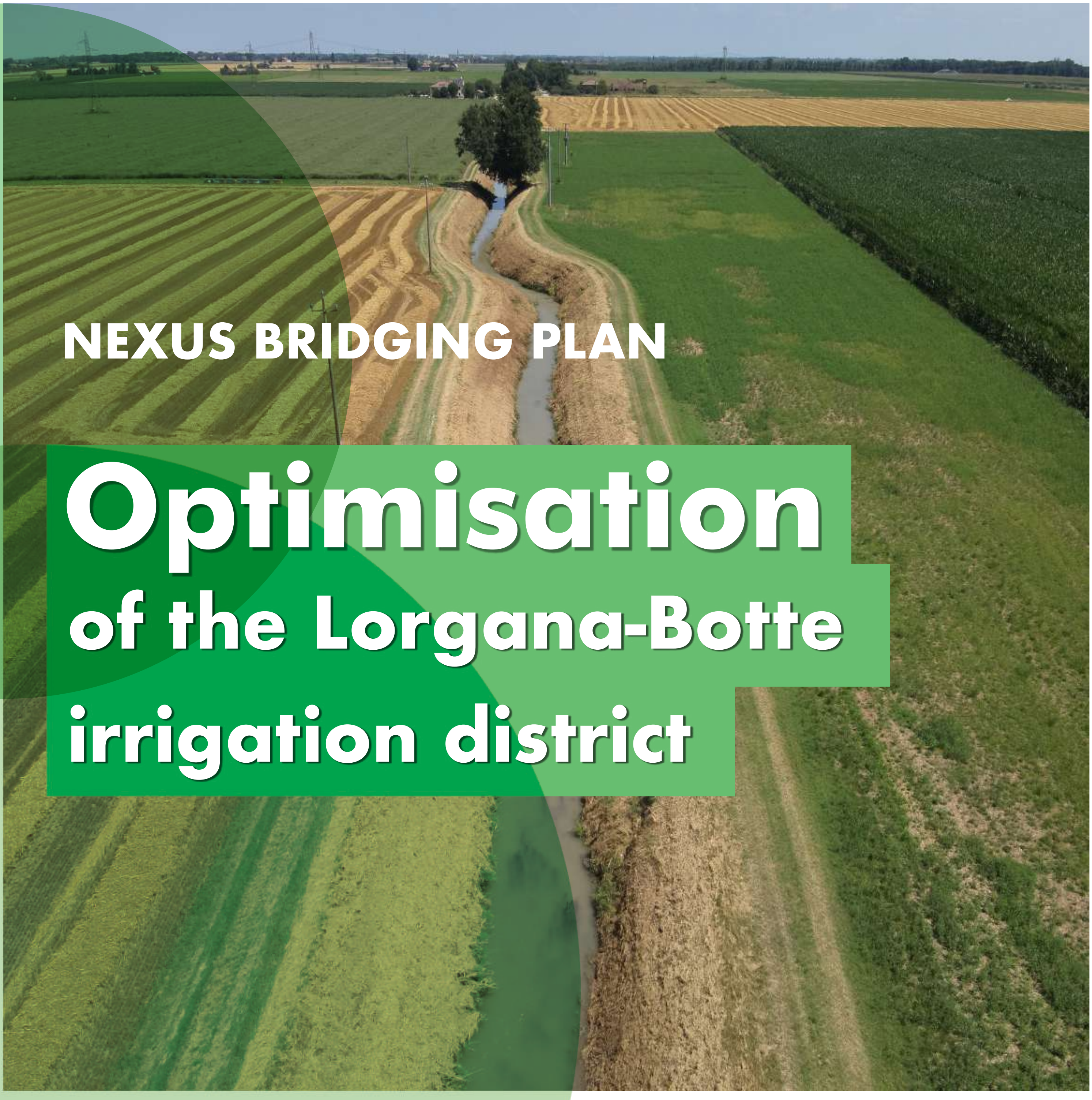
BONEX



NEXUS BRIDGING PLAN

Optimisation of the Lorgana-Botte irrigation district

Emilia Romagna, **Italy**

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

This project is part of the PRIMA programme supported by the European Union.

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BONEX Boosting Nexus Framework Implementation in the Mediterranean

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Executive summary

In the past, water availability was never a concern in the *Emilia-Romagna* region. However, it has become an increasingly valuable resource due to different factors. In the recent years, irrigation season has been marked by high-water stress, with scarcity conditions becoming more frequent. It is therefore essential to optimise water use and reduce distribution efficiencies.

Moreover, water quality is another critical issue. The quality of water flowing in canals is not always good, and during the water scarcity, conditions can further decline due to low water quantity and less dilution. The agricultural sector, vital to the region's economy, is the most affected. These challenges also harm the broader ecosystem of the *Emilia-Romagna* region, causing environmental degradation that is widely recognised and felt by the local population.

The WEFe (Water-Energy-Food-ecosystems) concept highlights the interconnected relationship between water, energy, food production, and ecosystem conservation. [The BONEX project](https://bonex-prima.eu)[1] aims to provide practical and adapted tools, examine concrete and context-adapted technological innovations, enhance policies and governance and facilitate WEFe nexus practical implementation that balances the social, economic, and ecological trade-offs.

