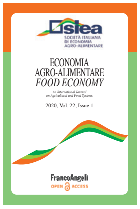
Economia agro-alimentare /
Food Economy

An International Journal on Agricultural and Food Systems

Vol. 22, Iss. 2, Art. 7, pp. 1-19 - ISSN 1126-1668 - ISSNe 1972-4802
DOI: 10.3280/ecag2-2020oa10413



New advanced designed systems to ensure safeguard of the territory and preservation of water resources for irrigation

Cinalberto Bertozzi[a], **Fabio Paglione**[*,a]

[a] Burana Land-Reclamation Board, Italy

Abstract

The Burana Land-Reclamation Board is an interregional water board operating in three regions and five provinces. The Burana Land-Reclamation Board operates over a land area of about 250,000 hectares between the Rivers Secchia, Panaro and Samoggia, which forms the drainage basin of the River Panaro and part of the Burana-Po di Volano, from the Tuscan-Emilian Apennines to the River Po. Its main tasks are the conservation and safeguarding of the territory, with particular attention to water resources and how they are used, ensuring rainwater drainage from urban centres, avoiding flooding but ensuring water supply for crop irrigation in the summer to combat drought. Since the last century the Burana Land-Reclamation Board has been using innovative techniques in the planning of water management schemes designed to achieve the above aims, improving the management of water resources while keeping a constant eye on protection of the environment.

Article info

Type:
Note
Submitted:
14/10/2019
Accepted:
06/05/2020

JEL codes:
O13, Q01, Q15

Key words:
Water management
Agriculture
Sustainability
Irrigation network
Water saving

* *Corresponding author*: Fabio Paglione - Engineer, Technical Manager - Burana Land-Reclamation Board - C.so Vittorio Emanuele II, 107 - Modena (MO), Italy - E-mail: f.paglione@consorzioburana.it.

Introduction

Directive 2000/60/EC – Water Framework Directive (WFD) establishes a framework for the Community action in the field of water, pursuing ambitious objectives, namely: preventing qualitative and quantitative deterioration, improving water status and ensuring sustainable use, based on the long-term protection of the available water resources.

Coherently to these objectives, in 2000 the European Parliament established a framework for Community action in the field of water policy: The Directive 2000/60/EC. In the first article of the Directive we can read: *"The purpose of this Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which:*

(a) prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems;

(b) promotes sustainable water use based on a long-term protection of available water resources;

…

(e) contributes to mitigating the effects of floods and droughts".

The European Union identifies among its goals a smart, sustainable and inclusive growth, that can be pursued through the use of structural monetary funds, coordinated by the Common Strategic Framework (CSF): a general guideline document that the member states have taken into account relied on for the 2014-2020s planning activities.

Within this program the European legislation aims to promotes the competitiveness of the agricultural sector, as strictly linked to the protection and development of rural areas, as well as the improvement of competitiveness for holdings in agriculture, agri-food, forestry, fisheries and aquaculture.

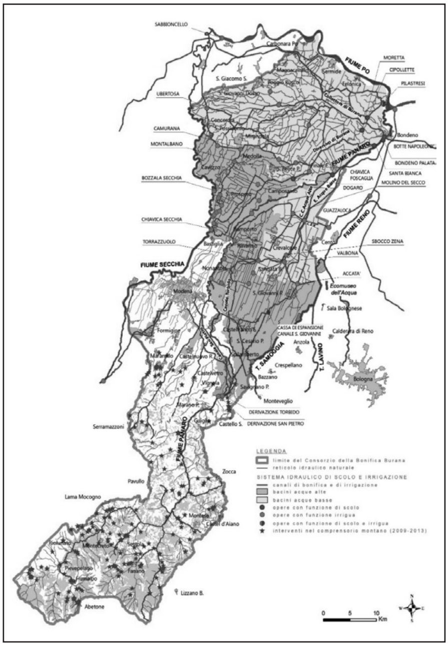
These tasks are carried on based on the importance of environmental sustainability, adaptation and mitigation of climate change, animal well-being quality production, innovation and job security.

1. Sustainable management of water

In ancient times the plain was almost entirely marshland. During the centuries, its inhabitants worked hard to reclaim and reshape the land, in order to achieve a better standard of living. Nowadays the threat of water has been transformed into opportunities by the action of all the Land-Reclamation Boards. At present, Emilia-Romagna is considered one of the richest European regions, with a remarkable balance between agriculture and industry. Burana Land-Reclamation Board contributes to the improvement of social, economic and environmental conditions.

The Burana Board is an interregional water board acting on ~~in~~ three regions and five provinces; it operates over a land district of about 250.000 hectares between the rivers Secchia and Panaro, coinciding with the drainage basin of Panaro River, from the Tuscan-Emilian Apennines to Po River. This area is one of the most fertile zone of the whole Po Plain, which is characterised by technologically advanced farming practices and strategic industrial districts. Furthermore, in this district are located several environmentally relevant wetlands and many rare species of plants, birds and animals live here. The water supply of these protected areas is guaranteed by the Board.

