost of expropriation, excavation works, pipe cost, technical equipment cost, concrete works cost, electrical equipment cost, pump cost, etc.);

Economic evaluation of the project (Cost & Benefit Analysis) and

Environmental Impact Assessment (EIA) and propose of possible mitigation measures and the monitoring plan.

MATERIAL AND METHODS

Agronomic part

Obtained climatic data for *Corato* region is collected and elaborated for 30 years period, and information about minimum, maximum, average temperatures and rainfall are obtained and dry year precipitation is calculated. Available soil physical and chemical properties are used to determine soil texture, effective depth, available water content, cation exchange capacity, electrical conductivity, exchangeable sodium percentage, organic matter, soil pH etc.

CROPWAT, software and modeling tool to support decision making for irrigation planning and management, was used in order to calculate reference evapotranspiration, crop water requirements as well as irrigation requirements. The data for twenty-one crops grown in the region were arranged using the FAO database and results of studies carried out in Apulia region. For the purposes of our project, after calculating the crop water requirements, CROPWAT model was used to generate the crop response curves that represent the yield response to different amounts of irrigation water applied. Different scenarios were introduced into the model, including different amounts of irrigation water from full irrigation to no irrigation (rainfed agriculture), under fixed management rules on evapotranspiration and effective rainfall estimation, as well as for irrigation timing, application and efficiency, (Smith et al., 1992).

Socio - economic part

The main objectives of the socio-economic analysis are to identify the optimal cropping pattern for the irrigation project area in *Corato* region that maximizes farmers utility, to assess the impact of different water pricing options on cropping pattern, on farm income and on water consumption and to choose the optimal water tariff system. To reach these objectives, a predictive model written in GAMS (General Algebraic Modeling System) programming language was used. It consists of a static and nonlinear optimization model aiming to represent farmer's behavior and to simulate his response to the introduction of irrigation. This is a constrained optimisation model that maximises an objective function subject to a set of constraints (land, water and crop constraints). Effectively, it assumes that farmers select the crop allocation that maximize the expected income and minimize the risk, which is measured by the risk aversion coefficient (the degree to which the farmer is averse to taking risks), (Hazell and Norton, 1986). Two sources of risks were considered in this model: market (i.e. price) and climate (i.e. yield) risks. Both prices and yields are assumed to be normally distributed and their means and standard deviations values are derived from regional statistical database (ISMEA – Istituto di Servizi per il Mercato Agricolo Alimentari, 2018).

Engineering part

A layout of the distribution network (reservoir, main pipelines, secondary pipelines, nodes and hydrants) are computed by Geographical Information System (GIS). In order to choose the proper diameters for each section of the irrigation network, it is necessary to compute the discharges in these sections which were calculated based on the peak month of the dry year. To avoid over-sizing the diameters of the pipelines, they were calculated using Clément first model probabilistic approach, in which, the probability that the flow discharge downstream of each section will not exceed Clément discharge is 95%. Selection of the most suitable pipe is done by an optimization process based on the peak discharge and network layout, (Lamadalena and Sagardoy, 2000). The optimization model that was used to calculate pipe diameters was developed by

Labye in 1981, and is called Labye's Iterative Discontinuous Model (LIDM). In order to facilitate the calculation of Clément discharges and LIDM's optimized diameters, a computer software package called COPAM was used, (Labye et al, 1988).

Cost and Benefit Analysis

In order to assess if a project is profitable for general welfare or not, and what would be the best project alternative, useful economic model is CBA. Two types of analysis are done, financial and economic. The CBA method is conducted in the following phases: determination of the time frame (construction, management and dismantling phase), determination of costs and benefits (in financial analysis, costs are related to the total investment and maintenance costs, while the benefits are obtained from the water agency revenue, while for the economic analysis, costs and benefits of farmers are added considering the situation before and after the implementation of the project), choice of rate of interest according to the Italian standards (Arborea et al, 2017). In order to show project's feasibility, performance indexes are determined (the Net Present Value, the Benefit Cost Ratio, the Internal Rate of Return and the Payback Period).