The present Nexus Bridging Plan (NBP) was developed within the scope of the BONEX Project for the seven Demonstration Projects across the Mediterranean Region. The NBPs are practical context-specific plans guiding the transdisciplinary implementation of the proposed WEFe solution approaches targeting policy makers and practitioners. The current plan outlines the WEFe Nexus Bridging strategy in *Lorgana-Botte* irrigation district (Emilia Romagna region), where different interventions related to the WEFe Nexus were applied, promoting innovative practices and ensuring replicability of results in other Mediterranean areas. The main objective of the DP is to quantitatively optimise the water balance of the irrigation water network in order to minimise losses and lower input water withdrawn from the renewable resources. By lowering water abstraction, also energy costs can be reduced, contributing to the sustainability of the agricultural sector. In this process, all water flows to/from the area must be considered. By carefully analysing water inflows and outflows, it is possible to identify and minimise water losses in the irrigation district and optimisde water balance. Moreover, improving water quality through Nature-based solutions (NbS) and continuously monitoring key quality parameters in the surface distribution network can help detect potential issues early and enable timely corrective actions.

The interventions carried out during the BONEX project include: 1) **closure of the water balance of the irrigation water network**, 2) **assessing the impact of WWTP effluent discharges on irrigation water quality**, and 3) **utilising NbS to improve water quality**. Apart from these, the implementation of water quality sensors, the awareness-raising initiatives for civil society and the construction of new reservoirs in peri-urban areas can, according to all stakeholders, have a positive impact on the WEFe nexus in the DP.

The current plan outlines the WEFe Nexus Bridging strategy in Lorgana-Botte irrigation district (Emilia Romagna region), where different interventions related to the WEFe Nexus were applied

[1] https://bonex-prima.eu

Methodological approach

The Italian demonstration project (DP) is located in the *Lorgana-Botte* irrigation district in the Emilia Romagna region of Italy. Covering a total surface of around 22,500 hectares, it is managed by the CBR (*Consorzio di Bonifica Renana*), the project partner responsible for the distribution of irrigation water in the area.

Initially, a scoping assessment was conducted in the context of the BONEX project. This was followed by stakeholder workshops, where **WEFe issues (irrigation water quantity and quality)** were identified through Causal Loop Diagrams (CLDs) and the potential interventions (to close the water balance of the distribution network and propose measures for water use and energy use efficiency, assess effects of NbSs and WWTP discharges on irrigation water quality) selected. CLDs were developed to visualise the complex interactions between WEFe components. A collaborative approach was used, with participants working in groups to identify key relationships. The interconnections were developed throughout multi-actor processes, with close collaboration between all value chain relevant actors, such as water managers, farmers, agri-food chain agents, public administration, technology providers, researchers, civil society organisations and consumers.

The interventions developed within the BONEX project are essential for addressing critical challenges of water scarcity and water quality within the case Italian DP

Subsequent steps involved a detailed analysis of hydrological and energy data within the DP. Additionally, irrigation water samples were collected from a wetland and along a channel under an innovative harvesting regime, as well as from a channel that received the WWTP discharge, to evaluate the effect of these measures on water quality. A comprehensive water balance of the irrigation water network was also carried out, and water leakage was accounted through seepage tests.

During the application of these technical steps, a stakeholder analysis was also conducted to **identify key actors** and ensure their involvement in the project. To gain insights into institutional frameworks and decision-making processes, interviews were conducted with key experts from the consortium responsible for irrigation water transport in the *Emilia-Romagna* region, as well as with the regional authorities, farmers and environmental specialists. An online survey was distributed to stakeholders identified through the stakeholder analysis and workshop participants to assess ecosystem services. Socio-economic assessments were conducted, utilising data from ISTAT where applicable.

The interventions developed within the BONEX project are essential for addressing critical challenges of water scarcity and water quality within the case Italian DP, issues that were already recognised by the different stakeholders. The timely and efficient implementation of these solutions would probably not have been so fast and complete without the support and resources provided by the BONEX project.

However, the implementation of the framework was partially hindered by challenges associated with the **large-scale nature of the irrigation district**. The vast spatial area and diverse socio-economic conditions within the district resulted in significant variability, making it challenging to identify and address the diverse needs of stakeholders. Additionally, extreme weather events, such as droughts and floods, further complicated the implementation process by disrupting the normal course of scheduled events.

Context description

Lorgana-Botte irrigation district (Figure 1), located in Emilia-Romagna region, is a macro-district within 4 municipalities: Baricella, Budrio, Minerbio and Molinella. The resident population in the DP area was estimated to be 49,799 inhabitants as the sum of the four municipalities (Baricella 7,021; Budrio 18,294; Minerbio 8,854; Molinella 15,630). This is only an estimate, as the DP area lies within the boundaries of these four municipalities but includes only part of each.

The DP covers approximately **22,500 hectares, of which 5,500 hectares are irrigated**. It is also characterised by well-defined water inflows and outflows, the presence of a significant wetland area (1,300 hectares) with important environmental functions, and 12 WWTPs that discharge their effluents into the irrigation network. The Nexus focus for this DP was to analyse water and energy conservation measures and approaches based on the real water balance, at district scale, considering also the effects and benefits provided by NbS. Moreover, the hydraulic network has various functions (irrigation water distribution, drainage water and treated wastewater collection, flood control, water quality regulation) that complicate its efficient management.