Figure 1 - Burana Board's District



Burana's main activities regard the conservation and safeguard of the territory, with particular attention to water resources and their use, ensuring water drainage from urban centres and farming areas and water supply throughout the area under its management to ensure irrigation and to fight drought.

Since the beginning of the century Burana Land-Reclamation Board has planned and designed modern hydraulics works, using innovative techniques, in order to improve water resources management and to be more mindful about ~~of~~ the environment.

In 2009 Burana Land-Reclamation Board received funds from the Ministry of Agricultural, Food and Forestry Policies and built a pilot pressurized irrigation system among agricultural holdings on the Diamante canal, whitin the Protected Designation of Origin (POD) area called *Basse di Vignola*, characterized by a huge production of the typical Vignola-cherries and plums.

Thanks to this micro-irrigation systems farmers use 3.250 m^3/ha/year: compared to the traditional submersion irrigation technique (the consume is more than 8.000 m³/ha/year), it Burana Board ensures water volume saving of about 60%.

As a matter of fact all of the 13 agricultural holdings involved into the sperimental project and the others, which have joined later, have replaced the traditional surface irrigation system with this innovative and advanced system, in order to save money and increase productions.

Figure 2 - Diamante Plant – pumping station and pipe lines

1.1. *Water efficiency for irrigation – A New innovative project to be carried out*

In 2016-2017 Burana Land-Reclamation Board took part in an european open call to receive funds within the *European Network for Rural Development*.

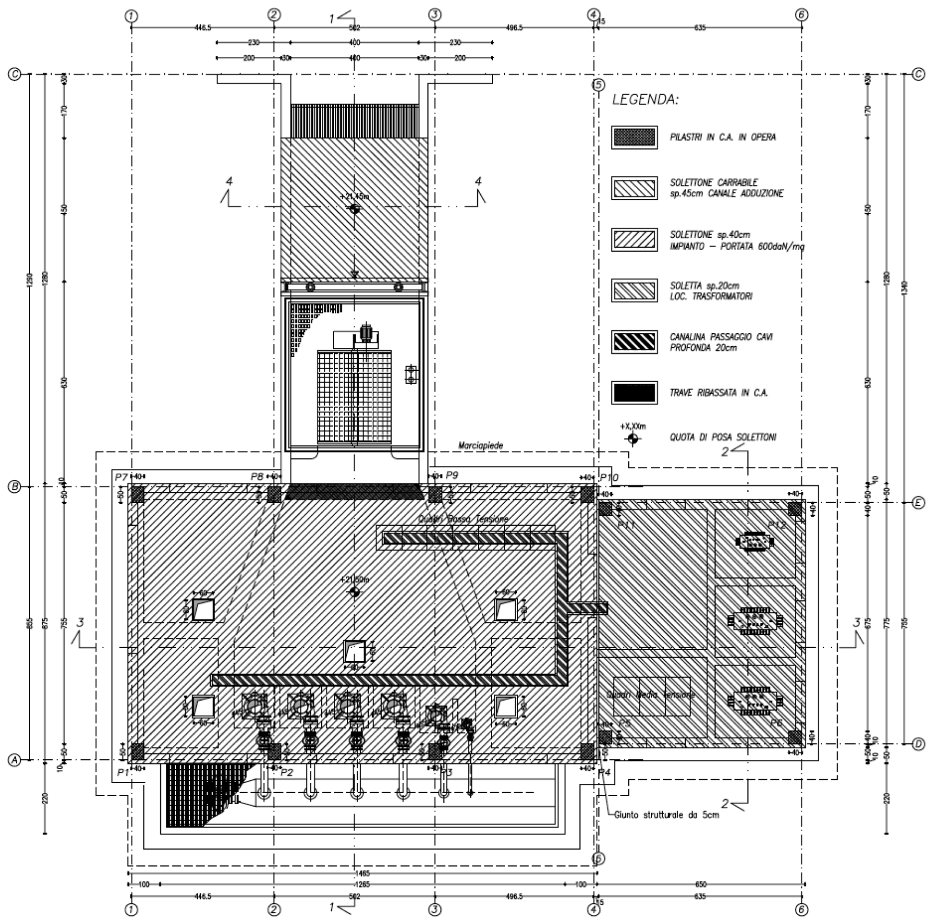
Within Burana's Plain sub-District, consisting of about 70.000 hectars, it was detected an area of about 700 hectars, characterized by a high agronomic value, where are cultivated some of the most precious-crops, such as pears, peaches, vineyards and melons.

The project is a new, innovative and technologically advanced irrigation system that includes the building of a new irrigation plant, to deliver pressurized irrigation water.