Environmental part

The environmental impact assessment (EIA) of *Corato* irrigation scheme project was analyzed through five main categories: natural resources, biological life, socio-economic, political and economic impacts. For each category of impacts, a positive or negative score was given for both project area and nearby areas. The impacts were assessed and scored using the Environmental Impact Assessment Decision Support System (EIDASS) proposed by CEDARE (Abu-Zeid and Bayoumi, 1999).

RESULTS AND DISCUSSION

Agronomic part

The thermo-pluviometric, Bagnauls-Gaussen diagram, based on collected and analyzed 30 years historical data set, indicated the period when irrigation could be needed. According to the Figure 1, it can be seen that the period of drought is present from May to September, while in the period of wet season (from October to April), agriculture can be considered as rainfed.

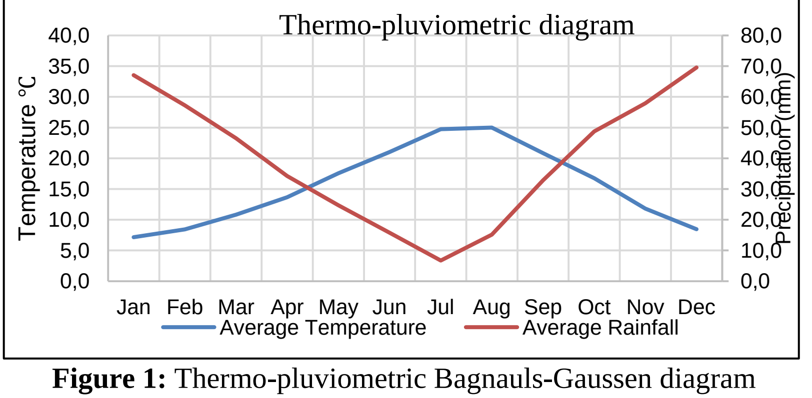

Figure 1: Thermo-pluviometric Bagnauls-Gaussen diagram

In order to determine values of the dry year's rainfall and according to that, peak irrigation requirements, monthly rainfall of the dry year was calculated using the annual rainfall of the dry year, the average annual rainfall and monthly average rainfall (Table 1).

Table 1: Monthly precipitation values for the dry year

Months	Average Precipitation (mm)	Dry year precipitation (mm)
January	67.1	58.8
February	57.2	50.2
March	46.5	40.8
April	34.3	30.0
May	24.7	21.7
Jun	15.8	13.8
July	6.7	5.9
August	15.2	13.3
September	32.8	28.8
October	48.8	42.7
November	57.9	50.8
December	69.5	61.0
Total	**476.5**	**417.7**

According to the obtained soil properties in *Corato* region (Table 2), it can be concluded that land is suitable for agricultural activities. Soil has clay-loamy texture, three horizons with total effective depth of 88 cm, good capacity to hold cations, pH that is suitable for most of the crops and other positive properties. Furthermore, electrical conductivity and sodium percentage cannot have any negative impact on crop production.

Table 2: Soil physical and chemical characteristics

<table>
<tr><td colspan="10">Physical characteristics</td></tr>
<tr><td colspan="2">Effective depth (cm)</td><td colspan="2">Soil texture</td><td colspan="4">Soil bulk density (g/cm^3)</td><td colspan="2">AWC (mm)</td></tr>
<tr><td>Ap</td><td>25</td><td colspan="2" rowspan="3">Clay loam</td><td colspan="4">1.23</td><td colspan="2">34.5</td></tr>
<tr><td>Bt</td><td>30</td><td colspan="4">1.20</td><td colspan="2">44.7</td></tr>
<tr><td>B/C</td><td>33</td><td colspan="4">1.22</td><td colspan="2">39.3</td></tr>
<tr><td colspan="10">Chemical characteristics</td></tr>
<tr><td colspan="2" rowspan="2">Effective depth (cm)</td><td rowspan="2">pH</td><td colspan="2">$CaCO_3$</td><td colspan="2">Cations</td><td>CEC</td><td>OM</td><td>EC</td></tr>
<tr><td>Tot.</td><td>Act.</td><td>Ca^{2+}</td><td>29.0</td><td>(meq/100gr)</td><td>(%)</td><td>(dS/m)</td></tr>
<tr><td>Ap</td><td>25</td><td>7.13</td><td>10.5</td><td>0.53</td><td>Mg^{2+}</td><td>2.8</td><td>34.63</td><td>4.6</td><td>0.658</td></tr>
<tr><td>Bt</td><td>30</td><td>7.09</td><td>8.5</td><td>0.25</td><td>K^{+}</td><td>0.7</td><td>31.93</td><td>3.7</td><td>0.611</td></tr>
<tr><td>B/C</td><td>33</td><td>7.03</td><td>9.4</td><td>0.33</td><td>Na^{+}</td><td>0.4</td><td>32.52</td><td>2.2</td><td>0.601</td></tr>
</table>