Water resources are unevenly distributed across the Mediterranean and the Emilia-Romagna region has experienced different water crises. For instance, in 2017, a state of water emergency was declared due to severe drought and a consequent water deficit. Other agricultural seasons have witnessed significant periods of summer drought (2015), spring drought (2016), or both (2012). In 2022, the unprecedented drought led the Po River to reach its lowest recorded level. Furthermore, the DP area was affected by the floods of May 2023 and October 2024. Climate change is intensifying, with altered rainfall patterns and increased air temperatures, which could reduce freshwater availability by 25-50% by 2050 in the Mediterranean.

Regarding the social and economic data, in the year 2022, based on ISMEA data, the Emilia-Romagna region contributed 12.2% to the total national production (in Italy), with a total annual value of 7,031,764 euros. In terms of cultivated area, the most representative crops in the DP are waxy maize for biomass, grain maize, soybeans, potatoes and sugar beet. All these data show an important food production nature of the DP.

Water scarcity is an environmental problem, compounded by **wetland loss for agriculture** and the **removal of riparian vegetation**. However, solutions like preserving riparian vegetation and regional measures, including incentives for wetland restoration, are being implemented. Energy consumption has risen due to economic growth and water scarcity, requiring pumps for water distribution. Water quality has improved with better treatment technologies, and irrigation efficiency has increased, though water losses remain a concern.

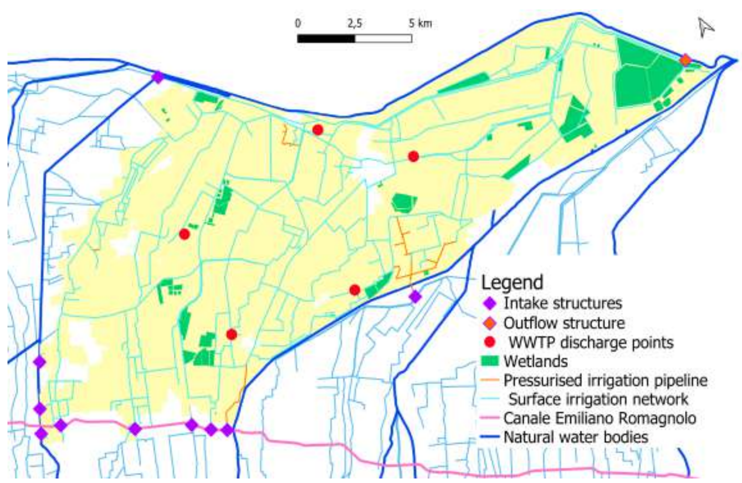

Figure 1 – The map of the Italian DP.

WEFe Nexus issue

During, the initial workshop, a series of WEFe issues, water quantity and quality being most important, were identified and analysed through exercises conducted with stakeholders. These issues provided the foundation for the development of the CLD and are linked to various components of the DP *(Figure 2)*.

Surface water availability is one of the main problems identified within the area boundaries by the relevant actors, who also mentioned **water scarcity** as the critical issue, both directly affecting the agricultural and other relevant economic sector. Many factors could positively affect these problems, such as discharge from the wastewater treatment plants and the construction of a new reservoirs to increase the surface water storage and therefore mitigate the effect of droughts and rainfall concentrated only at certain times of the year. On the other hand, wetlands, a natural solution, can increase both surface water quantity and quality. In the Italian DP, surface water quantity, representing water WEFe component, is also directly correlated to food (water needed for agricultural production), energy (pumps are used for water conveying and distribution) and ecosystem (water resources needed for wetland and ecosystem development) elements.

The important variable to consider for water quality is the **presence of wetlands** that can alleviate water scarcity but can also positively affect water quality through natural treatment processes. Another variable are the **wastewater treatment plants**, that discharge their effluent in the surface water network of the DP. **Water reuse** and improved irrigation technologies are key variables for increasing water use efficiency. Increasing the quality of irrigation resources can generate higher profitability of production. Reusing treated wastewater is also considered an