The plant is composed of:

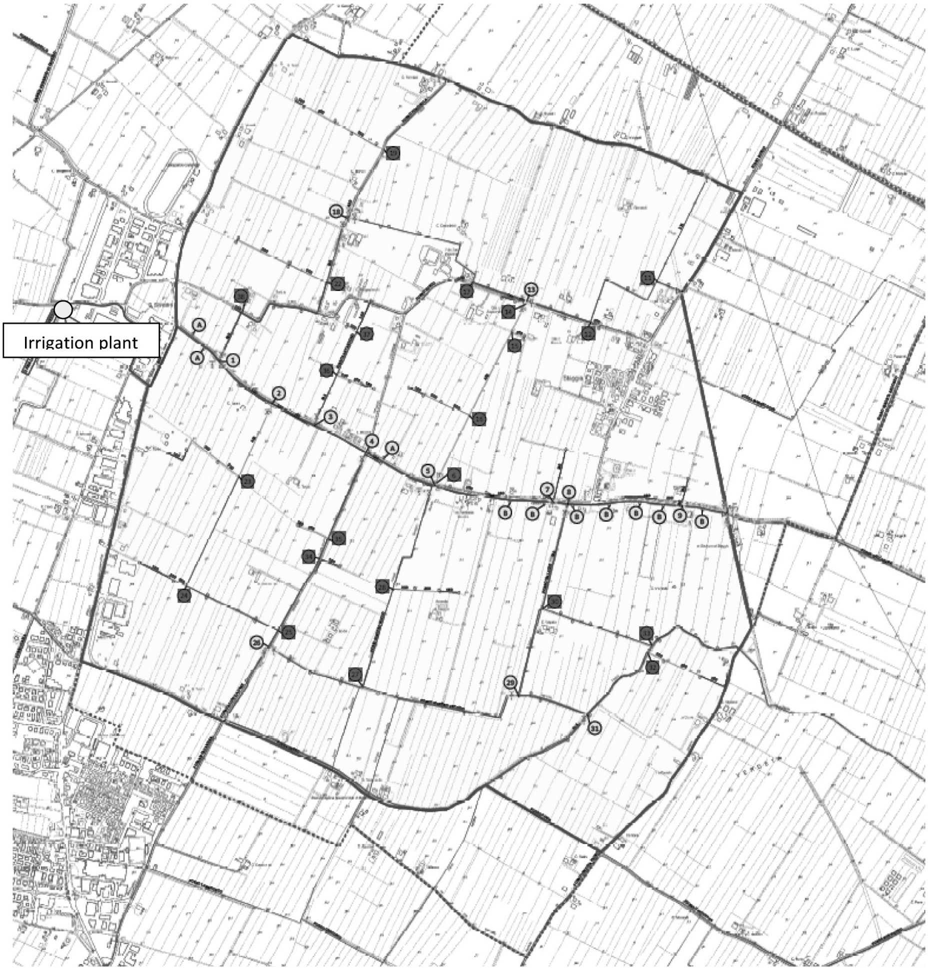
- A pumping station, with a maximum discharge of 700 l/sec. and a pressure of 7,5 bars. There are 6 vertical axes centrifugal pumps: 4 pumps of 175 l/sec., 1 pump of 100 l/sec. to control water stream and 1 pilot pump of 20 l/sec. Energy consumption is about 800 kW in total.

Figure 3 - Staggia Plant – layout pumping station



- An undergorund irrigation network, made of about 26 km of pipes (7.620 meters are made of cast iron and 17.900 meters are made of PVC) with a diameter ranging from 160 mm to 800 mm and 124 irrigation hydrants.

Figure 4 - Staggia Plant – irrigation pipe network



This advanced pressurized irrigation system makes it possible to **save a medium annual water volume amount, needed for irrigation, of about 41%** and about **38.800 kW of energy consumed** by irrigation plants.

In order to quantify water saving it was compared the total water volume per year: in one case it was considered the volume delivered to crops using open channels and in the other case the volume delivered through underground pipe network.

1.2. *Water Balance*

Croops need a volume of water which is lower than the total amount of water Burana Board uplifts from natural rivers, since during delivering activities, due to the losses during the transition through ~~to~~ open channels, a huge amount of water is lost. Below it is shown how to compute water losses, according to some parameters related to this phenomenon, and how to compare data before and after the construction of the new innovative irrigation plant described in par. 2.1.

a) Before Analysis

- **Crops need**: The total amount of water needed per year for all areas is calculated multuplying for each crop its cultivated areas by crops need specific value. Crops' water need data are estimated in partnership with Canale Emiliano Romagnolo Board (CER), in spite of cultivated areas are discovered by AGREA database.

