



Canale
Emiliano
Romagnolo



THE VALUE OF THE EMILIA ROMAGNA CANAL

*Anyone who can solve the problems
of water will be worthy of two Nobel prizes –
one for peace and one for science.*

John F. Kennedy

Project of the Irrigation Consortium
for the Emilia Romagna Canal



Written in collaboration with



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Francesco Vincenzi

National Association of Reclamation and Irrigation Consortia – ANBI

I am happy to present this volume dedicated to the value of the Emilia Romagna Canal for the Emilia-Romagna region. I also wish to thank the CER for taking on this initiative. The need for innovation in irrigation, to support modern agriculture, requires us to have a deep knowledge of our heritage, our best practices as well as our shortcomings.

The study effectively highlights the role played by the CER and illustrates it by adequately highlighting each of its aspects, for example benefiting various sectors, including agriculture, the environment, the industry sector, the civil sector and, last but not least, research. Our achievements show that the Consortium, like all reclamation Consortia, makes a major contribution to protecting and enhancing the environment and rural areas thanks to its experience and planning skills, which have always been at the service of the communities and the Institutions. This has become even more apparent in recent years, as climate change has had severe repercussions on all sectors, thus drawing the media's attention on the country's vulnerabilities. The reclamation system responds to the great rainfall concentrated in few hours, which allegedly leads to widespread hydro-geological instability, or long drought periods, which have a devastating effect on agriculture, with an infrastructure that is often not sufficiently developed to meet the real needs of the area, thus forcing the entire system to take on new roles and plan new supporting systems and areas for water management. Much has been done to reduce the disruptions caused by the climate, but not enough: future challenges will have to be tackled with further efforts. The implementation of major infrastructural policies, cutting-edge when it comes to irrigation, will lead to a more resilient territory, so as to continue generating the benefits described in this study in the future. These include for example improving the existing resources and plants, increasing the water reservoir and distribution capacity, also through digital systems such as IRRIFRAME, supported by sustainable and integrated energy sources. Sharing the choices and projects would not only mean tackling climate emergencies, but together with the Institutions, Public and Private Bodies, professional organisations and all the companies of the Italian agri-food system, would offer new job prospects for local economic growth in a crucial historical time, not only for Emilia-Romagna, but for Italy as a whole.

Such studies should therefore be promoted and taken as a point of reference to carry out simple and clear dissemination, which, at a regional level as well as more broadly at a national level, would be a shared asset and value.

Nicola Dalmonte

Chairperson of the Irrigation Consortium for the Emilia Romagna Canal

In Emilia-Romagna, the supply of high-quality water for irrigation, environmental, civil and industrial purposes has always been crucial for the sustainable development of the territory. In its extremely far-sighted nature, the CER, year after year, maintains and enhances its role of strategic infrastructure. This is even more true in light of the recent climate change phenomena that have forced the entire production and civilian world to pay further attention to water. The CER, in this respect, has taken on a key role at an economic, territorial, social and environmental level in the various fields in which it has been engaged. For these reasons, the Consortium now plays a major “economic function” towards the development of Emilia-Romagna and its leading sectors.

These are the foundations of the present study on the benefits brought about on the regional territory thanks to the CER’s infrastructure and the intense research and experimentation activity on irrigation, as well as irrigation planning and management, which is carried out every year in collaboration with the associated Bodies. The volume includes an estimate of the CER’s value based on three aspects: the direct benefits enjoyed by the agricultural sector thanks to irrigation, estimated by calculating the increase in production and quality of the crops present in the underlying territory and the increase in value of the soils; the environmental benefits connected to the maintenance of the natural ecosystems, the rural landscape and the recharge and protection of the sub-surface water bodies; the estimated benefits to society in terms of increasing employment and through the effect of the presence of water for drinking and industrial purposes.

The results are an important tool to manage, plan and prevent climate emergencies which, with ever greater frequency, are affecting the Emilia-Romagna region. In fact, this volume goes beyond merely providing and preserving a picture of the water system in the area overseen by the CER, it constitutes the foundation of knowledge to trigger virtuous mechanisms of protection and enhancement of the territory, thus fostering its sustainable development.

THE VALUE OF THE CER FOR STAKEHOLDERS



Stefano Bonaccini

President of the Emilia-Romagna Region

The Emilia Romagna Canal (CER) is one of the most important hydraulic works ever made in Italy. An infrastructure work of extraordinary value at an agricultural, industrial, civil and environmental level that benefits a territory that is among the most developed and most capable of innovating.

A far-sighted project that was realised after the end of the Second World War, whose effects are even more significant today, as climate change and the frequent droughts lay bare the need for a rational use of water.

Also from this point of view, the CER has much to teach us. Its central role was also apparent last summer, when it guaranteed water supply to the Romagna area. The commitment to research, which combines rationality in the use of irrigation water with the quality and productivity of the crops. Also thanks to cutting-edge assets such as IRRINET and IRRIFRAME.

The study conducted in collaboration with Nomisma is therefore more relevant than ever before. Not only to assess the impact that the CER's activity has today, but also to catch a glimpse of its development prospects when it comes to the future.

In this respect, it is interesting to see the results of the interviews carried out among the main stakeholders concerning the role the CER can play in a scenario in the nearby future regarding resorting to new technologies, the attention towards and the safeguard of the environment, as well as the supply of ecosystem services.

These are key functions and objectives, consistent with the commitment made by the Emilia-Romagna region to complete a green transition that today appears indispensable, and which must be pursued with tenacity and determination.

To this end we bring together resources and planning, creating a system of the many skills that Emilia-Romagna can fortunately offer. And among these the CER is undoubtedly one of the most important, along with those who work on it every day and develop cutting-edge solutions.

Irene Priolo

Vice President of the Emilia-Romagna Region, Councillor for the Green Transition, Countering Climate Change, Environment, Soil and Coast Protection, Civil Defence

The idea of building a canal capable of making the waters of the Po River available for irrigating the Emilia-Romagna plain dates back to over 400 years ago. It was only in the 1940s that in Italy, in the aftermath of the Second World War, the desire to bounce back made it come true and the works to create it began. Still today, the Emilia Romagna Canal is among the most important hydraulic works in Italy, and plays a key role in supplying water to the eastern part of the Emilia-Romagna region, necessary for irrigation, but also for civil and industrial purposes, in particular to serve Ravenna's Industrial District.

The severe summer drought confirmed the importance of this hydraulic infrastructure: in light of the ongoing climate change, the CER is the only waterway that can guarantee water in the hottest period of the year to the Romagna area, which features hydro-demanding agriculture and – in particular in the Ravenna province – a chronic lack of water for potable uses.

The study conducted by Nomisma clearly highlights the importance of the Canal: it has estimated that thanks to irrigation, there can be a potential increase in land value worth 2.4 billion Euros. But that is not all. The analysis includes another key element: the CER's "environmental value". The estimate of the value of the ecosystem services it provides is of 20 million Euros.

Moreover: by replacing the withdrawal of groundwater with surface water, it provided a key contribution in slowing down subsidence; the availability of water from the Canal is also instrumental in protecting biodiversity, in particular of the coastal wetlands of community interest, such as Punte Alberete and Valle Mandriole.

These elements are complemented by the key role played by the Consortium: apart from managing the hydraulic work, for sixty years it has been conducting intense research, experimentation and technical assistance on irrigation and water saving, which started with the goal of delivering to farmers, along with water, all the necessary information to use it in a correct, economical way without wasting it. Among the instruments resulting from this activity is the IRRINET/IRRIFRAME, the service that supports farms in water management, thus enabling remarkable water saving.

The further development of monitoring and support systems will be crucial to address the consequences of climate change. To tackle them, inspiration must be drawn from the same far-sightedness of those who 70 years ago worked to create the CER. We must be forward looking, with the support of the technologies and knowledge acquired in the meantime, in order to create the preconditions for true sustainability and a growth that respects the value of the natural resources.

Alessio Mammi

Councillor for Agriculture and the Agri-food Sector, Hunting and Fishing

Droughts are a growing phenomenon affecting the whole of Mediterranean Europe. Last summer, the situation in Italy was critical, above all in the Northern regions that benefit from the basin course of the Po river, there was great pressure, and this is also due to a very negative combination with a 40% decrease in rainfall in the past 20 years and an increase in temperatures. The water crisis has taken a toll on Italy's agricultural production, above all of tomatoes, maize, fruit and rice. Water is life; the lack of water deeply undermines food supplies. This problem certainly concerns the agricultural production sector at an economic level, but above all it puts at risk our food security, after a two-year long pandemic and an ongoing war just over one thousand kilometres away. In light of this complicated framework, the value of the Emilia Romagna Canal is even more apparent: the water capacity provided by the "CER system" – which crosses the provinces of Romagna and guarantees the necessary irrigation supply to the crops – is a resource that has an impact on the entire agricultural territory and beyond. The CER's water system is a leading system at European level thanks to its level of research and technological application in its efficient use of water, with peaks of cutting-edge innovation at European level and a team of people committed on a daily basis to ensuring the sound running of a complex and sensitive work, which also has an impact on our territory and on the preservation of biodiversity. Investing in water means acknowledging the key value of water for companies, people and the environmental system, as was universally witnessed in the past months. This impact has a positive effect on our communities. Today agriculture requires new solutions that are sustainable, practical and applicable on the ground. This is why Emilia-Romagna invests 4% of all its resources in research, compared to the 1.5% national average. Precision irrigation is one of the frontiers that universities, research centres and companies are exploring: it is one of the viable solutions to counter the effects of climate change. Production should be done through a better use of natural resources, which is a hard challenge, but not an impossible one. In general, we are supporting and promoting projects to increase the level of "per hectare" knowledge, with clearly outlined and targeted applications. The experiments by Acqua Campus, which are also being done by the CER, go in the same direction, and are yielding positive results. This is a comprehensive strategy consisting of integrated actions to be carried out together and to be shared. The path we are called upon to undertake must include informed choices that are suitable to the historical period we are in. The regulatory developments at a national and EU level must also be taken into account. There are ongoing water infrastructure works worth 250 million Euros, and over 350 million Euros of the National Recovery and Resilience Plan will be allocated all across the Emilia-Romagna region; we will also increase the annual water availability by 73 million cubic metres. In the upcoming months Emilia-Romagna shall take on a fully-fledged Marshall Plan of irrigation investments: these are investments that will radically improve the region's irrigation system; we must pick up the pace when it comes to administrative simplification to realise these works. There is no more time to waste: the agricultural world must win the water challenge, with a resilient response to the effects of climate change.