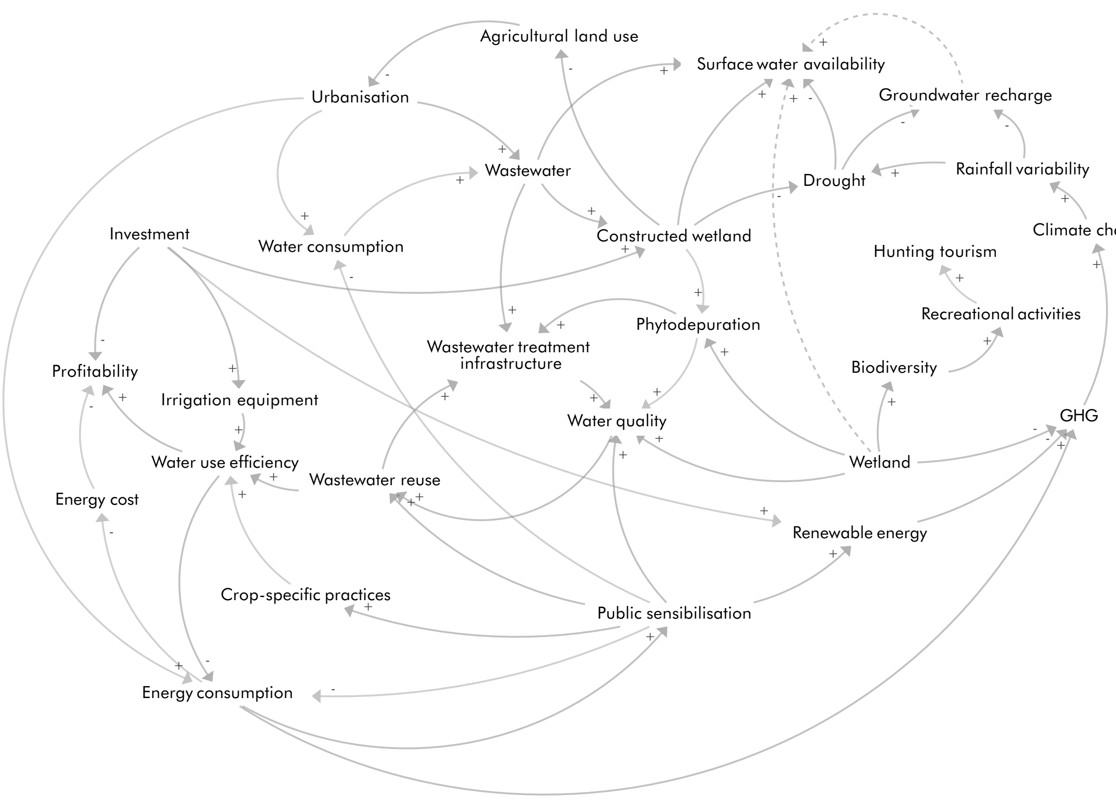

Figure 2 – Causal Loop Diagram DP.

important strategy for addressing drought-related challenges. Finally, the need for efficient communication among different stakeholders emerged as necessary. Similarly, the presence of public and private investment to address the issues is identified as very important.
The problem of **water quality** is very relevant within the Italian DP due to the presence of several wastewater treatment plants that discharge directly into the irrigation distribution network. Proper treatment of polluted water can improve water quality and increase the profitability of the cultivated products and agricultural productivity in general. Reuse of water increases water availability, which in turn can decrease energy consumption (with a positive impact on GHG emissions) benefiting the environment and economy.

From an **energy** perspective, the seasonal differences between summer and winter are particularly relevant and noteworthy. During winter there is less energy use because the water is drained, most of the time by gravity, excluding the use of pumps. On the other hand, in summer the irrigation season is at its peak and the water has to be moved to reach all areas of the district, requiring the use of electricity. The rise in energy costs that have occurred in recent years has created problems for all productive sectors in the region, including domestic costs with rising energy bills. Moreover, a greater efficiency in irrigation distribution ensures greater water availability, a factor that positively influences food production and the economy. Therefore, it is crucial to close the water balance of the irrigation water network, identifying and quantifying all the important components (*e.g.* infiltration water loss).

In general, the **ecosystem** value of the study area is low, but numerous actions are aimed at increasing it. The regional authorities' incentive for the wetland creation and restoration that increases the environmental value of the entire area. Good ecosystem health provides many benefits to the entire population, increasing the scenic and recreational value of the area. A complex and healthy ecosystem is also more resilient against alien species, which cause many problems for the agricultural sector and not only.

Stakeholder engagement

Apart from UNIBO and CBR, which are the project partners, various other stakeholders have been involved in the project's progress. **CER**, the land reclamation consortium, plays a key role in managing water resources by conveying water from the Po River to agricultural areas in *Emilia-Romagna*. While the primary focus of both **CBR** and **CER** is irrigation water management, their interests extend to drainage, flood prevention, sustainable agriculture, and environmental quality. ***ANBI Emilia-Romagna*** represents all land reclamation and irrigation consortia, along with other regional entities engaged in soil protection and water resource management. Additionally, **ARPAE**, the environmental agency of *Emilia-Romagna*, is responsible for monitoring water and environmental quality, while **HERA**, a multi-utility company, manages the integrated water system and wastewater treatment plants in the DP area, as well as energy distribution.

Other key stakeholders include **CONFAGRICOLTURA**, Italy's oldest organization representing agricultural enterprises, and **COLDIRETTI**, the country's largest farmers' association, which collaborates with local and national authorities. The *Unione dei Comuni Terre di Pianura*, an administrative union of municipalities where the DP is partly located, faces WEFe challenges, particularly during summer months when water scarcity impacts irrigation and ecosystems. This union is part of the larger **Metropolitan City of Bologna**, another significant institutional stakeholder. The *Emilia-Romagna* regional authorities contributed to the project through various departments focused on sustainable water management and environmental protection. Environmental groups such as **LEGAMBIENTE**, which advocates for environmental and societal well-being, and **GEV Bologna**, a group of voluntary ecological guards monitoring water quality, also play a role. **Wetland owners**, typically farmers managing wetlands in the DP, are directly involved in the WEFe nexus by storing and gradually releasing water, influencing both water quantity and quality.