Crops	**Areas (ha)**	**Crops need (m^3/ha/year)**	**Water volume needs for crops (m^3/year)**
Sugar Beet	40,83	1.496	61.085,08
Onion	0,07	2.853	203,79
Watermelon	10,08	2.455	24.747,10
Alfa Alfa	112,36	1.178	132.361,79
Maize	71,78	2.188	157.059,36
Melon	5,57	1.521	8.467,08
Potato	1,55	1.973	3.049,69
Pear	54,16	1.701	92.120,18
Peach	0,55	747	407,35
Soy	12,85	1.343	17.251,20
Grapevine	106,45	1.276	135.825,49
	416,23	**Total**	**632.578,12**

- **Efficiency of irrigation systems**: according to DGR n. 1415/2016 "Guidelines to quantify water volumes for irrigation" (Emilia-Romagna, 2016), depending on the irrigation systems used by agricoltural holdings on the considered area, it is selected an irrigation efficiency index of 0,7.

Parameters	**Water volume needs for crops (m^3/year)**
1 - Crops need	632.578,12
Efficiency index	0,7
2 - Crops need due to efficiency of irrigation systems (1/index)	**903.683,03**

- **Infiltration losses**: to compute infiltration losses, in 2013, Burana Board studied how much water goaes across the ground from canals to underground water. The infiltration coefficient for this area is 0,34 $m^3/m^2/d$ (Raimondi, 2013).

  Then, to calculate total water infiltration volume during an irrigation season, it has been considered these additional parameters:
- Open canals lenght which deliver water to the study area;
- Irrigated water level into these canals;
- Irrigation season period.

  This table contains all the data described above.

Canal name	**Lenght (m)**	**Hydraulic perimeter (m)**	**Days/ year**	**Coeff. ($m^3/m^2/d$)**	**Water infiltration volume (m^3)**
Fosso 1° ordine – (Gallarana)	3.400	1,0	120	0,34	138.720
Fosso 1° ordine – (Gesso)	3.840	1,0	120	0,34	156.672
Fosso 2° ordine (Scorticacane)	1.270	0,9	100	0,34	38.862
Fosso 2° ordine (Ginepro Nuovo)	1.290	0,9	100	0,34	39.474
Fosso 2° ordine (Ginepro Vecchio)	1.300	0,9	100	0,34	39.780
Fosso 2° ordine – (Valluzze)	815	0,9	100	0,34	24.939
Fosso 2° ordine – (Fanin)	550	0,9	100	0,34	16.830
Fosso 2° ordine – (Bosco)	2.850	0,9	100	0,34	87.210
Fosso 2° ordine – (Forcirola)	2.460	0,9	100	0,34	75.276
Fosso 2° ordine – (S. Antonio)	560	0,9	100	0,34	17.136
Total					**634.899**

- **Evaporation losses**: evaporation losses can be quantified as 1,5% of all water delivered thanks to open canals; this value emerges from the study made by CER in 1993 “L’evaporazione dalla superficie del Canale Emiliano Romagnolo” – Edagricole (Romagnolo, 1994).

So, using all parameters and data described above, in next table it is shown how much water (expressed in cubic metres per year) has to be delivered to the study area.

Parameters	**Water volume (m^3/year)**
1 - Crops need	632.578,12
2 - Crops need due to efficiency of irrigation systems	903.683,03
3 - Infiltration losses	634.899
Total (2+3)	**1.538.582,03**
4 - Evaporation losses (1,5%)	23.078,73
Total volume (2+3+4)	**1.561.660,76**

Comparing total volume with the crops' need, water losses are about 60%.

B) After Analysis

- **Crops' need**: The total water need per year for all areas is calculated moltiplying for each crop its cultivated areas by the crops' need specific value. Crops' need data are estimated in partnership with Canale Emiliano Romagnolo Board (CER), in spite of cultivated areas are discovered by AGREA database.

Crops	**Areas (ha)**	**Crops need (m^3/ha/year)**	**Water volume needs for crops (m^3/year)**
Sugar Beet	40,83	1.496	61.085,08
Onion	0,07	2.853	203,79
Watermelon	10,08	2.455	24.747,10
Alfa Alfa	112,36	1.178	132.361,79
Maize	71,78	2.188	157.059,36
Melon	5,57	1.521	8.467,08
Potato	1,55	1.973	3.049,69
Pear	54,16	1.701	92.120,18
Peach	0,55	747	407,35
Soy	12,85	1.343	17.251,20
Grapevine	106,45	1.276	135.825,49
	416,23	**Total**	**632.578,12**

- **Efficiency of irrigation systems**: according to DGR n. 1415/2016 "Guidelines to quantify water volumes for irrigation" (Emilia-Romagna, 2016), depending on irrigation systems used by agricoltural holdings on the studing area, it is selected an irrigation efficiency index of 0,7.

Parameters	**Water volume (m^3/year)**
Crops need	632 578,12
Efficiency index	0,7
Crops need due to efficiency of irrigation systems (1/index)	**903.683,03**

- **Infiltration losses**: No losses.
- **Evaporation losses**: No losses.