Alessandro Bratti

Secretary General of the Po River District Basin Authority

The Po River District Basin Authority (Autorità di bacino distrettuale del fiume Po), through its activities, which are necessary for drawing up and implementing the District Plans, plays an indispensable role in the safety of the territories and the protection and management of surface and groundwater.

This extremely important and prestigious task is also possible thanks to the support of the various public and private players that enable the implementation of what is entailed in the Plans through their active collaboration and the further knowledge gained and research activities they carry out.

Among these is the Reclamation Consortium for the Emilia Romagna Canal (CER), a strategic player that contributes to the sound management of the territories and water uses within the fields it is active in, cooperating not only to protect the water from a quantitative and qualitative level, but also to protect biodiversity.

As a Second-Degree Reclamation Consortium, the CER has developed a long and growing series of studies conducted in the "Acqua Campus-ANBI" scientific laboratories of applied research in Budrio (BO), concerning irrigation and reclamation, management and infrastructure development actions, training and technical assistance, disseminating and favouring the implementation of all the best practices linked to the correct use of water resources and in line with the new strategies that support national and European policies to ensure sustainable development.

As a confirmation of the value of the activities carried out by the CER for the Po river district, also proven by the study presented, the Protocol of Understanding stipulated between the Po River District Basin Authority (Autorità di bacino distrettuale del fiume Po), the Reclamation Consortium for the Emilia Romagna Canal and the National Association of Consortia for the Management and Safeguard of the Territory and Irrigation Water is being implemented for the updating process and innovation of the cognitive frames of reference for the planning tools of the Authority, aimed, among other things, at outlining and promoting a common action on the matter of optimising management protocols of resources concerning irrigation, soil protection and protection of the territory.

Michele Zaccaro

CEO of Ravenna Servizi Industriali SCpA

The great work of hydraulic engineering that is commonly known as the CER constitutes a vital, irreplaceable infrastructure for the industry sector and territory of Ravenna, but also more generally of the Romagna area.

The CER provides water to one of the most vital and active industrial districts nationwide which, owing to the nature of its production processes, deems it an indispensable element for the functioning of its production cycles. Water is used not only as a refrigerating element or, as vapour, as an energy fluid, it is also a constituent element of finished products: dairy or adhesive products, construction or agricultural materials.

Without the water of the CER river, there would be no Italian tyres, shoe soles, cables, glue, construction materials, fuel or fertilisers. There would be a total dependency on foreign imports.

An industry worth about 1,800 million Euros in local turnover with 1,700 direct employees and at least just as many employed in the related industries.

The CER's water is not only a means of production but also an element of safety, if used as an extinguishing agent or as a protection barrier. The CER's water to preserve and maintain the wonderful natural environment of the Ravenna province's coastline.

The intertwined destinies of the water transported by the CER create a single system in which agriculture, industry and the environment are interconnected, communicate with one another and create welfare for all.

Nicola Bertinelli

President of Coldiretti Emilia-Romagna

Once upon a time there was a “project to extract water from the Po River north of Piacenza to irrigate the Piacenza, Parma, Reggio, Modena and Bologna provinces.” These were the words that in the 17th century Abbot Raffaello Tirelli from Reggio Emilia said to the Duke d’Este, which led to the idea of the Emilia Romagna Canal, more simply known by most people as the CER. However, that idea would be implemented only several centuries later, with a project that aimed (this is the argument or conjecture whereby, from known or even partly imagined facts, more or less certain inductions are derived) to combine the needs of the flooding of the Reno River with the irrigation requirements of the plains of Bologna and Romagna. It was an example of hydraulic architecture and knowledge at the service of a surface that was over 3,000 km² large, distributed in the provinces of Ferrara, Bologna, Ravenna, Forlì-Cesena, Rimini and a very small part in the Modena province. An area with many civil and industrial settlements and with a particularly hydro-demanding agriculture, which is why the CER promotes researching strategies and technologies aimed at saving water in agriculture and thus increasing the value of agricultural production. And on these issues of water saving, used rationally down to the last drop, the farmers in Emilia-Romagna have for years been engaged in creating the foundations of a model, now virtuous and indispensable for the country, of aware and informed agriculture.

The same farmers who for one hundred years up until today, thanks to their everyday work, have also played a crucial role in creating the Po Valley itself, its habitats and biodiversity; an agriculture that today is the common denominator of an agri-food sector that is famous around the world, as well as a strong role model of quality fruit and vegetable growing, of typical products that, thanks to the water supply work of the Consortia, can boast extremely high levels of quality. The far-sightedness and ability to create strategic works for irrigation and to give sustainability and prospects to this success story, today as in the past, is a very relevant and strategic theme to win the challenge of climate change and its most severe repercussions, which often take a major financial toll on farmers. The CER has contributed to the progress of this territory, through planning strategies integrated with the social, environmental and economic context of the region, the planning of strategies that become instruments to maintain and develop the economy of the Emilia-Romagna region, of the fruit and vegetable growing and industrial sectors, as well as the civil sector. Water, more so than in the past, is precious. The CER's structure guarantees a responsible governance, thus ensuring that water use occurs with efficiency, innovation, waste prevention and reuse. Thus preserving that precious resource, and thus also the landscape and environment of this region can benefit from the CER's water.

The Emilia Romagna Canal, despite its 135 km of total length, does not only entail the withdrawal, conveyance and distribution of water along our territory, it also entails protection, research, experimentation, studies and analyses. It entails technical assistance (for farmers to improve the use of water), environmental safeguard, education and information. The Emilia Romagna Canal entails all these elements. And that hostile plain from which humans used to flee to reach other, more hospitable soils, today, through hydraulic reclamation projects such as the CER, is one of the most productive, anthropised and attractive areas in Europe.

Marcello Bonvicini

President of Confagricoltura Emilia-Romagna

The Emilia Romagna Canal (CER) is a major hydraulic work (that was strongly supported by the agricultural world) for the Emilia-Romagna region's productive sector.

At an economic level, the CER ensures to the agricultural world a constant water supply, aimed at developing the agri-food network, which constitutes an undeniable resource for the manufacturing fabric of the community, given that the provinces of Bologna, Ferrara, Forlì, Cesena, Rimini and Ravenna have witnessed the emergence of a first-rate agriculture that enhances the Made in Italy brand, and embodies a strong entrepreneurial spirit.

The CER has contributed to creating a comprehensive system, resorting to the collaboration and co-operation of the First-Degree Reclamation Consortia it brings together, for more practical and efficient water distribution which, in light of the ongoing climate change, tends to guarantee the main resource of agriculture, namely water, whose shortage takes a heavy toll on agricultural production, both at a quantitative and qualitative level. This in turn favoured its position on the market, and consequently made farms more competitive.

The efficiency and vitality of the CER also enhance the environment and landscape. The rational use of water undoubtedly favours the preservation of the agricultural system in all its organisational forms. This maintains and preserves environmental harmony, which improves the community's quality of life.

Preserving a natural environment as much as possible has favoured not only the value of our farms, but has also created welfare for the entire community, which provides goods that are deeply rooted in a balanced environment, tied to our traditions. A close bond between past and present has been formed, which helps look to the future with a strategy based on environmentally sustainable development.

Non-agricultural land and urban land also benefit from this, as it makes them more attractive and capable of enhancing the quality of our civilised life.

The CER, through the projects carried out and those to be carried out, is the result of constant commitment to being the protagonist of the true socio-economic progress of agricultural entrepreneurship.

Stefano Francia

President of CIA Agricoltori Italiani Emilia-Romagna

Imagining today an agriculture in Emilia-Romagna without the CER is, for most farmers of the areas concerned, unfathomable. This key work is the cornerstone of specialised and quality agriculture of a vast territory, which features quality, specialised and diversified agriculture, among the best across Europe and beyond, in terms of GSP per hectare, productivity and, just as importantly, employment.

Regardless of the environmental benefits, and therefore benefits for the entire community, that the presence of water brings to the territory, and without forgetting the fundamental human and industrial use that the CER guarantees to a major part of the region, the certainty of having water available has allowed over the years for the development of the region's agriculture. Many farms have grown, the arrival and permanence of many young people in the sector was secured. These young people, by relying on the indispensable availability of water, were able to devise and create new business models, undertake new cultivations, diversifying their products to meet the new demands of the market, and therefore of consumers.

The study carried out by the CER in collaboration with Nomisma highlights through quantification the importance of this hydraulic work, which provides an economic benefit and a heritage benefit to the territory. What we are most interested in, however, is knowing that we can count on an efficient structure that even during these trying years, when the negative effects of climate change are becoming increasingly apparent and frequent, ensures the necessary irrigation water availability for our production to reach their normal harvest.

One must also not underestimate the importance of research and innovation when it comes to irrigation, which over the years the CER has been able to develop along with the progressive length increase of the main course and the necessary realisation of the capillary distribution network in a positive synergy with the associated Consortia.

The research on new irrigation techniques, the use of ever more sophisticated and integrated computer technology are crucial elements for cutting-edge agriculture, that is ever more sustainable and respectful of natural resources, among which water is paramount. Research and experimentation carried out directly by those who distribute water are a guarantee for agriculture as a whole.