The data for twenty-one crops grown in Corato region were arranged using the FAO database and results of studies carried out in Apulia region. They were used to estimate crop water requirements, irrigation requirements and crop response to water curves, which is presented in Table 3, (Allen et al. 1998).

Specific continuous discharge, q_s, expressed in $ls^{-1}ha^{-1}$, is used in the engineering part of the project in order to design the irrigation network in Corato region. For determination of value for specific continuous discharge, data about crop water requirements have been used for the peak period of the dry year and for the cropping pattern chosen by GAMS model (in economic part). In that case, enough amount of water will be provided even during the driest months.

$$q_s = \frac{GIR\left(\frac{mm}{month}\right) * 10\left(\frac{m^3}{ha}\right) * 1000\left(\frac{l}{m^3}\right)}{31(days) * 24(hr) * 60(\min) * 60(s)} = 0.422\ l/s/ha$$

Where GIR is weighted average gross water requirement for the chosen cropping pattern and irrigation technique during the peak period of the dry year (mm/month).

Implementing simplified salt balance in order to describe potential salinity hazard in *Corato* study area, it is concluded that salinity problems could possibly appear after about 6 years of irrigation (through potentially injurious salts). However, in reality, it is expected that some natural leaching process occurs during the winter season due to the precipitation (Ayers and Westcot, 1985).

Table 3: Seasonal ETc, Peff, NIR and yield percentage under different crop water requirements for the average year

Crop	**Etc**	**IRR**	**Peff**	**Yield (%)**				**Avg yield t/ha**
				0% NIR	50% NIR	75% NIR	100% NIR	
Citrus	712.1	549.9	162.2	52.8	76.7	88.7	100	20
Cherry	471.6	288.0	183.6	26.3	63.6	82.0	100	10
Pepper	502.5	422.2	80.3	21.4	63.6	84.1	100	25
Olive Tree	427.8	305.2	122.6	60.3	80.6	90.6	100	7
Sunflower	542.9	462.6	80.3	30.2	67.7	84.2	100	4.5
Tomato	659.8	569.7	90.1	22.5	61.2	80.6	100	75
Wheat	397.1	193.7	203.4	80.2	91.2	96.2	100	6
Peach	704.3	538.0	166.3	36.7	68.4	84.3	100	40
Grapevine	569.5	413.9	155.6	48	75.0	88.2	100	30
Watermelon	391.5	368.8	22.7	30.9	65.6	83.1	100	70
Soybean	506.0	424.2	81.8	43.8	72.9	87.1	100	3
S. sugar beet	587.4	476.1	111.3	31.5	66.4	83.5	100	70
A. sugar beet	634.7	455.0	179.7	48	73.4	86.3	100	80
Lettuce	145.2	2.6	142.6	99.9	100.0	100.0	100	45
Artichoke	801.1	532.4	268.7	50.8	75.7	88.0	100	20
Common Potato	372.2	272.0	100.2	38.2	71.7	87.9	100	40
Early potato	312.6	176.1	136.5	64.4	83.5	92.9	100	30
Eggplant	582.5	508.2	74.3	23.7	62.1	81.1	100	35
Broad bean	337.8	140.8	197.0	18.1	78.2	92.1	100	4.5
Carrots	378.1	225.5	152.6	48.9	76.1	89.3	100	45
Maize	606.2	536.7	69.5	6.9	54.2	77.9	100	7.5

Economic part

After running the economic model, the optimal crop allocation for the base case scenario was chosen. As it can be seen from the Table 4, the highest percentage of area is dedicated to grapevine under full irrigation technique (T_1), while the lowest percentage is devoted to rainfed lettuce (T_0). Olive trees are present in almost 40 ha, and according to the current climatic conditions, there is no need for irrigation. Peach and tomato can be both grown with full and partial irrigation techniques (T_2 and T_3), while watermelon is suitable for full and complementary irrigation. All available crops that require irrigation in March (wheat, olives and cherry) can be grown only with rainfed technique due to water availability constraint (irrigation season from April to November).