Utilizing all parameters and data mentioned above, in next table it is shown how much water(expressed in cubic metres per year) has to be delivered to the study area. After the construction of the new irrigation plant, the only water loss is due to the efficiency of the agricoultural holdings irrigation systems. e can therefore affirm that the new plant can save the following volume percentage of water:

$$V_{tot\ saved}\,(\%) = (1 - 903.683{,}03/1.561.660{,}76)\% \approx \mathbf{41\%}$$

Last but not least, if agricoltural holdings decide to improve their irrigation systems with new advanced ones, like microirrigation, then the efficiency index would increase to 0,9, and water saving wil be:

Parameters	**Water volume (m^3/year)**
Crops need	632.578,12
Efficiency index	0,9
Crops need due to efficiency of irrigation systems	**702.864,57**

$$V_{tot\ saved}\,(\%) = (1 - 702.864{,}57/1.561.660{,}76)\% \approx \mathbf{55\%}$$

2. Climate change and environmental issue related to irrigation

The design and innovation activities led by Burana Board on its infrastructure aim to ensure a the correct management of the water resource for irrigation, and the correct development for a greater competitiveness of the agricultural sector, together with the protection of rural areas, agri-food, forestry, fisheries and aquaculture businesses. These goals are achieved while taking into account criteria such as environmental sustainability, reduction of the effetcts on climate change, quality of production, innovation and job security.

In last fifteen years Burana technicians has had to face five unexpected water crises, with fluctuating climatic conditions characterized by poor railfalls and snowfalls during autumn and winter, very high temperatures and evaporation from soils and vegetation during summer, as well as very low water levels into Po river from June to September.

2.1. *A land affected by drought – an example of ecological and economic losses*

The lack of water resources could create damages on local agricultural activities, above all to tree crops like pears, peaches and vineyards. However, besides the economic damage, drought induces other chain reactions on the environment, which are not immediately quantifiable in monetary terms, but on the long term they will be the cause of a deterioration of the ecosystems first, and human health after.

Drought influences the quality of underground waters too, as a matter of fact in case of a not sufficient volume of rainfalls and melted snow after winter, the recharging of aquifers can be compromised and their hydrological structure modified untill irreversible conditions.

Another phenomenon which must not be overlooked, that is becoming increasingly in recent years, is the drying of the soils surface layer.

The lack of adequate rainfalls during autumn and winter seasons (when we talk about adequate rainfalls we have to think about steady rainfall events, not anomalous meteorological events), followed by a sudden increase in temperatures and evapotranspiration, usually creates strong stress conditions in soils. This could be the cause of a huge lost in organic, chemical and physical properties, the ones that in normal conditions characterize the Po river Valley for being one of the most fertile zone in Europe.

In recent years the water catchment area of the Panaro river has been affected by increasingly drought phenomena, during which Burana was ordered to reduce the volume of water resource which can be drawn, or even to suspend its uplift, in order to guarantee the respect of a condition of minimum outflow into the river;. This was needful to the maintenance of the natural ecological integrity. As a matter of fact nowadays we are observing a dangerous change of the Appennine watercourses hydraulic conditions: they are all becoming torrential courses, featuring very critical flows during flood events and almost dry riverbed during the summer.

One of the agricoltural areas which are most at risk of drought, under Burana Board management, in which during the coming years it could be possible to stop irrigation in case of a lack of water, is located surrounded Nonantola, Ravarino and Sant'Agata towns. In these territories there are crops of high agronomic value, like pears, peaches, vineyards, melons and plums; here are also cultivated lot of precious field crops as sugar beet, alfa alfa, maize and some vegetables, as tomato. In 2017 Burana technicians had to close irrigation for some field crops, in order to avoid more damages to high agronomic crops.

In next table we can find a lot of crops, it is possible to find in an irrigation subdistrict close to Nonantola town; for each crops we can find cultivated area, specific water need for year and total water need for year for all areas.

Crops	**Areas (ha)**	**Crops need (m^3/ha/year)**	**Water volume needs for crops (m^3/year)**
Sugar Beet	140,00	1.620	226.800
Alfa Alfa	700,00	1.320	924.000
Fodder	35,00	1.320	46.200
Maize	215,00	2.470	531.049
Apple	3,00	2.900	8.700
Vegetable	17,00	2.000	34.000
Pear	180,00	2.900	522.000
Peach	1,00	1.490	1.490
Tomato	20,00	2.000	40.000
Soy	77,00	1.781	137.137
Plum	21,00	1.490	31.290
Grapevine	140,00	1.303	182.420
	1.549	**Total**	**2.685.086**

Using these data, it is possible to quantify economic losses caused by drought and a lack of water. At the same time we can compute a productivity index for water use. All the analysis are made for two crops, selected for the following reasons:

- Maize: it is one of the most water-demanding crop and there are a lot of cultivated areas; moreover in case of scarcity, this colture is one of the first deprived of water;

- Tomato: there are not so much areas cultivated with tomatoes, but this is one of the most water-demanding crop and it suffers more than the others the lack of water.