Mattia Tampieri

Vice President of Confederazione Produttori Agricoli

The constant series of dry seasons that, in recent years, have taken a toll on our best agricultural production, as well as the many seasons with high levels of rainfall concentrated in short periods of time have led Copagri Emilia-Romagna to confirm the importance of the far-sighted decision made by the region many years ago and strongly supported by our organisation on the strategic importance of the CER and the activity of the Reclamation Consortia.

We are increasingly convinced of the importance and need for an effective governance of water for irrigation purposes through a capillary and regulated distribution of water and the strategic importance the CER has had on the entire regional territory throughout its long history.

Over the years the CER has been able to generate a virtuous system for the farms that today centre their work and profitability on top-quality agricultural production that requires an ever-greater irrigation technique. Irrigation is crucial and indispensable and, together with the experience and technologies that are made available on a daily basis for the farms thanks to the constant research carried out by Acqua Campus, it results in greater water saving for an ever more efficient and precise water distribution.

We at Copagri Emilia-Romagna believe that, also for the future, the relevance of the CER is extremely important not only for the agricultural world but for the entire population to provide answers to those who use water in a rational and useful manner for their companies and the territory's socio-economic fabric to grow.

Tonino Bernabè

President of Romagna Acque - Società delle Fonti S.p.A.

100 years since the foundation of the ANBI, taking stock of the benefits of the Emilia Romagna Canal, both as a body and infrastructure, is absolutely necessary. The CER is a great opportunity for Romagna, for all the areas served and the various ways water can be used (irrigation, industrial, drinking for civil use, environmental and to safeguard natural habitats, biodiversity and ecosystems). Together with the Ridracoli Dam it contributes to safeguarding Romagna from the risk of subsidence and meets most of nearly all the water demand of the Romagna municipalities (and in particular of the Ravenna province area). In fact, from 2017 and 2022 thanks to the CER over 57 million cubic metres of volume were distributed to the water purifier of Ravenna Bassette (water coming both from the Po Eiver and the Reno River) and nearly 84 million cubic metres of volume to the water purifier of Ravenna Standiana (water coming from the Po River). In total over 140 million cubic metres of distributed volume were guaranteed. This was a fundamental service to complement the volumes necessary to guarantee the complete water supply of Romagna. As soon as Romagna Acque builds the third route of the Romagna aqueduct, which will connect the Standiana Water Purifier with the Monte Casale loading tanks and enable the connection links for coastal adduction (from Forlimpopoli to Casone di Cesena to Torre Pedrera di Rimini) to be upgraded, withdrawing a significant additional volume of water will be possible. Hopefully the value of the resource that the CER makes available for civil potable uses will always be guaranteed, in any critical condition of the Po River in the irrigation season (given the low quantity compared to the other uses, and especially compared to those used for agriculture).

The future further potential infrastructural development of the Emilia Romagna Canal to cover all of Romagna can be a further integration opportunity. The CER has always been collaborative with Romagna Acque to solve any technical-administrative issue.

So I wish to thank its President Nicola Dalmonte, Director General Raffaella Zucaro, all the members of the Council of delegates/administrative committee and the entire technical administrative structure, wishing to both the bodies they represent a solid future rich in challenging actions in a field with major investments, in the interest of the quality of life of the communities served and the economic welfare of all businesses we supply.

Tomaso Tommasi di Vignano

Executive Chairman HERA spa

The study conducted by the Reclamation Consortium for the Emilia Romagna Canal clearly shows the key role played by the Emilia Romagna Canal (CER) for the economy and the environmental framework of a major part of the Emilia-Romagna region; the same region that fostered by birth and development of Gruppo Hera, a company that for 20 years has been working to provide citizens and companies with high-level services of public interest in the water, energy and environmental sectors.

The study clearly shows the strategic vision of those who devised, planned and realised this impressive, complex hydraulic work, and the technical and managerial expertise of those who, over the years, were able to develop and maintain it.

The value of the work, moreover, has grown over time. Though maintaining the irrigation functions as the primary functions, the CER has acquired functions and uses that today are essential, also to counter the effects of climate change: these include powering important aqueduct systems in the Metropolitan area of Bologna and in Romagna. The water volumes made available by the CER allow for the consolidation of some important hydro-potable supply systems in the Imola and Ravenna provinces and for the maintenance of these resilient systems before the challenges created by climate change. The availability of surface waters, moreover, reduces the use of groundwater, which are thus preserved as a strategic reserve; this thus also helps counter subsidence and consequently the damage to the territory is limited.

The CER, together with other important infrastructural works realised in the past century, are therefore a testament to the ability of the Institutions of this region of planning in an effective and far-sighted manner the development of the territory, also thanks to a high-level industrial and entrepreneurial system, capable of guaranteeing high management levels that benefit the citizens, companies and the environment.

Aida Morelli

President of the Parco Delta del Po Emilia-Romagna

The extraordinary economic and social importance of water being distributed to the agriculture in Romagna by the Emilia Romagna Canal is by now known by the entire community, especially since climate change determines a major reduction in rainfall. Regarding this alarming climate trend, the CER for decades has been committed to effectively carrying out research applied to water saving in agriculture, which is also well known both at a scientific and agricultural level, and provides the territory with a further added value.

What may be less known are the very interesting, positive environment- and nature-related effects for the Parco del Delta del Po Emilia-Romagna, which are determined by the distribution of water of the CER in the region's plain. The surface water coming from the Po River replacing the groundwater reduces the dangerous phenomenon known as subsidence, which reduces the depth of the sandy shores and determines salt intrusions in the coastal wetlands, with a serious loss of animal and plant biodiversity. The freshwater brought by the CER to the humid coastal oases of international importance of the Park (biotopes of Punte Alberete and Valle Mandriole) enables their survival, with a great effect in defending nature.

The sensitivity of the Consortium towards nature is also acknowledged for its now historic activity of environmental safeguard and research carried out in the Oasis of Volta Scirocco in collaboration with the Regional Park of the Delta Po ever since the 1990s. Natural research and biodiversity defence activities that are still carried out today with excellent results in the Oasis, recently called by the CER "Acqua Campus Natura."

Umberto Re

Legal Representative MA.GE.MA. s.a.c.

The MA.GE.MA. S.a.c company, concerning the future water supply to its production site, has sought to identify the best solutions regarding water management which, now more than ever, is a critical factor in terms of both economic and environmental sustainability.

One only needs to consider how much water influences the economic returns of its productions and how important it is to favour the use of surface water rather than groundwater to pursue one's policy of sustainable development.

The MA.GE.MA. believes that the use of the CER's water is in accordance with its policies of sustainable development, for example:

- allocating high-quality water (coming from the aqueduct) to the community, while Companies can use untreated water (coming from the CER);
- unburdening the public water network (aqueduct);
- guaranteeing a water supply capable of meeting the growing production demands and maintaining its competitiveness, which is also related to protecting levels of employment;
- favouring the withdrawal of surface water.

It is within this framework that MA.GE.MA. has set the technical terms of connection with the Emilia Romagna Canal, paying for the implementation of the water purifying plant and the realisation of the water distribution system within its production site.

Following what was mentioned above, the CER does not lead to a shift in the water cycle, but rather to maintaining the natural balances, and the company's internal policy is to continue preserving them.

Alessandro Senni

Sole Director Nuova Termica Srl

The Emilia Romagna Canal is to Nuova Termica, thanks to major investments made for the canalisation, the number one and most important resource, in the water department, of its process.

Nuova Termica, a company from Gatteo (FC) jointly held by the industrial laundry Linea Sterile Spa and Cil Spa, provides water and steam to the two industrial laundries to guarantee, without interruption, the supply necessary for the reconditioning of linen used in the hospital and accommodation facilities of Romagna and the Marche region. The possibility of drawing the water of the Emilia Romagna Canal rather than from groundwater of the territory enabled the preservation of water resources that the community could benefit from and at the same time guarantee a constant supply source for our linen reconditioning processes.

The CER's water supply has been especially valuable in the recent past for Linea Sterile Spa, the industrial laundry of the group, which offers a linen rental and reconditioning service to hospital facilities of the regional and national territory with certified disinfection, washing and ironing services that, also within the framework of the COVID-19 pandemic, guaranteed, in every condition, adequate supply of linen and uniforms for healthcare professionals and hospital wards in accordance with the hygiene and sanitation protocols adopted in the hospital facilities served.

Moreover, in the summer of 2022, despite the water crisis recorded at a national level, the Emilia Romagna Canal proved once again to be a valuable and irreplaceable infrastructure that guaranteed a constant flow of water, necessary for our linen reconditioning processes. This water was for the 4,000 hospital patients and 15,000 healthcare professionals that we serve on a daily basis, as well as the thousands of tourists that have frequented the Romagna coast as guests of facilities that benefit from our linen washing and rental services.

Attilio Toscano

Full Professor of Agricultural Hydraulics – University of Bologna

The Emilia Romagna Canal can certainly be considered one of the greatest water infrastructure works of Northern Italy and certainly has a strategic value, ever more relevant, to guarantee water supply security, not only for irrigation purposes, of most of Emilia-Romagna and of an extremely valuable productive fabric for the entire country.

The far-sighted choices made decades ago enable us today to count on an infrastructure that is vital for countering situations of water shortage that are ever more frequent because of climate change, as well as on a Reclamation Consortium that manages it in a modern and efficient manner, and which is fully capable of providing its users, farmers and stakeholders with constant updates and experiments to correctly use water in agriculture. The value of the Emilia Romagna Canal is therefore, to me, undeniable and, probably, widely perceived, not only by the professionals of the field.