Table 4: The optimal crop allocation for the base scenario

Crops	Irrigation Techniques				Area	
	T0	**T1**	**T2**	**T3**	**ha**	**%**
Watermelon		30.03		8.92	38.95	14.93
Tomato		25.24	13.71		38.95	14.93
Lettuce	26.35				26.35	10.10
Peach		37.73	4.67		42.40	16.24
Grapevine		75.74			75.74	29.02
Olive Tree	38.95				38.95	14.93

The Table 5 shows the effect of the risk aversion coefficient on the cropping pattern. It is noticed that increasing Φ (from 0 to 1.65) increases the crop diversity and reduces the farm's profit and utility. A risk aversion coefficient of 1.6 was chosen by the model for the base scenario because it is the best prediction of the farmers' behavior. According to that, the expected income of this area is 13139 €/ha and the water consumption by this pattern is 4004 m^3/ha.

Table 5: Sensitivity analysis for different risk aversion coefficient

Crops	**T**	Φ1	Φ2	Φ3	Φ4	Φ5	Φ6	Φ7	Φ8	Φ9
		0	**0.25**	**0.5**	**0.75**	**1.0**	**1.25**	**1.5**	**1.6**	**1.65**
watermelon	T1	78	78	78	78	78	66	41	30	26
watermelon	T3							2	9	11
tomato	T1	78	78	78	78	78	66	43	25	19
tomato	T2								14	18
lettuce	T0	235	235	235	157	93	57	32	26	24
peach	T1						38	44	38	35
peach	T2								5	7
grapevine	T1							62	76	80
olive trees	T0				78	78	66	43	39	38
Profit (ha)		27582	27582	27582	24417	21494	18536	14500	13139	12679
Annual water use (m^3/ha)		3270	3270	3270	3270	3270	3753	4122	4004	3960

Figure 2 shows the net margin and the area per each crop for each technique in the optimal cropping pattern. For example, the highest net margin is recorded for tomato T_1 (37035 €). However, this crop occupies only 25.2 ha of the cultivated area, because, first, it is a risky crop, shown by the high price standard deviation, and, second, it is restricted by the crop rotation constraints implemented in the model. On the other hand, the net margin of olive trees is quite low (1247€), compared to other crops; however its area represents around 15% of the total farm land. This indicates that the net margin is not the only driver for selecting the optimal cropping pattern. Other key factors such as the farm constraints, the risk aversion coefficient and the standard deviation of yields and prices play a critical role.