After 2017 drought, Burana technicians, calculated that the profit for maize per year, for a standard irrigation season, is 1.218,46 €/hectars; so into the irrigation subdistrict close to Nonantola town, for 215 hectars of maize, the total profit is more than 260.000 € per year. Therefore, if a reduction of resource for agricolture occours, it could be the cause of hundreds of thousands euros losses on an area of less more than 200 hectars.

After a SIM project meeting at the Ministry of Agricultural, Food and Forestry Policies, we decided to compare profit value, calculated as shown above, with an associated hypotetical profit value simulated using economic water productivity data for maize, calculated by the team of Prof. Ing. Marco Mancini during SIM project researches (Mancini & Menenti, Waterjpi, 2019) (Mancini, SIM, 2019). The index is 0,39 € for each cubic meter delivered to maize (Mancini & Menenti, SIM: Smart Irrigation from Soil Moisture Forecast using Satellite and Hydro Meteo Modelling, report, 2019); consequently moltipliyng this index for total water volume needs for maize (513.049 m^3/year) it can be found that the hypotetical profit is about 210.000 €.

Using the same calculation model for tomatoes, which index is 2,44 €/m^3, total economic losses, in case of resource scarsity, are about 100.000 € for only 20 hectars.

Lastly, after the economic analysis described in this paragraph, it is possible to understand why it will be so important for Burana Board to reshape irrigation systems and to design new advanced irrigation structures; one of this enterprise is the project described in next paragraph.

The enterprise of a new path for water resources from Po River

In order to reduce the increasing risks due to drought into Panaro river Basin, Burana Board has begun a campaign of hydraulic surveys and the evaluation of further water uplifting from the Canale Emiliano Romagnolo (CER). CER takes the resource from Po river close to Ferrara, so it will be possible to uplift it untill Modena, going to rescue Nonantola irrigation sub-district, increasingly hit by the crises due to the lack of water for irrigation.

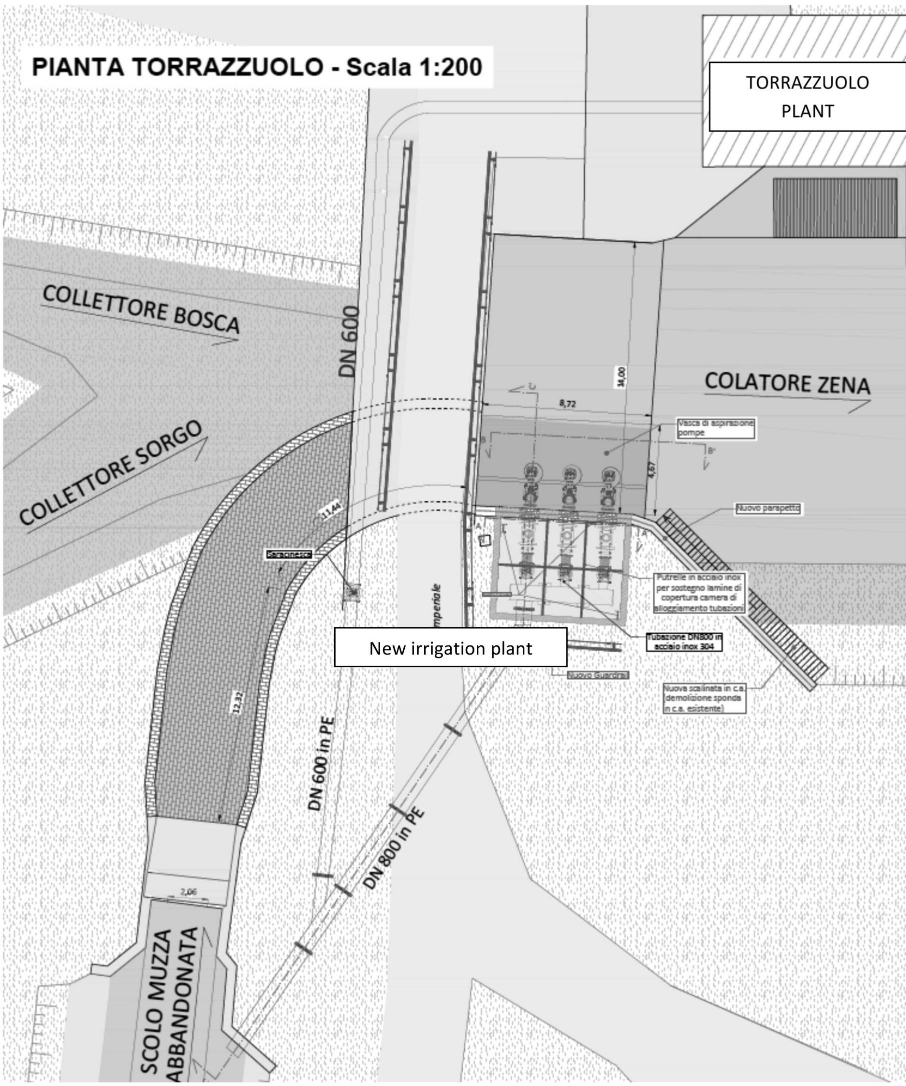
Figure 5 - Project to be carried out to increase water supply into irrigation sub-district called Nonantola