However, the interesting study conducted by the CER Consortium in collaboration with Nomisma has the great merit of “quantifying” this value through a systematic and accurate approach, highlighting the various elements that generate the total value of the Canal, not only its economic value, and thus also highlights those aspects that are normally less evident, but not consequently less important, such as those related to the ecosystem and environmental services generated by the Canal or those related to the value of the innovation developed and promoted by the CER Consortium. The externalities highlighted in the study thus enable the reader to realise, in a more informed way, what the great value of this historic infrastructure is.

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The CER is undoubtedly a very important hydraulic work that has changed, in a structural and lasting way, the economic fabric of a large part of Emilia-Romagna. Thanks to this infrastructure, with its imposing 135 kilometres in length, but at the same time well integrated in the environmental context it finds itself in, the Consortium can bring and distribute the water withdrawn from the Po River on over 3,000 km² of territory. With this study, the CER has once again attempted to provide an economic assessment of the effects generated by this irrigation work on the territory, considering the positive effects, both direct and indirect, that it generates on the agriculture of the territory and on the environment, but also on the industrial and civil sectors, as well as on research and innovation. Making this type of assessment is as necessary as it is difficult: the externalities generated by such a work, in fact, are multi-faceted and, above all, they are not easily or immediately quantifiable. On the other hand, having no idea of the economic impact generated by such an important work undoubtedly risks leading to an underestimation of the importance of the work itself and of the services that it secures to a large part of Emilia-Romagna's economy. This is the main reason why this study is particularly useful and important. The complexity of the assessment of these externalities has made the structure of the study difficult to devise and by no means to be taken for granted. The approach adopted is therefore based on the identification of the various positive effects of the work on the main economic sectors concerned, as well as on their specific quantification with methodological approaches that are inevitably different and complementary to one another. The greatest impact the CER has made is certainly on agriculture: the chance of securing water for irrigation purposes to agricultural land that would otherwise not have this option inevitably entails a major increase in the value of the agricultural production that can be obtained, which has been estimated by the study at over 303 million Euros per year. This consequently leads to an increase in the land values of the land concerned equal to 1.7 billion Euros. The increase in land value certainly entails an increase in the production enabled by the possibility to irrigate the land itself, but overall the values presented enable a closer observation of the CER's effects on the territory's economy. The quantifications of the other effects, both environmental and on the industrial and civil sectors, are even more complex. The environmental impact of the ecosystem services generated across the entire territory, including both agricultural land and wetlands, as well as the continuous and discontinuous urban fabric and the presence of irrigation bodies, has enabled the quantification of a further contribution equal to about 20 million Euros per year. As was highlighted in the study, it is, especially in this case, a difficult estimate to make, so it is made with prudential criteria, which nevertheless provide a major contribution. The analysis is complemented by in-depth studies on subsidence, which is heavily present in major parts of the territory where the CER is present, as well as on the important functions of the infrastructure for Ravenna's industrial district, which occupies an area in which there are companies with very large turnovers, as well as HERA and Romagna Acque's water purifying plants which serve the areas in the territories of Imola and Ravenna. A final impact, which is particularly important, was the contribution the CER made and is still making in the field of research and development, above all in the monitoring and optimisation systems in the use of water for irrigation purposes. The IRRIFRAME service developed in recent years has become an increasingly key instrument when dealing with climate change, which generates growing difficulties in managing the ever scarcer amount of water available. And these services are increasingly important also beyond the context of the territory strictly served by the irrigation infrastructure, both at a regional and extra regional level. In short, the study is certainly an important contribution that shows the effectiveness of the CER, an infrastructural work that is both important and far-sighted.

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INTRODUCTION

- The establishment of the Consortium** The Reclamation Consortium for the Emilia Romagna Canal, as a second-degree body, **was founded back in 1939** and manages a large part of the territory located between the provinces of Bologna, Ferrara, Forlì-Cesena, Rimini and Ravenna. It is an indispensable source of water, not only for agriculture, but also for industrial and civil uses; it also has a vital environmental function.
- The CER for the agricultural sector** When it comes to the **agricultural sector**, the CER can provide water for irrigation use to five Consortia located across six provinces of Emilia-Romagna, covering a surface of about 3,000 km². This led to a great enhancement of this area making it, starting from after WW2 up to today, one of the most important and productive areas of the primary sector nationwide.
- CER and industrial uses** Among the main **industrial uses** are those related to the associated Ravenna Servizi Industriali (RSI), Ravenna's petrochemical industry (ENI), which would not have been born without the certainty of having water available, supplied by the CER. Other uses, for example, are those to serve Frullo's incinerator by Hera, of the agro-industrial plants of Amadori chicken (Avicoop), of the Gruppo Martini, Bunge and Conserve Italia.
- CER and civil uses** One must also mention the key role of the Consortium in the sector of **civil uses**, thanks to the power supply with raw water of HERA-Imola's water purifier and of the three purifiers of Romagna Acque Società delle Fonti: NIP1 (Bassette di Ravenna), NIP2 (Standiana) and Forlimpopoli (Selbagnone), capable of ensuring water supply to the entire Romagna area.
- Its environmental function** The CER, moreover, has a vital **"environmental" function**, tied for example to the survival of the wetlands of international importance such as Punte Alberete and Valle Mandriole; it also plays an "indirect" role by providing surface water replacing groundwater withdrawals. This reduces the negative phenomenon of subsidence of some of the areas of the territory.
- Research and Innovation** A very important function also concerns the role of **research and innovation** that the CER plays for the entire primary sector. With the Acqua Campus research and innovation facility in Budrio, the Consortium has been a pioneer and brought about a turning point in irrigation studies, providing assistance to thousands of farmers and stakeholders who over time undertook a path with the CER towards a modern agriculture aimed at protecting the environment, improving the quality of the productions and the companies' economic performances.
- The CER's "economic function"** The CER, in this respect, has taken on a key role at an economic, territorial, social and environmental level in the various fields in which it has been engaged. For these reasons, the Consortium now plays a **key "economic function" towards the development of the region, in particular of Romagna and its leading sectors.**

The aims of the study

The study presented in this report has the ambitious goal of **analysing and quantifying, in terms of economic value, the complex role played by the CER on the territory.**

Determining the economic value of the CER is no easy feat: as said before, the CER has multiple functions, given that they enable the use of water for a number of purposes.

Given the complexity of these actions and the numerous benefits resulting from them, the decision was made to adopt an approach involving multiple assessments, each capable of shining a light on a different type of externalities generated by the CER's activity.

The common denominator of the assessments is the goal of providing an economic quantification of each assessment, thus reaching a total economic estimate of the benefits guaranteed by the CER infrastructure.

Three different assessments will be made, which are presented below.

The infrastructural value

The first assessment is a sort of estimate of the "asset" value, meaning the economic value of the CER's hydraulic infrastructure located across the territory.

The supply and distribution of water in the territory of competence of the CER take place thanks to the presence of infrastructure that guarantees its correct functioning. These have a strictly real estate- and asset-related value, which must be quantified to determine what the economic and financial commitment necessary would be to create such a major work, capable of generating all the benefits mentioned in this work. Many sectors of civil society, in fact, owe part of their economic activity to the CER's infrastructure, its correct functioning and management. Therefore, for an overall assessment of the general benefits generated by the CER one should know the exact value of the infrastructure that can create them.

Of course, as the Consortium that manages the CER is a public body, this value is purely theoretical, meaning that the infrastructure of the CER is not a set of transferable goods, therefore there is no market where this value can appear. It is nevertheless important to understand what the necessary investment would be to build a work like the CER using a counter-factual logic, meaning that, without the CER, to obtain the benefits guaranteed by this work there would be the need for an economic commitment quantified in our analysis.

The presence of this infrastructure creates a social and working fabric not only for those who are directly involved in the management of the infrastructure but also and above all for the activities that benefit from the services they provide. The CER's infrastructure is ultimately an attractive element for the territory, capable of generating investments, productive activities and employment resources.

To provide an accurate assessment of its infrastructural value, specific analyses of the main plants will be carried out. The plants will be divided into plants for lifting water,

transporting water, for multiple uses, and the category of property dedicated to the Consortium's administrative and research activities.

The analysis will be conducted through the preparation of description sheets indicating the economic value of the single plant, both referring to the current value and to the cost of building it. In the total assessment, to maintain a precautionary approach, the main course and the expropriated land were not considered.

The agricultural value

The second assessment concerns the benefits that the CER brings to the agricultural sector, through water distribution across the territory. Many of the crops grown in Romagna are hydro-demanding, which is why a major part of the agricultural production generated in the territory depends on the supply of water guaranteed by the CER.

To economically assess the benefit provided to the agricultural sector, two different assessment methods will be applied, so as to provide two perspectives and two assessments of the same scope of analysis.

The first method consists in offering an estimate of the value of the agricultural production tied to the supply of water that the CER guarantees to the Reclamation Consortia; the second method, on the other hand, seeks to calculate the value differential between the land that can access irrigation and those who cannot. Clearly both methods seek to shine a light on the role played by the water provided by the CER on the territory and the economic value it can produce.

When it comes to the first method, concerning the estimate of the value of the agricultural production guaranteed by the supply of water by the CER, the assessment is based on counter-factual logic: what would be the loss in agricultural production if the CER could no longer supply water to the territory?

The analysis methodology is based on the application of statistical models that seek to reproduce the agricultural context of the territory on which the CER is active (directly or indirectly) considering all the variables that influence agricultural production, including water. Thus one can implement multi-step simulations in which one hypothesises a progressive reduction of the water, firstly to understand how the mix of crops to adopt would change, and secondly to calculate what the loss in terms of agricultural production tied to a given water scenario would be.

The simulations imply the creation of hypothetical progressive scenarios that envisage, within each step, a 1% reduction in the water available, all the way down to a 100% reduction, i.e. of the entire volume of water guaranteed by the CER.

The effects of every reduction are assessed through criteria of utility and rationality, considering the fact that the economic players (i.e. the farmers) will seek, by acting rationally, to maximise their utility, given the mix of crops that is reasonably most advantageous in relation to the quantity of water available.