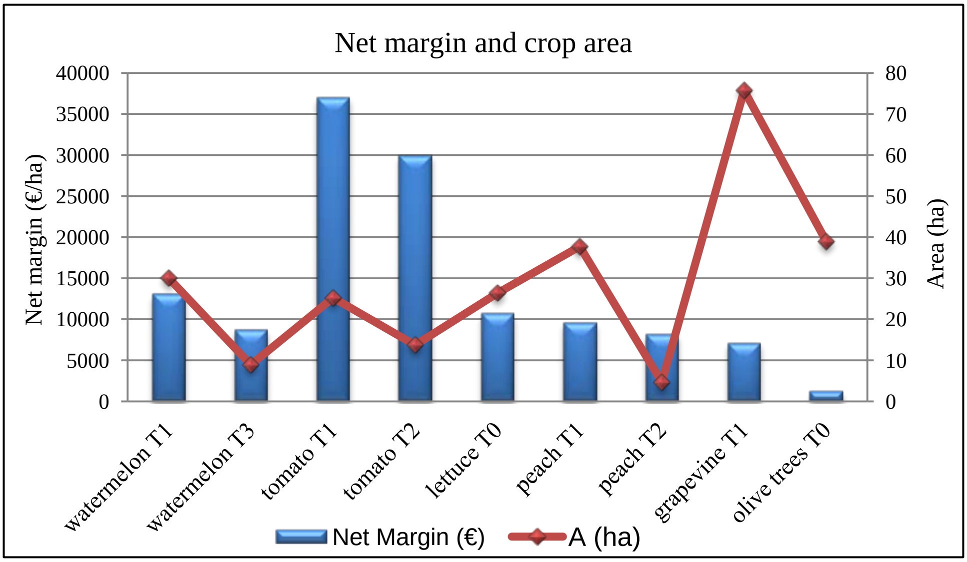

Figure 2: Net margin and the area dedicated to each crop of the optimal pattern

To study the impact of water tariff on the crop allocation in the project area, 10 different water tariff scenarios were modeled (from S_{01} to S_{10}). Water tariff is binomial and is based on fixed and variable tariff. The fixed tariff depends only on irrigable land (30 €/ha), while the variable tariff depends on the quantity of water consumed under each block. From S_{02} to S_{04}, water tariff is increasing proportionally for the three blocks. From S_{05} to S_{10}, only water tariffs of the second and third blocks are increasing. It can be noticed that increase of water tariff (water cost) leads to three effects:

- Increase in land occupied by rainfed crops (olive trees and lettuce) in detriment of irrigated crops (watermelon, peach and grapevine);
- Reduction of land cultivated by water intensive crops (such as peach);
- Switch from high water intensive techniques (T_1) to water saving techniques (T_3)

The choice of the optimal water tariff depends on compromising between the needs of: the farmers, the water agency, and all the society members. In order to choose the best scenario, the multi-criteria method, called Compromise Programing was used. In this method, a weight is given to each purpose according to its degree of importance. The highest weight was given to the minimization of water consumption, which has to be interest of all stakeholders, followed by the maximization of farm profit which is important for the economic viability of the irrigation project. And based on these assumptions, the best scenario was chosen as S_{05}, because it is the best in water conservation without significantly affecting the farmers' profit, (Romero and Rahman, 2003).

Engineering part

Water for the study area is supplied by two wells located at elevations of 215 m a.s.l. and 223,5 m a.s.l. The first well is located at a distance of 298,3 meters from the reservoir, while the second is at distance of 350,9 meters. Water is delivered by set of four pumps, designed to provide the required discharge of the network and satisfy a minimum pressure at the hydrant level (20 m). A pressurized tank is installed just after the pumping station in order to regulate and control the pressure of the pumps. In addition to the hydrants, the network consists of several tools: 2 air valves to remove air excess from the network, 3 relief valves to clean the network and remove all present sediments and 24 gates to control the operation and maintenance of the network. By combining three farms together or less, modules of 5 ls^{-1} and 10 ls^{-1} are used for hydrants, while the elasticity (farmers' freedom) is fixed at 3. A hydrant of 5 ls^{-1} can serve an area up to 4 ha, while a hydrant with the module of 10 ls^{-1} serve maximum of 7,65 ha. The total number of hydrants installed is 61, and 38 of them are with the module of 5 ls^{-1} and the rest, 23, have the module of 10 ls^{-1} (Figure 5).

The peak upstream discharge of the designed network is 205 ls^{-1}, obtained by COPAM, and the total price of optimized pipes is 208037 €. In the Table 6, the summary of the outputs is presented, considering pipe diameters and pipe length.

Table 6: Summary of optimization results for the network using COPAM

Diameter (mm)	Length (m)
110	3489.4
125	1248.8
140	1696
160	2107.8
180	435.7
200	1249.4
225	755.6
280	652.7
315	421.3
450	811
500	404

However, in order to avoid over-design of the system, network performance analysis is checked and indexed characteristic curve has been designed. The network is capable to satisfy only a percentage of the possible configurations by different values of upstream discharge and the corresponding piezometric elevation. The curve was drawn using 1000 random configurations of hydrants between 150 and 250 ls^{-1}. The Figure 3 shows, that the point corresponding to a discharge of 205 ls^{-1} and piezometric elevation of 244,12 m a.s.l. falls in the indexed curve of 75%, which means that the head of the hydrants is higher than the minimum head required (20m) in 75% of all the examined discharge configurations. Similar to that, hydrant reliability curve and hydrant deficit envelope curve have been designed, which showed that hydrants are reliable in more than 85% of the cases, which is more than satisfied result.