The project is made of several works, thank to Burana Board it can achieve its purposes and perform its duties:

A) Building a new pumping station, called Sussidiario Torrazzuolo

After the check of pumps layout it was clear the impossibility to increase irrigation flow up to Nonantola sub-district using only the old pumping station; therefore Burana's engineers designed this new station equipped with n. 3 pumps with the power of 400 l/s each (2 operating pumps and 1 spare pump). The water is uplifted into a pipe and then discharged into Muzza Abbandonata canal, to starts its journey towards Modena.

Figure 6 - Layout Sussidiario Torrazzuolo Plant



B) Building two new pumping hydraulic works:-Redù and Principe

To uplift water from areas lower than others, untill territories close to Modena, it's necessary to build two new hydraulic works (called Redù and Principe) equipped with two pumps of 380 l/s each and two sluice gates to stop downstream and storage water between the hydraulics works designed.

Moreover, thanks to the opportunity of setting sluice gates, it is possible to control the discharge through the hydraulic works; so in case of a low rainfall event, which could be the cause of a not huge flow into canals, Burana thecnicians can store a volume of water, saving it from uncontrolled discharge and storaging into the canal. This makes it possible to reduce consumption of energy too.

Figure 7 - Redù hydraulic pumping work – front view

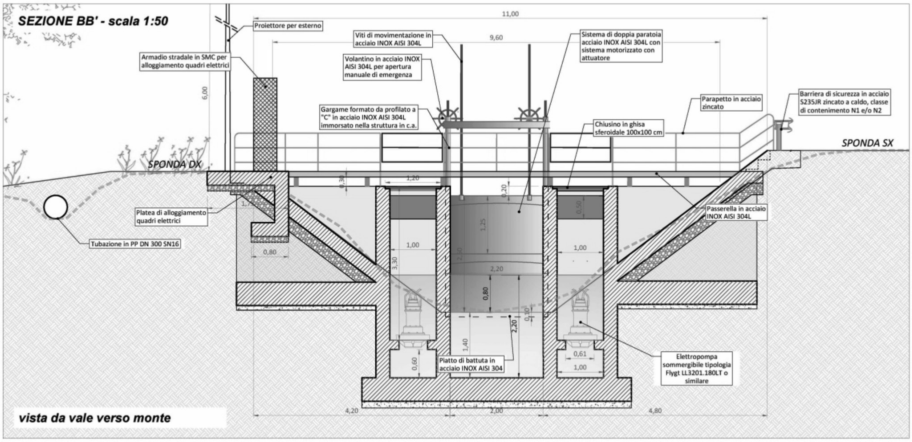
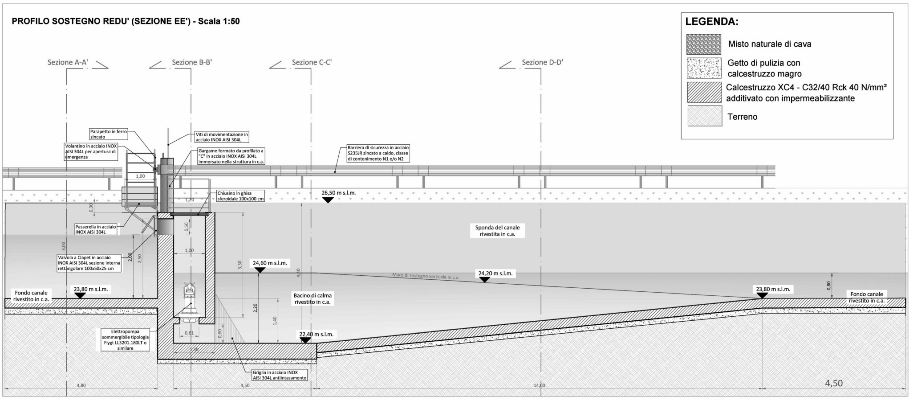


Figure 8 - Redù hydraulic pumping work – side section view



C) Laying PEAD pipe to carry out water from irrigation main canal to irrigation sub-district

At last, in order to make possible the irrigation of Nonantola sub-district, it's being built a PEAD pipe to connect the main irrigation canal, the Gaggio-Panzano, to the first irrigation canal into Nonantola sub-district, called Canaletta A-B; then it will be possible to deliver water resource even in case of a strong drought. To control flow through the pipe, a sluice gate will be put on its entrance, which can be controlled and set by Burana technicians, depending on the irrigation needs.