At the end of the simulations we will highlight the crops that it would be most advantageous to adopt in the absence of the water provided by the CER, and the estimate of the loss in value of the agricultural production that this different scenario would entail.

Water is indispensable in agriculture not only in terms of productivity but also when it comes to employment and social matters. The analysis will also provide an estimate of the reduction in the workforce that would be triggered in a hypothetical scenario where the CER did not supply water.

The second method, used to highlight the capacity of the CER's water supply of generating economic value in the agricultural sector, focuses on the analysis of the increase in land value a land can benefit from by accessing irrigation.

Hydro-demanding crops, in fact, are more productive than other crops. The chance to benefit from a constant and guaranteed amount of water generates an increase in the prices of agricultural land. This increase in value can be quantified, in particular in terms of differential compared to the rainfed land present in the same area studied.

The presence of water can therefore modify the value of the land and agricultural properties, which is why this type of value too must be taken in due consideration to describe the impact of water on the territory.

The environmental value

The third, final assessment concerns the environmental and ecosystem benefits that the presence of water guarantees to the territory.

Thus far it has been shown that water generates a series of benefits ranging from the availability of water for civil and industrial use to the possibility of irrigating agricultural land. However, the utility of water goes beyond these tangible and quantifiable benefits.

There are a series of services guaranteed by water that can be more or less apparent, and which contribute to increasing the environmental quality and the psycho-physical well-being of the residents (and of others too).

These services, called ecosystem services, are now recognised at international level, as is the need to give it a value so as to not underestimate the utility of water: these include the safeguard of the territory in terms of subsidence prevention; the activity of water regulation of rainwater to prevent floods and overflows; the importance of water to guarantee life and the proliferation of the natural habitats; the historical and aesthetic importance of the peculiarities of a landscape, made unique by the presence of water.

The CER is perfectly embedded in this context, as it manages a resource that is at the basis of the creation of a whole series of ecosystem services. For these reasons identifying the environmental benefits generated by the CER's activity is crucial, in particular starting from the function of water availability, and then moving on to an

estimate of the economic value of these benefits for the territory where they are enjoyed.

The categories of ecosystem services according to the scientific literature

To reach this estimate, firstly, we have resorted to the scientific literature available to classify the environmental benefits in the internationally recognised categories of Ecosystem Services. Specifically, reference will be made to the *Millennium Ecosystem Assessment* (2005), the largest collection of scientific knowledge on the state of the ecosystems in the world, which classified the ecosystem services in 4 main categories:

- ✓ Habitat supporting services: they enable the formation of all the elements that are indispensable for the growth and development of natural organisms.
- ✓ Regulating services: they enable the monitoring of natural phenomena, such as mitigating climate change, improving air quality, water purification, preventing hydro-geological instability etc.
- ✓ Provisioning/availability services: they concern all consumer goods (including agricultural resources) that derive from the ecosystems and which humans use to meet their needs.
- ✓ Well-being and cultural services: the ecosystems contribute to human beings' wellbeing because they guarantee, apart from natural resources, recreational experiences, relaxation opportunities as well as cultural and spiritual enrichment opportunities.

The assessment method of the ecosystem services

Once the environmental benefits guaranteed by the availability of water from the CER have been identified and classified, an assessment of the overall economic value will ensue: assessing an ecosystem service from an economic point of view is a complex operation, as it often clashes with constraints related to the absence of a free trade market for that given ecosystem service and, consequently, of its price.

To this end, we will once again resort to the relevant scientific literature which, among the various methodologies, puts forward the Benefit Transfer method, an assessment technique for those goods and services that do not have a market of reference and which consists in considering the information and the estimates of other scientific studies carried out in similar territories, and subsequently transferring and applying said results to the area being studied. The research process will end with an in-depth study of the danger climate change poses to water: water is indeed one of the resources that is most threatened by climate change, as it is part of all the components of the climate system (from the atmosphere to the cryosphere). The study will therefore highlight the impact of climate change on water availability on the mid and long term, and how this phenomenon can affect the ecosystem services identified in this work.

1. THE CER INFRASTRUCTURE: HISTORY AND FUNCTIONS

1.1. THE HISTORY OF THE CER IN A NUTSHELL

From 1620 to the first stone

The first idea of creating the Emilia Romagna Canal dates back to 1620, when Abbot Raffaello Tirelli from Reggio Emilia proposed to Duke Cesare d'Este a "project to extract water from the Po River north of Piacenza to irrigate the province, as well as those of Parma, Reggio, Modena and Bologna".

The idea was picked up again in 1810 by engineers Parea and Bolognini, within the framework of the territorial unification that began with the establishment, in 1805, of the Napoleonic Kingdom of Italy. The short-lived kingdom and the new fragmentation of Emilia, following the restoration and the Congress of Vienna, prevented the initiative from being carried out.

The Cavo Napoleonico (Reno River Basin) was equally unsuccessful: it was an ambitious attempt to bring back to the Po River the Reno River that for centuries flooded and turned into marshland the lowland of Emilia. It sought a hydraulic solution for the territory, regarding which the people of Bologna and Ferrara had very different ideas.

Right after the unification of Italy between 1859-61, in 1863 the first comprehensive project on the issue was presented to the government of Turin, drawn up by engineer Annibale Certani from Bologna, in collaboration with his colleague from the same city Cesare Perdisa. The assignment came from a committee chaired by another man from Bologna, MP and lawyer Camillo Casarini. The great project envisaged the diversion of 200 cubic metres per second from the hydraulic right of the Po River between Valenza and Bassignana, in the province of Alessandria, to transport it to the Bevano River in the province of Forlì, through a 337-kilometre course dominating 726,000 hectares of territory. The estimated cost is of 159 million Italian lire of the time.

Various reasons, including the creation of the Cavour canal between 1863 and 1866, lead to the "postponement of the issue", as was diplomatically noted in the report dated 10th December 1892 by Cavalier Italo Maganzini. He, as the head engineer of the Public Works Department (Genio civile) is commissioned to resume the project twenty-five years later, in 1889, on the initiative of MPs Fortis, from Romagna, and Codronchi, from Bologna, to "not abandon so improvidently" a work "of such undeniable importance".

The figures of the new project, which put the input on the Becca in the province of Pavia and brings water all the way to the Marecchia River, are equally impressive: initial water flow 200 cubic metres per second, length 300 kilometres, territory dominated 742,000 hectares, cost 180 million lire.

In 1893, the hydraulic Commission of the Ministry of Agriculture, Industry and Trade also rejects the new project, justifying the decision by arguing that "under the current financial conditions, building the huge Canal would not provide the advantages that

one would expect from such a work.” Two factors led to this attitude: the General Company of Italian Canals closing down, which built the Cavour Canal, and the enduring hostility of the people of Piedmont and Lombardy.

1939: The first steps toward the realisation

The years go by and in 1939 Minister of Agriculture Giuseppe Tassinari asks Mario Giandotti, an engineer of the Public Works Department and Reclaimer of the Renana and Parmigiana Moglia Consortia, to proceed with a new inspection on the chance and value of diverting water from the Po River to irrigate the plain of Emilia-Romagna. The answer was yes and **with Royal Decree no. 8288 of 28th September 1939 the Second-Degree Reclamation Consortium for the Emilia Romagna Canal is born**, and engineer Giandotti is appointed as its government commissioner. The first Giandotti project, of August 1940, starts from Boretto with an initial volume of 100 cubic metres per second, serving twelve Reclamation Consortia, which included bodies from Reggio Emilia and Mantua.

The idea of the Emilia Romagna Canal was officially approved for the first time with a vote on 15th December 1941 by the Higher Council of Public Works, but the war interrupted the works (Lenzi, 2018).

The subsequent political and social upheavals lead to the defection of the Consortia of Reggio and Modena which, like Parma before, decide to supply themselves from the Po River autonomously. The choice is also based on the little enthusiasm of the Elementary Reclamation Consortia towards common solutions and becomes apparent both over the first few years of existence of the Second-Degree Reclamation Consortium, and in subsequent events concerning the body and the water system.

The critics of the project clash after the end of the Second World War with a body that by then has its own legal form, with the tenacity of engineer Giandotti and the economy's reconstruction and recovery needs.

After the Higher Council of Public Works acknowledges, with a vote on 12th September 1946, the removal of the Consortia on the hydraulic left of the Panaro River and recommends the “diversion in a suitable point... using the Cavo Napoleonico”, the commissioner of the second-degree body draws up shortly after, in September 1947, two historic projects, one for the “mitigation of the floods of the Reno River by adjusting the Cavo Napoleonico”, which is thus reborn, also just with spillway functions and no longer of permanent diversion system like in 1807, the other “for the irrigation of the plain of Emilia-Romagna through the adjusted Cavo Napoleonico”.

The latter, the “Giandotti II” project, first begins its long journey in 1955 and, after being updated in 1964, becomes the Emilia Romagna Canal, which now reaches the province of Rimini.

In the same years, with the 1955 granting decree, the works in the Ravenna province begin to build the mobile dam on the Reno River which would supply, thanks to the creation of a channel, the blossoming petrochemical hub, while the construction of the main canal takes place in the 1970s all the way until the Sillaro river.

Since the 1980s, the most recent project phases

It is only in the 1980s that the works picked up the pace, with granting decrees following one another and enabling the canal, in 1984, to completely enter Romagna.

The other major construction season is in the early 2000s owing to the Multiple Uses, the herringbone branches in the following areas: Senio-Lamone, Ronco-Bevano, Bevano-Fiumi Uniti, Bevano-Savio, Selice-Santerno and Montone.

The final part of the canal, from the Uso river to the Rio Pircio, so in the area of the province of Rimini, was inaugurated in 2017 and another project is a further extension to meet the needs that have emerged in recent years.