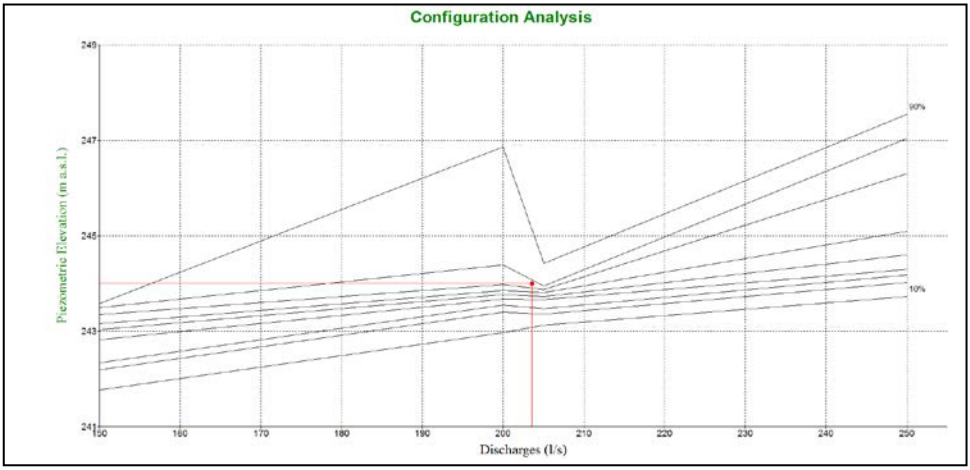

Figure 3: Index characteristic curve (configuration analysis)

In order to supply the network, two conveyance pipes are designed: the first one with a diameter of 280 mm and the second one with 315 mm. The total length includes both convey pipes, 452 meters from the bottom of the wells to the surface and 660 meters from the wells surface to the reservoir.

Using Darcy-Weisbach and Colebrook equation, the friction losses are calculated and used in order to determine the required pressure head for two submerged pumps. According to the discharges of the wells (50 and 80 ls^{-1}) and pressure head of the pump, from *Caprari* catalog E12S42, two pumps have been chosen, 4A and 6A (Pp_1 =157,1 KW and Pm_1 =174,5 KW; Pp_2 = 260,4 KW and Pm_2 = 289,3 KW).

To reward the daily water deficit between the water source and the network demand through the peak period, storage reservoir is designed. Volume of the designed reservoir is 4212 m^3 for 9 hours and it is higher than the volume of water going out from the reservoir for a 15 hours working reservoir. It is assumed that the reservoir has a shape of truncated pyramid and dimensions of 40 x 33 x 3.5 meters.

The pumping station design has been made to supply the network with maximum upstream discharge ($Q_{clé}$=205 ls^{-1}), and at the same time maintaining an upstream pressure sufficiently enough to ensure a minimum pressure head in each hydrant. 4 pumps are selected, type (80-160) and 2900 rpm-50 Hz (Pp = 17,94 KW and Pm = 19,94 KW). Pressurized regulating tank is designed in order to control the opening and the closing of the pump. The volume of the pressurized tank is obtained as 12 m^3, and the dimensions of: diameter of 2,2 m, the height of 3,15 m with an additional 50 cm for sensors in the tank to turn on and turn off the pumps. An important step in the project, more precisely, in engineering part is the total cost of the project, presented in the Table 7.

Table 7: Final cost of the project

Cost of Pipes	298037
Excavation Cost	226011
Technical Equipment	146015
Expropriation	104037
Concrete for reservoir and manholes	59108
Building cost of pumping station	102900
Electrical Equipment	25000
Protection works	2000
TOTAL (1)	**963,108**
Cost of Design (3%)	28893
Supervision of work (1%)	9631
Topographic Studies (1%)	9631
TOTAL (2)	**48155**
TOTAL ==> (1) + (2)	**1,011,263**
Taxes (20%)	202253
TOTAL (including taxes)	**1,213,515**
Maintenance cost (8%)	97081
FINAL COST	**1,310,596**

Cost and Benefit Analysis

From the table below (Table 8), it can be concluded that from financial, private, point of view, the project is not cost effective since the NPV is negative during the whole life cycle.