Figure 9 - Hydraulic connection between Gaggio-Panzano canal and Canaletta A-B canal – layout PEAD pipe

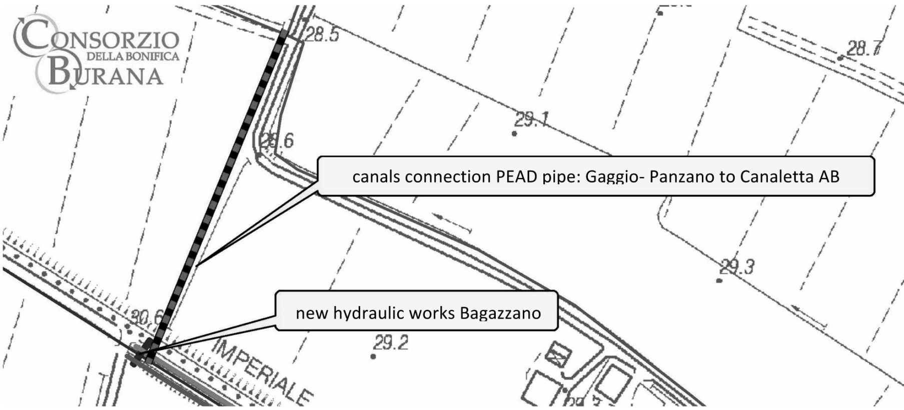
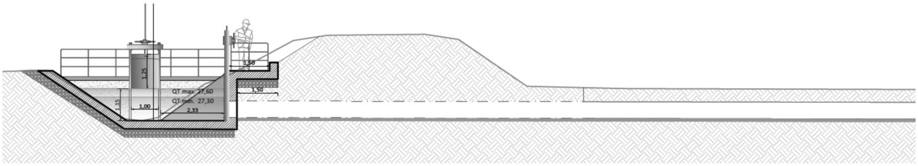


Figure 10 - Hydraulic connection between Gaggio-Panzano canal and Canaletta A-B canal – section view PEAD pipe



3. Conclusion

The projects described in this article, which use modern irrigation technologies and materials, are the clear proof of the reduction of water consumption in irrigation and of the optimization of the surface water resources for "top grade specialization" farms gathered together.

Moreover, thanks to these new works it is possible to provide indirect benefits to the environment, such as: fighting against drought, increasing the value of ecosystems and natural water habitats.

All the projects are repeatable in other territories, so it will be useful to encourage their implementation in the areas that are lacking in available surface water resources and where a huge use of surface water and groundwater can get ecosystem qualitative status worse. Moreover, an improvement in water management systems can be quantified immediately in a financial return of hundreds of thousands euros per year for each agricoltural holdings, as discussed in par. 3.1.

In conclusion, in Chapter 3, we underlined the opportunity to use a part of flood waters, setting sluice gates. In such a way we can storage a volume of water, which is bounded between an hydraulic works and another, transforming the threat of a flood into a resource for agricolture, environment and ecosystems.

References

Consorzio di Bonifica Canale Emiliano-Romagnolo. (1994). L'evaporazione della superficie del Canale Emiliano Romagnolo. *Irrigazione drenaggio – Edagricole*.

Mancini, M. (2019). *SIM project*. -- Retrieved from www.sim.polimi.it/meetings/.

Mancini, M. & Menenti, J.S. (2019). SIM: Smart Irrigation from Soil Moisture Forecast using Satellite and Hydro Meteo Modelling. -- Retrieved from https://meetingorganizer.copernicus.org/EGU2019/EGU2019-16137.pdf.

Mancini, M. & Menenti, J.S. (2019). *Waterjpi*. -- Retrieved from Waterjpi, http://www.waterjpi.eu/joint-calls/joint-call-2015-waterworks-2014/sim.

Raimondi, G.S. (2013). *Progetto ITER 2013. "Acquisizione di conoscenze sulla falda ipodermica come contributo per la gestione della rete di canali di bonifica e irrigazione gestita dal Consorzio della Bonifica Burana"*.

Regione Emilia-Romagna (2016). Delibera di Giunta Regionale n. 1415. *Guidelines to quantify water volumes for irrigation*. Bologna, Emilia-Romagna, Italia.

Cinalberto Bertozzi
Burana Land-Reclamation Board, Italy
C.so Vittorio Emanuele II, 107 - Modena (MO), Italy.
E-mail: c.bertozzi@consorzioburana.it
Engineer. General Manager and Project Manager. He supervises all technical and administrative tasks.

Fabio Paglione
Burana Land-Reclamation Board, Italy
C.so Vittorio Emanuele II, 107 - Modena (MO), Italy.
E-mail: f.paglione@consorzioburana.it
Engineer. Technical Manager. He is in charge of designing and construction supervision and he is involved in all research and development activities.