1.2. THE FUNCTIONS OF THE CER

A work with multiple purposes, i.e. not only agricultural but also civil, productive, environmental and tourism-related purposes

The Second-Degree Reclamation Consortium for the Emilia Romagna Canal has a public legal person status. The CER, as described, is a complex water system: apart from envisaging a feed pipe it also includes some networks delivering water to the Associated Consortia; moreover, it is not only an agricultural infrastructure, but rather a work with multiple functions which, though maintaining irrigation as its primary mission, it also includes civil, productive, environmental and tourism-related uses.

The role of the Second-Degree Consortium and its related coordination function towards the First-Degree Consortia, Public and Private Bodies and other people concerned

Like all Second-Degree Consortia it was born following the presence of common interests of various First-Degree Consortia that, therefore, are associated to it:

- The Burana Reclamation and Irrigation Consortium;
- The Ferrara Reclamation and Irrigation Consortium;
- The Renana Reclamation and Irrigation Consortium;
- The Western Romagna Reclamation and Irrigation Consortium;
- The Romagna Reclamation and Irrigation Consortium.

The Ravenna Servizi Industriali S.C.P.A., an extra-agricultural associate, is also part of the Second-Degree Reclamation Consortium.

These bodies are recipients of water supply, as part of the resources the CER has at its disposal. In particular, the associated Consortia are entrusted with the irrigation distribution of the resource throughout the territory.

This possibility is envisaged by the reference regulation which is still Royal Decree no. 215 of 13th February 1933. New rules for the complete land reclamation under art. 54 that to ensure the coordination of the activity of the First-Degree Consortia – and where necessary, of public bodies, private bodies and other persons concerned – there is the possibility to build Second-Degree Consortia (art. 57).

On the basis of what is enshrined in the national regulation, Emilia-Romagna, under art. 21 of Regional Law no. 42 of 2nd August 1984 “New rules on the matter of land reclamation bodies. Delegation of administrative functions”, establishes that Second-Degree Reclamation Consortia can be established “for the coordinated realisation

and management of land reclamation or irrigation works as well as the realisation of common services concerning multiple Reclamation Consortia”. These services also include “the distribution of water for industrial use to its associates in a quantity not higher than 20% of the quantity that was already granted by the Consortium”.

Differences between First and Second-Degree Consortia

Therefore, the difference between a First and Second-Degree Consortium is that, generally, First-Degree Consortia have by statute a territorial jurisdiction (administrative surface) on the management and distribution of water to the irrigation users (e.g. Land Reclamation, Irrigation and Land Improvement Consortia) and have diversion concessions, meaning the authorisation to withdraw water in given moments and in given volumes (modules).

Second-Degree Consortia, generally, do not have territorial jurisdiction but rather management competence on irrigation schemes and irrigation surfaces included in the Management Plans of the hydro-graphic districts.

Tasks and functions

Moreover, still in article 21 of Regional Law no. 42 of 2nd August 1984, it is also established that the tasks and goals of a Second-Degree Consortium are indicated in the related Statute. In fact, art. 3 of the Statute of the CER Consortium lists its tasks and functions, explained “for the purposes of the rational use of water in agriculture and the other hydro-demanding sectors”. In particular, the Consortium performs:

- the study, planning and execution of the diversion works of the Po River, from other rivers and reservoirs, as well as irrigation canals of common interest to the territories of the provinces of Ferrara, Modena, Ravenna, Forlì-Cesena, Rimini and the metropolitan city of Bologna;
- the maintenance and exercise of the intake works, lifting systems, the course of said irrigation canals and the related infrastructure;
- the distribution of water to the associates;
- the pre-financing of the expenses for the construction of the above-mentioned works;
- the coordination of the activities of the associated Consortia for the execution of the irrigation works and the integration thereof with the works of the Second-Degree Consortium, to best use the CER’s water;
- the rearrangement of their utilities and water use;
- the use of water in multiple uses of the water pursuant to the legislation in force;
- the promotion of initiatives to adapt agriculture to droughts and climate change, for the mitigation of the related effects, for the protection of the productions and the economic enhancement of the area;
- carrying out study, research, experimentation, dissemination activities, as well as technical assistance and training on irrigation, water saving and the quality and protection of the waters in agriculture, in favour of the Reclamation Consortia and of other public and private bodies and subjects within the limits of the institutional purposes and in accordance with the rules on the procurement of the services.

Initiatives on saving, improving water and safeguarding the environment

Among the tasks of the Consortium is the promotion of every initiative aimed at saving water, using water properly, protecting its quality and reducing subsidence. In fact, for example, the Consortium provides technical assistance to farmers to improve the use of water, for saving purposes. Moreover, it carefully monitors the quality of the water that flows within the canal and takes care of its qualitative maintenance, as well as safeguarding the environment. Regarding the latter aspect, the action carried out by the CER results in benefits for the environment in that, replacing the groundwater with the surface water in production uses, it preserves the territory from subsidence (which occurs when the withdrawal of groundwater exceeds the natural recharge possibilities).

Applied research aimed at improving irrigation techniques

Finally, as was previously mentioned, the Consortium also carries out applied research activities. Thanks to this sector, the Reclamation Consortia of Emilia-Romagna participate in many regional and European research projects aiming to improve the irrigation techniques for the various cultivation varieties, as well as experimenting with new technologies to reduce irrigation and improve agricultural production.

The IRRINET and IRRIFRAME instruments: developing new technologies for a more efficient use of water and to increase agricultural production

The research and experimentation carried out at Acqua Campus led to the creation of a supply chain of instruments that follow the entire agricultural activity, from the technological choices within the companies, such as SETI and TECNIRRI, to the advanced irrigation advice from IRRINET. IRRINET is an interactive assistance system on irrigation that provides farms with precise and personalised information on the moment of intervention and the volumes to use to obtain a quality product while saving water. The CER has also designed the similar service called IRRIFRAME (Genovesi et al.) for ANBI Currently available for 69 Land Reclamation Consortia of 16 Italian Regions, which cover about 60% of the national irrigation surface. Further instruments are available for all stakeholders, including FALDANET for the monitoring of the shallow groundwater table in Emilia-Romagna.

The CER in industry planning

As part of the planning process of the use of water at national level and pursuant to the Water Framework Directive 2000/60, managed by the Hydro-graphic District Authorities, the multiple functions of the CER are very important and must be analysed and enhanced as part of the Economic Analysis of the Management Plan of the Hydro-graphic District of the Po River. The Second-Degree Reclamation Consortium also plays an important role in the process of planning investments in irrigation and modernising the national irrigation system.

The Framework Directive introduced for the first time the concept of “Economic Analysis”, an innovative concept on the matter of water governance aimed at pursuing quality objectives, as it recalls a sustainability analysis of the environmental goals concerning the measures envisaged and to be envisaged for their achievement. This rule therefore states the need to guarantee that environmental policies are supported by a strategic plan, i.e. referring to the “Water Management Plan”. Within this framework the Economic Analysis is a tool that supports the decision-making process for the identification of the best structural and non-structural measures,

meaning the most effective and sustainable at an environmental, economic and social level.

As provided by the Framework Directive, the Economic Analysis during the analysis of the starting situation provides an overview of the use of water and the value it produces for various sectors, the impact of the users and the consequent pressure, both in terms of withdrawal and pollution it produces, it identifies those who are negatively affected by this, what the deriving costs are and who covers them, while also drawing attention to the existing relations between the various uses and the consequent cause-effect relation (polluter pays principle).

In accordance with art. 5 of Annex 5 of the Water Framework Directive, for the purposes of the economic analysis there must be a study of all the uses that have a major impact in terms of pressure and impacts on water. These uses include both uses and services, as defined by Ministerial Decree no. 39 of 25th February 2015 “Regulation containing the criteria for the calculation of the environmental cost and the cost of the resource for the various sectors in which water is used”.

For agriculture the agricultural use of irrigation is envisaged.

The water services

Water services, on the other hand, include all the activities - public and private - of withdrawal, containing, storage, treatment and distribution of groundwater and/or surface water, management of rainwater, collection and treatment of waste water as well as activities aimed at preserving water and protecting people, goods and human activities from the risks connected to extreme events (floods, droughts).

Water services include:

The Integrated Water Service (IWS or SII in Italian)

✓ The Integrated Water Service (IWS below):
The CER is a wholesale supplier of raw water to be turned into drinking water for Hera S.p.a. in Imola and for Romagna Acque società delle fonti S.p.a. to the water purifiers of Bassette and Standiana, located in Ravenna. The latter plant realised by Romagna Acque is powered by the water of the Po River, lifted and transported thanks to the Emilia Romagna Canal. The water purifier – which has a maximum volume of 1,100 litres per second – thus makes a very large quantity of water available (about 20 million potential cubic metres of water serving an area of over 150 thousand people) to be added to the 110 million that are distributed on average, for a total of 130 million (for an in-depth description thereof see paragraph 1.3).

The water service for managing whitewater networks

✓ The water service for managing whitewater networks:
it includes the set of public services for managing the separate urban pipelines serving only run-off rainfall water (white sewage system), including those that use infrastructure of the Land Reclamation Water Service and excluding those already included in the Integrated Water Service.