Table 8: Financial analysis indexes

Total Investment Cost (€)		1 213 515
Annual O&M Cost (8% of the total cost)		97 081
Annual Water Agency Income (€)		51 701
Rate of interest (%)		4
Indexes	NPV (€)	-1 932 073
	BCR	0.31
	IRR (%)	undetermined
	PBT (Years)	never

Furthermore, the income of water agency from chosen water tariff cannot cover the annual costs of operation and maintenance (O&M). When IRR is lower than discount rate, which is 4% in our case, it means that our investment costs cannot be returned as revenue.

In the economic analysis, social objectives are considered. Benefit of both, the water agency and farmers are taken into consideration. To obtain the costs and benefits of farmers, two situations are projected. The first one is to consider the cost and benefits before the implementation of the project (rainfed scenario), and the second after running the irrigation project. In the economic analysis (Table 9), it is proved that the project is justified, by having a positive NPV and satisfactory values of all of the rest economic indexes.

Table 9: Economic analysis indexes

Total Investment Cost (€)		1 213 515
Annual O&M Cost (8% of Total Cost) (€)		97 081
Annual Water Agency Income (€)		51 701
Discount Rate (%)		4
	Before Project	After Project
Annual Farmers Benefit (€)	537 910	3 703 360
Annual Farmers Cost (€)	295 880	1 277 666
Indexes	NPV (€)	34 195 245
	BCR	2.81
	IRR (%)	129%
	PBT (Years)	2

The used variables for different sensitivity analysis are discount rates, volumetric water tariff and fixed water tariff. The increment of the interest rate shows the decrease in the net present value significantly. Fixed water tariff does not have impact on economic analysis, since the increase of the agency benefit leads to the increment of the farmer’s cost with the same amount. From financial point of view, increment of the fixed water tariff will not cover the total costs, and he net present value stays negative. Considering volumetric water tariff sensitivity analysis, from the economic point of view, NPV values decrease as water tariff increase due to the fact that as water price increases, farmers’ income decreases. From the financial point of view, net present value is higher due to increased agency revenue, but in the scenario number 5, where the price of only the first water block is reduced to 0,09 €/m^3, the benefit for the water agency cannot cover the costs.

Environmental Impact Assessment

Figure 4 shows the difference between the three alternatives according to its impact on each of the environmental categories, as well as, the overall weighted impacts of the three alternatives.

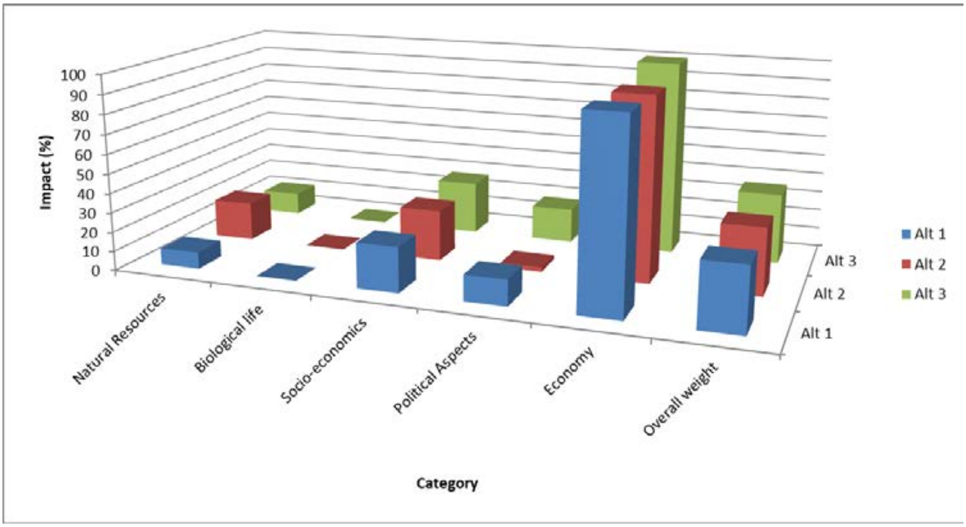

Figure 4: The impacts of each alternative on each category and the overall weighted impact