Non-monetary value estimation

In Italy, 13 surveys were conducted with stakeholders closely involved in agricultural cycle in the district. The findings highlight a strong emphasis on the practical importance of natural resources, particularly water, energy, and ecosystems, which are considered essential for sustaining agricultural production, economic stability, and food security. These resources are also seen as fundamental to industrial growth and local livelihoods. While the **economic benefits of natural resources** dominate perceptions, some stakeholders also recognise their role in maintaining cultural traditions, strengthening social networks, and fostering a sense of community.

Additionally, there is an underlying acknowledgment of nature's intrinsic worth, even if it is not always at the forefront of decision-making. This case study provides valuable insights into the WEFe nexus in Italy, illustrating how local communities perceive their environment and offering important considerations for sustainable resource management. Stakeholders expressed a variety of perspectives/emotions shaped by their experiences and relationship with each component of the WEFe *(Figure 3)*.

The Italy case study highlights a strong reliance on material and economic aspects of **socio-ecological systems**. While the experiential and cognitive dimensions indicate generally positive environmental interactions and a solid understanding of local ecosystems, there remains room to enhance environmental awareness and engagement. The emotional dimension reflects a strong sense of connection to the land, with many stakeholders expressing deep attachment to their surroundings. At the same time, the philosophical dimension reveals a widespread belief in the importance of nature and sustainability, suggesting a cultural appreciation for the environment that may not always translate into direct action. These insights contribute to a more integrated approach to managing the WEFe nexus, ensuring that economic priorities are balanced with cultural and ecological considerations.

Figure 3 – Word cloud with the values identified by the interviewees to the four components of WEFe.

WEFe: Interventions and complementary measures

Based on the problems that were identified in the Italian DP and on the discussions with the key stakeholders in the area, including those during the project workshops, three interventions were designed. These were designed to address the issues of water quantity and water quality in the DP and comprise:

1. Closure of the water balance of the irrigation water network to reduce water and energy needs
2. Use of NbS to improve irrigation water quality
3. Assessment of the impact that WWTP discharge has on irrigation water quality

Each of them was applied on a different scale and thanks to the early start of the project activities, measurements from a longer period of time are available.

Closure of the water balance of the irrigation water network

The intervention aimed at closing the water balance of the irrigation water network focused on the quantification of different components of

Figure 4 – Typical irrigation canal in the DP.

the balance and their water volumes (*e.g.* crop water needs, infiltration, evaporation), but also on the closely connected energy consumption. Data from four years (2021-2024) were analysed, considering also weather conditions. For example, during the intensive rain events, the irrigation water network is usually emptied in order to be able to receive all the precipitation water and protect the area from flooding.
Some of the components of the water balance, however, weren't considered in detail in the past and therefore their empirical estimation was needed. For example, infiltration trials were performed in different types of irrigation canals *(Figure 4)* using various methods, also through isolating of a canal reach by creating an upstream and downstream barrier, and measuring the variations in water level during time. The evaporation from the water distribution network is another variable that can affect the water balance and it was calculated using Penman-Monteith method. Its application required different primary data that were not readily accessible. For example, infiltration depends on the water depth as well as groundwater level in the specific time moment. In the case of high groundwater table and its contact with the canal bed, it can be assumed that infiltration losses are non-existent. On the other hand, during summer months, there can be a certain distance between the groundwater level and canal bed, indicating presence of infiltration water losses.

Use of Nature-based Solutions to improve irrigation water quality

Two types of NbS were applied in the Italian DP: i) wetlands, either already existing ones or restored, ii) nowel mowing technique that foresees limited riparian vegetation removal along irrigation canals. The **primary benefits** of this intervention are water quality, biodiversity enhancements and cultural ecosystem services. NbS offer a way to improve water quality with a minimal amount of energy for their operation, leading to less energy demand and a decrease in GHG emissions. Moreover, the creation of natural and peaceful areas, such as wetlands, attracts fauna, increasing biodiversity and improving overall environmental statusy.

Wetlands comprise an important portion of the irrigation district and their use is promoted both by the regional government *(Figure 5)*. They are usually located in the farms and therefore farmers are those who manage them. On the other hand, wetlands often function in a batch mode - they are feed from the irrigation network, usually by the pumps, when their water level is below a certain value. On the other hand, when water level increases (*e.g.* due to the rain and/or drainage water income) or when there is a need to create turbulence and prevent stagnant water conditions, they discharge water in the irrigation network. Due to presence of biodiversity and different treatment processes, water quality can improve in the outlet. The sampling campaign was performed in different wetland systems present in the DP, showing their positive effect on the irrigation water quality.

The traditional way of managing riparian vegetation along the water distribution network is its regular harvest in order to enable unobstructed water passage. The novel approach applied in the DP consists of leaving a certain percentage of riparian vegetation (based on the canal width) in order to achieve a positive effect on the water quality *(Figure 6)*. However, the vegetation can slow the water velocity lower the overall water volume that the irrigation network can store. Therefore, a compromise needs to be found between a positive effect on water quality and flood control from one side, and the need for a certain volume of the distribution network on the other.