- The industrial water service** ✓ The industrial water service:
it includes the set of services of catchment, transport and distribution of water for industrial uses, sewage and purification of industrial waste water, excluding the one included in the integrated water service.
- The role of the CER** The CER has among its associates Ravenna Servizi Industriali S.p.a. (RSI) a consortium company established in December 2004 in the Petrochemical Site of Ravenna operating in the sector of providing industrial services and in the production and distribution of utilities to companies in the industrial district of Ravenna; it is a company subject to the management and coordination of Eni S.p.a. The supply of water from RSI takes place through the Reno River thanks to the mobile dam of Volta Scirocco, the mobile barrier built specifically by the CER on the river itself. During the summer period the supply can also take place with the water of the Po River transported by the Canal and conveyed to the Lamone River all the way to the Petrochemical Site.
- The irrigation water service** ✓ The irrigation water service:
It includes the set of services of catchment, accumulation, transport and distribution of water for agricultural and irrigation uses.
- The CER carries out water catchment, accumulation, transport and distribution services to the associated Consortia, while with reference to the direct delivery to agricultural users, this only takes place along the Canal (about 135 km long).
- The regulation water service of Lakes Maggiore, Como, Iseo and Garda** ✓ The regulation water service of Lakes Maggiore, Como, Iseo and Garda:
it includes the set of public regulation services of the hydro-metric level of the great lakes, of the diverted volumes and management of the regulation works thereof, aimed at protecting the ecosystems connected to the lake environment, to the allocation of water for irrigation and distribution over vast areas of water, which also plays a role in replenishing the aquifer.
- The management service of the reservoirs and other works of flood control, accumulation, transport and/or conveyance of the water** ✓ The management service of the reservoirs and other works of flood control, accumulation, transport and/or conveyance of the water:
The CER carries out regulation activities of the reservoirs and of other works of flood control, accumulation, transport and/or conveyance of the water, including the regulations of the multiple uses (programmed production of electricity and wholesale of water), maintaining the capacity of the reservoir, managing the discharge systems, flood control. It must be noted that the canal itself acts as a reservoir and with the river mobile dam on the Reno River it accumulates up to 6 million cubic metres. In other words, the water system of the Emilia Romagna Canal (Cavo Napoleonico, Canal on the hydraulic left of the Reno River, main Canal, Reno Subsystem) is, in fact, a complex system of water lifting works and reservoirs of about 18 million cubic metres, constantly regulated to maintain the levels, volumes and discharge works through techno-controlled equipment aimed at regulating the multiple uses.

The water service for managing the reclamation network and works for hydraulic and hydro-geological defence

- ✓ The water service for managing the reclamation network and works for hydraulic and hydro-geological defence:

It includes the set of services concerning planning, realisation and management of the land reclamation works with the (exclusive or mixed-use) purpose of drainage and removal of rainfall water as well as mountain reclamation works for the regulation of run-off from the hilly and mountainous territory¹.

The CER carries out services concerning planning, realisation and management of the land reclamation works with the (exclusive or mixed-use) purpose of drainage and removal of rainfall water as well as mountain reclamation works for the regulation of run-off from the hilly and mountainous territory. In particular, the Cavo Napolenico (with its spillway function of the Reno River's floods) carries out reclamation activities for hydro-geological defence, discharging the water into the Po river. In emergency conditions the CER can carry out an important function or removing rainwater or river water from the territories of the low plains of the Bologna area, discharging the water into the Po River. On the 2nd, 3rd and 4th February 2019, for example, it discharged 4 million cubic metres of water that had come out of the riverbank breaking of the Reno, saving from floods densely populated settlements.

The water service of managing natural watercourses and hydraulic works

- ✓ The water service of managing natural watercourses and hydraulic works:

includes a set of public services aimed at safety, environmental safeguard, water reclamation (for example: river redevelopment, enhancement of the self-purification capacities, renaturation and environmental restoration, vivification of lake and valley bodies of water etc.) as well as ordinary and extraordinary maintenance:

- a) of the works of hydraulic arrangement and reduction of the risk related to extreme weather events and hydraulic matters;
- b) of flood plain areas, banks, areas or goods intended for hydraulic protection purposes;
- c) of riverbeds.

The CER carries out services of environmental safeguard, water reclamation and ordinary and extraordinary maintenance. In particular, **the CER in this respect has realised a wetland for the phytodepuration of the water located in the lowest part of Acqua Campus' Research Area**, in the village of Ronchi di Budrio (BO), powered with company waste water.

The realisation of phytodepuration wetlands has a two-fold effect: it limits pollution by reducing the effects of the widespread releases and has positive effects on the environment and the surrounding territory, as it improves its biodiversity. The project led to: a reduction in the pollution of the waste water caused by agricultural activities; the enhancement of bodies of water in preparation for their reuse for irrigation

¹ With ruling no. 66/92, the Italian Constitutional Court stated that land reclamation activities are part of the broader public action for the defence of the soil, the protection, enhancement and correct use of water resources, the protection of the environment as an ecosystem, in a comprehensive view of the measures on the territory. This action concerns major public interests headed by local communities as a whole rather than single categories of private subjects.

purposes within the company itself; the introduction of landscape elements that create added value; the increase in the reservoir capacity of the territory's drainage network, to prevent sudden floods due to intense rainfall, which have been very frequent lately, also off season.

The CER has set up a capillary network of withdrawal points of samples along the entire course of the canal, scheduled for the entire duration of the irrigation season and analysed in the in-house chemical laboratory. In short, there is a monitoring of the quality of the water conveyed in the water system under the responsibility of the Emilia Romagna Canal. This monitoring action has shown that the water of the CER comes from the Po River, but its quality is higher compared to that of the large river thanks to a series of favourable circumstances and effects, such as:

- a) the phytodepuration action of the Cavo Napoleonico, with its huge section and riverbank plants;
- b) The CER's hydraulic insulation – through the territory it goes through – planned so as to not receive at any point waste water or potentially polluted effluents;
- c) the constant contact with the atmosphere and the low speed levels of the water throughout the entire Canal;
- d) finally the CER, apart from the river regulation of the level of the Reno through the mobile dam of Volta Scirocco, guarantees the vital minimum outflow of the Lamone River through the conveyance of the water of the Po river. Conveyance is a practice concerning the use of natural watercourses as carriers of irrigation water, widespread above all in Emilia-Romagna and Veneto.

Important environmental functions of the CER

Finally the **CER also performs important environmental functions** related both to the relief of the aquifer and subsidence and for supplying and safeguarding wetlands of the central-eastern Emilia-Romagna plain.

In the coast area of Ravenna, the CER brings the freshwaters of the PO and Reno rivers to **the wetlands of Punte Alberete and Valle Mandriole, protected by the Ramsar Convention to defend them from the progressive salinisation**. The areas cover over 500 hectares and are located within the Regional Park of the Po River's delta.

The multi-industry water service

- ✓ The multi-industry water service:
It includes the set of water supply and transport works that, singularly or as parts of a complex system, are capable of supplying water, directly or indirectly, to multiple territorial areas or different categories of users. Within this framework, the CER operates the multiple use of irrigation waters, i.e. water uses that entail the return of the water and are compatible with the subsequent uses and, in particular, with irrigation uses.

The CER and the production of uses and services

It must be highlighted that, as part of the Water Management Plan of the hydro-graphic district and, in particular, in the socio-economic characterisation of the uses, divided in uses and services, the information concerning water use is analysed based on the existing relations between the economy and the environment. The analysis

serves to understand the added value created by the various uses of the District's economy and the potential capacity of the single uses to contribute to covering the costs of the measures envisaged in the Water Management Plan. In fact, the planning process, in line with what was envisaged by the Water Framework Directive, must consider a **sustainable "management of the resource", i.e. that can reach multiple objectives at the same time:**

- **environmental**, namely the protection and management of the natural capital for the future generations (**environmental sustainability**);
- **social**, meaning the need to guarantee the equal sharing and accessibility for all to a resource that is fundamental for life and economic development (**social sustainability**);
- **economic-financial**, meaning objectives in terms of efficient allocation of a scarce resource (**economic sustainability**) and finding the financial resources for the realisation of the infrastructural, management-related and non-structural measures to achieve the environmental objectives (**financial sustainability**).

Therefore the contribution of the CER in terms of producing services must be observed in relation to the value that water takes on regarding the economy and agricultural productions, environmentally in the management of the natural capital but also the defence of the territory, hydraulic defence and contrasting hydro-geological instability, and socially, as it is capable of generating income and maintaining the populations in the rural areas (thus preventing depopulation) and guaranteeing water in an equal manner and for various uses. On the other hand, to implement the general principle of covering the costs, one must consider both water services and the activities that entail major levels of exploitation of water or that have an impact on it and the related ecosystems. With reference to the latter one must thoroughly examine and assess the specifications of the hydro-electric sector (driving force production) in the districts where this is relevant.

The CER and electricity production

The CER is planning to realise photovoltaic plants located near the main lifting plants for the production of clean energy, with the goal of covering the energy costs related to the plants themselves. Moreover, to combine energy saving, which can be achieved through the use of photovoltaic renewable energy, and water saving, achieved through a rational use of drip irrigation, **the CER has developed a drip photovoltaic irrigation system (SOLARDRIP)** through which one can give little water to the crops in the periods of the year with short days (or on summer days but with cloud coverage), and vice versa more water on long and very sunny days, on which the evapotranspiration demand and therefore water demand of the plant is high.

The CER contributes to the achievement of the Sustainability Goals envisaged by the 2030 Agenda

Also **the matter of ecosystem services is part of the district's economic analysis.** Notably, some natural and rebuilt water ecosystems can perform functions (water retention, flood control, abatement of nutrients, phytodepuration, recharging aquifers etc.) that, under certain conditions, can be considered "services" subject to remuneration or compensation. Therefore, the assessment of the ecosystem services generated within the framework of the CER can be part of the economic analysis of

the management plan as the quantification of any environmental benefits that can “balance” any major pressures that can turn into an environmental cost or of the resource to internalise through the economic instruments indicated by the European and national regulations.

Finally, based on what was described the CER contributes to the achievement of the Sustainability Goals of the 2030 Agenda and, in particular, the following goals:

- 3) Health;
- 6) Clean water – Quality of the water;
- 7) Clean and accessible energy;
- 8) Decent work and economic growth;
- 9) Companies innovation and infrastructure;
- 12) Responsible consumption and productions;
- 13) Struggle against climate change;
- 15) Life on Earth – Biodiversity.