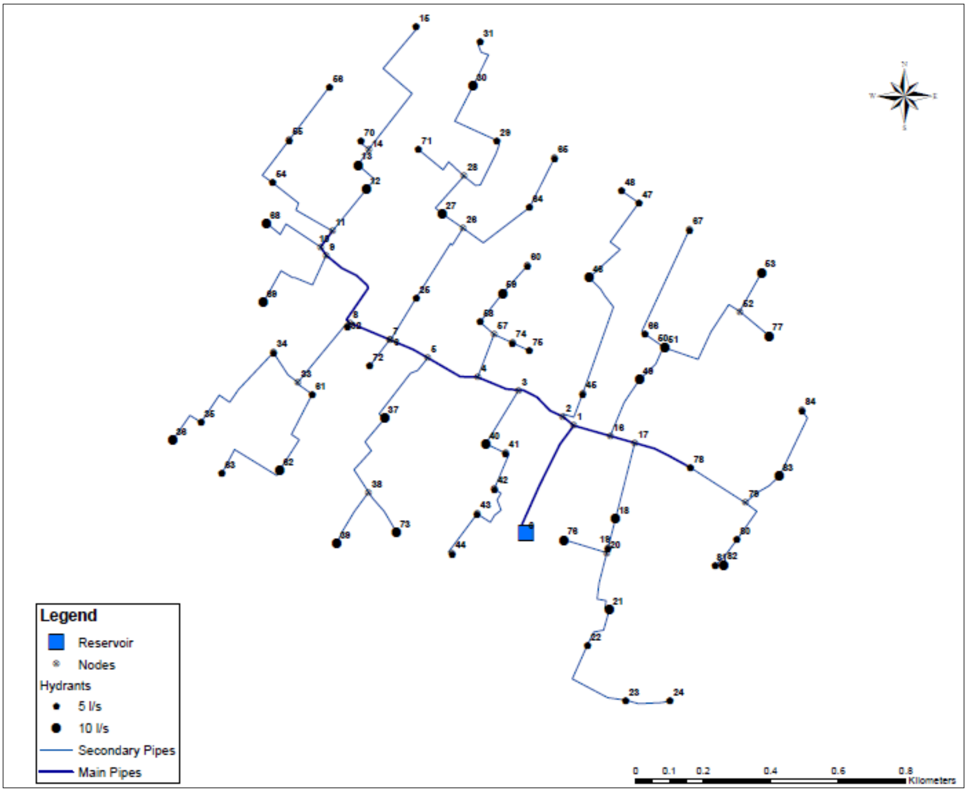

Figure 5: *Corato* irrigation network scheme

CONCLUSIONS

This research aimed to conduct a study for the design of an irrigation project in the agricultural region of *Corato,* in order to cover the cropping pattern requirements during the peak period of a dry year.

Historical climatic data were collected and analysed, and they represent suitable conditions for plant growth. Furthermore, the soil in the area is clay-loam with high fertility levels and insignificant salinity levels. The source of water for the project is groundwater, with good chemical composition, through two wells located within the study area.

After adopting cropping pattern that is possible to be grown even during the peak period of the dry year, the irrigation network was designed. Furthermore, simulations of several scenarios based on different water tariffs in order to determine the best water saving technique without a large decrease of farm income were conducted. The discharges of each section in the network were calculated based on a probabilistic approach and pipe diameters were optimized to minimize the network costs. In addition, a reservoir was designed to receive and store water from the wells by submerged pumps, and then deliver the stored water to the irrigation scheme system by a pumping station composed of 4 pumps and regulating tank.

Analysis results showed that the project was not convenient from private point of view, while it was cost-effective on social basis and will fully recover its initial investment in two years. The developed irrigation project has a great potential to improve the conditions of local community, considering the overall social benefit including the enhancement of farmers' income without having negative impact on the area.

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