The successful implementation of NbS necessitates the active engagement of a diverse range of stakeholders, including private landowners potentially subject to expropriation, nature conservation associations, farmers' associations and local authorities, and **several critical barriers** impede the effective implementation of these systems. Significant financial resources are required for both the adaptation and maintenance of existing wetlands and the acquisition of specialised mowing machinery. To address this barrier, potential solutions include the formation of purchasing groups to facilitate shared equipment procurement, fostering collaborative networks among wetland managers and active seeking funding from external sources and negotiating tax incentives with local authorities.

Identifying suitable locations for the creation of new wetlands often presents significant challenges due to bureaucratic hurdles and potential expropriation issues. To overcome these obstacles, a comprehensive review of spatial planning at a broader level is crucial. This could involve identifying areas prone to flooding as potential sites for new wetland development and establishing clear regional guidelines for the

Figure 5 – One of the wetlands in the DP.

Figure 6 – Novel mowing technique.

regulation of expropriations in the public interest. However, difficulties in irrigating wetlands during drought periods pose a significant challenge to wetland management. To address this, it is crucial to review and optimise management practices by reducing the continuous recirculation of water to conserve water resources. Coordinating water needs between wetlands and agricultural activities during periods of drought is essential to avoid competing demands. Additionally, the economic value of ecosystem services provided by wetlands should be explicitly recognised within expropriation procedures.

Finally, inadequate cooperation among stakeholders can hinder the successful implementation of NbS. To foster effective collaboration, dissemination activities are crucial to engage citizens and demonstrate the tangible benefits of these systems in improving community well-being. Developing formal stakeholder agreements with clearly defined information-sharing mechanisms, aligning the objectives of all involved parties, and ensuring stakeholder participation is important (*e.g.* involving only those with direct interests) are essential.

Assessment of the impact that WWTP discharge has on irrigation water quality

In the DP there are different WWTPs that discharge their effluents into the irrigation network and therefore it is necessary to investigate the effect that these discharges can have on irrigation water quality. The water quality trend in an irrigation canal affected by treated wastewater discharge was performed in different periods during the irrigation seasons of 2023 and 2024. In specific, the sampling campaign monitored several points before (blank sample – irrigation water not affected by WWTP discharge) and after the WWTP discharge point (mixture or irrigation water and treated wastewater) along the irrigation canal. Moreover, the flow rates at these dates were also estimated since it can affect the results and give a clearer picture.
The primary benefits of WWTP discharges into the irrigation network are increased water quantity, especially important due to climate change and precipitation pattern change, and reuse of nutrients present in domestic wastewater providing double economic benefit: (i) if domestic wastewater is reused for crop irrigation there is no need to achieve high nutrient removal, thus lower

treatment costs (ii) increased nutrient content in the irrigation water can lower the use of chemical fertilisers. However, to achieve these benefits, the effect that WWTP discharge can have on irrigation water quality needs to be assessed from a wider point of view, considering pollutants other than nutrients. In this sense, it is rather important to monitor pathogen concentration since these can have negative effect on crop production and human health. Moreover, nutrient concentration must be monitored in order to provide clear bases that can convince farmers to lower their fertiliser use in agricultural production.

The successful reuse of treated wastewater for irrigation necessitates the active engagement of key stakeholders, including farmers, farmers' associations, municipalities, irrigation consortia, the regional entities, as well as industrial enterprises and multiutilities.
Several critical barriers impede the widespread adoption of treated wastewater for irrigation. Firstly, the reuse of reclaimed water would require increased water quality monitoring in order to ensure data transparency and timely responses to incidents that could affect water quality. This is crucial for the risk management planning, also required by the European legislations, but the more complex monitoring schedule would inevitably lead to higher costs. To mitigate this financial burden, collaboration between institutions and companies is crucial to avoid overlapping and reduce monitoring expenses. Furthermore, the implementation of system-wide strategic plans for the reuse of treated wastewater is essential. For instance, a carefully defined sampling plan (*e.g.* avoid sampling during intensive rain events or specific moments of the day that could bias the overall values) and design (*e.g.* composite samples over 24 hours) is paramount to ensure the acquisition of representative data. Moreover, the shared purchase of online analysis instrumentation for monitoring water quality parameters, coupled with automated data transmission and analysis facilitated by the managing entity, can significantly enhance data quality. Finally, a shared inter-entity protocol for sampling planning is also necessary to ensure data consistency and comparability. The active involvement of farmers' associations and other interested stakeholders (*e.g.* environmental NGOs) is essential to effectively utilise these advanced technologies. Sharing monitoring experiences among stakeholders can further enhance data quality and inform best practices.

On the other hand, the current regulations pertaining to water quality may not be sufficiently robust to support the safe and effective reuse of treated wastewater for irrigation. This constitutes an institutional arrangement barrier. To address this, the establishment of an irrigation council system specifically focused on water quality is proposed, but, at the same time, optimisation of the performance of existing WWTPs is crucial. Furthermore, public awareness campaigns are necessary to disseminate information about new regulations, particularly among farmers and residents within the affected territories. These campaigns should emphasise the techniques, instruments, and results obtained from various studies to enhance user awareness and understanding. Finally, adapting local regulations to the specific realities of the regional area is crucial to ensure the successful and sustainable implementation of wastewater reuse for irrigation.

Additional potential interventions

In addition to the three interventions implemented in the DP, three more potential interventions were identified in collaboration with stakeholders during the second workshop, and their barriers and potential impacts were evaluated.

Construction of new reservoirs in peri urban areas can enable storage of excess rainwater during the intensive precipitation events, contributing to the better flood protection of the areas as well as providing additional water resource during the dry periods. However, their construction is a high-cost project with significant maintenance and operating expenses, requiring also detailed feasibility studies to identify the most suitable areas. On the other hand, while building these infrastructures incurs a certain cost, their proper functioning safeguards water and other resources that can be reinvested. Reservoirs might also be combined with floating photovoltaic panels that provide renewable energy source and limit heating and evaporation water loss. There are national and international funds available for the construction of new reservoirs. Implementation of sensor technologies for real-time water quality monitoring can offer the clear picture of the irrigation water quality in every moment, enabling better environmental protection and a more sustainable agricultural production. On the other hand, the costs of the necessary equipment might be too high, and it is not clear who exactly should sustain them. Moreover, the sensors might require constant supply of energy, not always available in the field. Some potential solutions were identified to these barriers as well. For example, different research projects related to water quality improvement could be used to cover either entirely or a part of costs. In addition, the real time monitoring could enable higher awareness on emerging contaminants and consequently their integration in the current water quality planning. Consequently, the higher data availability could offer opportunities for better connection of different stakeholders.
Raising awareness of civil society is a necessary step to improve the overall management of the DP area and enable full application of the WEFe concept. However, the costs necessary for dissemination activities, education of staff and application of different programmes might be a limiting factor. On the other hand, the national or European funds can be used to cover the part of the costs while some private companies can also find their interest in financing these activities. Local network formed by civil society might be a useful partner for these initiatives and they could facilitate the connection and agreements with educational institutions and NGOs.

REWEFe tool application

To assess the status of water, energy, food and ecosystem sectors, both individually and jointly, the REWEFe (Rapid evaluation of Water-Energy-Food-ecosystem nexus) tool was used as it provides quantitative insights on the production, consumption, import and export potential of water, energy and food and accounts for the ecosystem impacts in monetary terms. This tool allowed the generation of five scenarios *(Figure 7)* to assess the effects of the interventions in the context of WEFe nexus.

The main changes that can be obtained in the Italian DP by applying the interventions proposed are:

- As a result of improved delivery efficiency (Scenario 1), less water and consequently, less energy, is required for irrigation; therefore, reductions in water and energy consumption are observed.
- The upscaled scenario (Scenario 5) shows the highest positive environmental impacts due to increased outflows from the Nexus unit, resulting in absence of blue water stress.
- Variations in food production are a result of changes in irrigated yield which is dependent on blue water availability. The fraction of blue water

available changes (increases for Scenario 1, Scenario 4 and Scenario 5) as irrigation requirements are reduced.

- A reduction in food production is reported for Scenario 3, as less nutrients are available due to being retained by the wetlands, leading to the higher nutrient stress and serving as a trade-off.

Improved delivery efficiency reduces energy consumption and increases blue water availability

within the Nexus unit leading to the fulfilment of sectoral demands. However, the development of wetlands within the area leads to a slight reduction in food production as nutrients are retained and the crops experience higher levels of nutrient stress. Though this development yields positive impacts on the environment as there is less nutrient leaching, the scenario calls for improved nutrient management measures to maintain agricultural production.

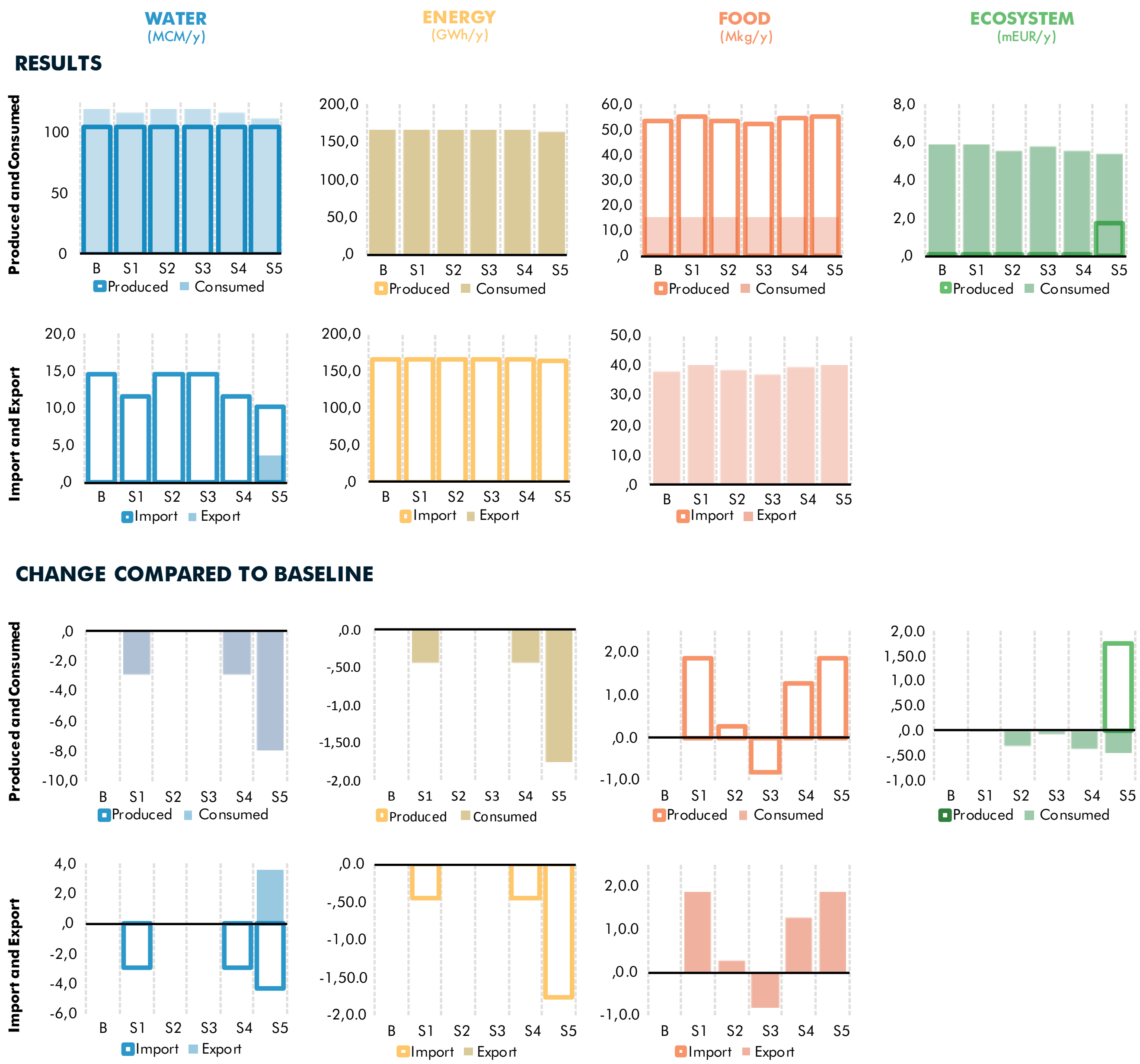

Figure 7 – Results of the three REWEF scenarios: ***Baseline (B)*** *– 100% of reclaimed water is used for irrigation;* ***Scenario 1 (S1)*** *– Effective management of water leading to higher delivery efficiency;* ***Scenario 2 (S2)*** *– Insights on water quality and nutrient demand leading to reduced fertiliser application;* ***Scenario 3 (S3)*** *– Use of wetlands for water treatment and reduction in nutrient leaching;* ***Scenario 4 (S4)*** *– combination of Scenario 1 and Scenario 2 to explore their synergetic effect; and* ***Scenario 5 (S5)*** *– Upscaled scenario based on higher adoption rate of BONEX interventions within the nexus unit*

Conclusion

By closing the water balance of the irrigation water network and identifying clearly all its components, it will be possible to reduce water losses, lower water abstraction from surface sources and therefore optimise overall agricultural water management.

Such an activity can improve **irrigation water availability**, suggest alternative ways of water management, and consequently reduce energy consumption that is needed for water distribution in the area. Moreover, the interventions oriented towards **water quality**, if applied on a larger scale, can certainly also improve this aspect and provide a more **sustainable approach to agricultural production**. On the other hand, solving these problems will enhance the environmental status and positively affect biodiversity in the area. The application of these interventions has also contributed to the development of a robust scientific methodology. For example, the monitoring of the irrigation water quality in a specific but recurring situation when treated wastewater is continuously discharged to an irrigation channel was performed in two different irrigation seasons.

Application of these interventions will require considerable financial resources and involvement of different stakeholders, a process already started with the **BONEX project**. The project has shown high awareness of the stakeholder regarding these problems, but also their great interest in resolving them, which is a positive sign.

By closing the water balance of the irrigation water network and identifying clearly all its components, it will be possible to reduce water losses

Assessing and managing trade-offs between water, energy and food, as well as ecosystem, during the project lifetime can contribute to sustainable and inclusive governance. Although the stakeholders involved had mostly a local or regional relevance, the positive change in the DP, especially if applied on a larger scale, could have a strong impact on different regional (*e.g.* Regional law 15/2006, Provisions for the Protection of Minor Wildlife in Emilia-Romagna), national (*e.g.* Legislative decree 152/2006, Environmental regulations) and international (*e.g.* Regulation (EU) 2020/741 on minimum requirements for water reuse) policies.

Moreover, the results achieved in the DP will also contribute to achieving several SDGs, namely Zero hunger (support of sustainable agricultural practices through reduction of water consumption and maintenance of ecosystems), Clean water and sanitation (improve water quality and promote polluted water treatment), Responsible consumption and production (sustainable management and efficient use of natural resources, as well as resource recycling through water reuse) and Life on land (protection of inland freshwater ecosystems through water quality improvement and wetland restoration).

Consortium

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