1.3. THE MULTIPLE USES OF WATER

The extra-agricultural uses of the CER

The Second-Degree Reclamation Consortium for the Emilia Romagna Canal has long been interested in enhancing its catchment area towards extra-agricultural uses, also obtaining the approval and funding of various important projects of water transport for multiple uses. Moreover, as mentioned before, **the CER is a majority shareholder of Plurima spa, a company established with Acqua Società delle Fonti S.p.a**, enabling the management of water for civil and industrial uses. The supply can take place thanks to transport networks that are minute, underground and piped, barely invasive for the environment and specialised in agricultural and civil-industrial distribution.

The industrial uses of the CER: the Industrial District and the Petrochemical district of Ravenna

A tangible example of the many uses of the water of the Canal for industrial purposes is the supply, 5 km away from the outlet of the Reno River, of the **Petrochemical district of Ravenna**, of the **industrial plants** present there, of **Ravenna's aqueduct** and the various water utilities of the territories north of the city. **Ravenna's Industrial District** in fact is a combination of diverse companies and production fields, which share the same location in the **industrial-port area of Ravenna** and a series of common services and infrastructure, mostly managed together and as a consortium. The site is managed by various companies, with their organisational autonomy but with a consortium management of the common infrastructure and services headed by the **company RSI, Ravenna Servizi Industriali**.

Figure 1.1 – View of Ravenna's industrial and port area



The industrial and port area is located on the hydraulic left of the Candiano Canal, near the city of Ravenna and its nearby lidos of Ravenna. The entire industrial area is located in a “sensitive” territorial environment of great complexity owing to the presence of the tourist area along the coast, of a water system that includes the **Piallassa della Baiona**, **Piallassa dei Piomboni** and a pine forest. The city of Ravenna is located a few kilometres south-west from the industrial area that to the north/north-west borders with the Park of the Delta of the Po River (in figure 1.2 one can see the industrial-port area, highlighted in red, and the area of the multi-company site, in yellow, within the territory of the Municipality of Ravenna).

Figure 1.2 – The industrial district of Ravenna



The production fields of the District of Ravenna

The main production fields concern:

- a) the petrochemical industry;
- b) the thermoelectrical industry with the presence of two power plants owned by Enipower (located within the Petrochemical area) and Enel Produzione (the Centrale Teodora of Porto Corsini);
- c) the agri-food industry, with companies of the production sector (food oils and flours for zootechnical use) and services (fertilisers and cereal products);
- d) the metallurgical and steel industry;
- e) the construction industry, especially the production of cement and ceramics;
- f) the plant complex for the treatment of waste water and waste, managed by Herambiente, at the service of the Petrochemical production site Ex-Enichem;
- g) The activities that include services to the port, such as logistics, handling of construction sites, shipowners, shippers, washing services, maritime agencies etc.

These services in 2022 recorded a **turnover of 1.8 billion Euros**.

The following are some of the major users of the industrial waters produced by RSI.

Table 1.1 – The largest users of the industrial water produced by RSI

Companies	Productions	Final applications of the products
Acomon	Additives and intermediates	Bases for optical lenses, stabilisers, plastic materials
Bunge	Oils and seeds	Oils and seeds
Cabot	Black smoke	Additives for polymer industry, toner for printers
Cray Valley	Liquid polybutadiene	Space vector propellers, insulating material
CFS Europe	Diphenols	Plastic material stabilisers, pharmaceutical intermediates, Vanillin (sweetener)
Ecofuel	Additives for petrol	“Green” petrol
Endura	Chemical additives	Insecticides for domestic use
Enipower	Electric energy and steam	Energy
Nippon Gases	Industrial gases (Oxygen, Nitrogen, Argon)	Industrial processes, welds, medical processes
Orion Engineered Carbon	Black smoke	Additives for polymer industry, toner for printers
Polynt	Maleic anhydride and tetrahydrophthalic anhydride production	Resins and composite materials
Yara Italia	Nitrogen compounds	Fertilisers
Versalis	Synthetic rubber	Automotive (for example tyres), Construction, Adhesive products, Footwear, Lubricants
Vinavil	Construction chemical additives	Adhesive products, paint, glue, bases for chewing gum

Source: Ravenna Servizi Industriali SCpA

Consortium management of the infrastructure and common services, headed by RSI

To meet logistical needs, the area in question is equipped with a port basin, located along the Candiano Canal, connecting Ravenna with the Adriatic Sea, for the docking of ships weighing up to 40,000 tonnes. The port area features about 16 km of docks, equipped with suitable systems for loading/unloading operations and for handling goods, and moreover has service areas and warehouses for the storage of incoming goods.

The infrastructure inside the area also features a 55 km railway network and an internal road network that is over 25 km long, which allows for efficient handling

both inside and outside the area itself. Naval transport takes place thanks to the Port-Canal, which is about 11 km long, connecting Ravenna and the sea.

The industrial and port area includes the famous **multi-company Production Site**, called **Petrochimico** (Petrochemical), which features manufacturing companies with diverse processes and services, mainly concerning the chemical and petrochemical industries, as well as energy production and waste treatment services.

The ANIC channel serving the ANIC Chemical Plant of Ravenna

The industrial district of Ravenna and the City of Ravenna are therefore powered by **two vital sources of supply**, the **Reno River** and, as already mentioned, the **CER**, through the **ANIC channel**, born in the 1950s of the past century to meet the process needs of the systems of the **ANIC Chemical Plant in Ravenna**. This canal transports water to the plant, partly as a pressure pipe and partly as an open air channel, with an extension of about 15 km. To this end, upon its creation, the Reno River was selected as source of supply of freshwater and, apart from the ANIC channel, the following works were realised:

- The building of a **mobile dam on the Reno River** in the village of Volta Scirocco, to fill the basin of the river with water and **allow for the diversion of the water intended for the ANIC**;
- The building of **specific intake works (water gates) upstream of mobile dam**;
- The building of a **water-scooping station**, in the village of Mandriole, **for lifting the diverted water**.

Industrial waters to power the distribution networks in the Industrial Chemical District of Ravenna

As of today, the raw water coming from the ANIC channel, within the Petrochemical area of the **TAC plant (Plant for the Treatment of Supply Water)** of RSI, is treated to obtain **industrial water**, at varying levels of purity, to be used to supply the various distribution networks within the **Chemical-Industrial District of Ravenna**.

The industrial water produced can be categorised as follows:

- **Fire-fighting water** (about 3,500,000 m³/y)
It consists of physically filtered raw water for the removal of mud or suspended solids.
- **Integration water** (about 7,500,000 m³/y)
Raw water becomes clear water chemically and physically in special equipment called "Circular Clarifiers" and powers the cooling circuits in the Plant (Cooling Towers).
- **Softened or Zeolitic Water** (about 800,000 m³/y)
This high-quality water undergoes preliminary clari-flocculation and softening with lime in circular clarifiers, followed by subsequent filtration over silica beds and a final softening process with cationic absorption resins to remove residual hardness. This water is used as reaction bath for the production of synthetic rubber, latexes and raw materials for the production of tyres, rubber products, materials and glue for construction.

- **Demineralised water or boiler feed water** (about 3,500,000 m³/y)
This is ultra-pure water that is obtained with a demineralisation process through ionic exchange resins after the above-described clari-flocculation processes. The water that is thus treated powers the boilers to produce technological steam.

1970s: Reno, the only alternative source of supply

Regarding **civil uses** on the other hand, in the late 1960s the existing **water supply and treatment works were insufficient** for the growing needs of the permanent population and the blossoming tourism industry in the northern lidos of Ravenna. The only possible alternative water supply source, apart from underground extraction, was the Reno River. Moreover, in the early 1970s subsidence, which was caused by the withdrawal of groundwater, was particularly critical with major decreases of the ground level in the areas near the port-canal. Therefore, the ANIC Channel started being used, as it is still today, to also power the **NIP city purifier of Romagna Acque**.

ANIC powered by the Reno and Lamone and strengthened by the CER in the summer period

Moreover, over the years, to handle the problems caused to production processes by the quality of water in the summer, it became possible to **pump water into the channel** not only from the **Reno** River but also from **Lamone** River, whose fluence in summer **was strengthened by the input, in the village of Pieve Cesato, of water of the Emilia Romagna Canal (CER)**.

The civil uses of the CER

The role of the Consortium is also vital in the sector of **civil uses**, thanks to the powering with raw water of some purifiers, such as that of **HERA in Imola** and **the three belonging to Romagna Acque Società delle fonti**, i.e. the previously mentioned **NIP1 – Nuovo Impianto di Potabilizzazione (New Purifier Plant) - (Bassette di Ravenna), NIP2 (Standiana) and Forlimpopoli (Selbagnone)**, which can secure the water supply of all Romagna.

Hera's purifier in Imola

Regarding **Hera's Purifier**, the CER with raw water, together with the Canale dei Molini (which in turn extracts water from the Santerno stream) also powers the main aqueduct system of the Imola area, represented by the **industrial aqueduct of Mordano (BO)** and the **four purifiers powered by it**, collectively called **Basins of Bubano**. The Basins have a potential of **450 litres per second** and inject into the network a water volume of **8.3 Mm³**.

In the first part of the treatment of water there is the production of water with qualitative characteristics that are **suitable to industrial activities**, partly used by various companies of the Municipalities of Imola, Mordano, Dozza, and partly allocated to the production of drinking water at the **treatment plants of Castel San Pietro, Mordano, Conselice and Sant'Agata sul Santerno**.

Reservoirs of Bubano, important

Reservoirs are an important reserve that allow for the tackling of periods of droughts, as well as avoiding sudden and temporary phenomena of pollution that may affect the canals. On average the water remains in the reservoirs for about 5 months. This

reserves for periods of droughts

favours the homogenisation of water, the elimination of part of the pollutants by precipitation and a major reduction of the bacterial load thanks to sedimentation and natural radiation of ultraviolet rays. The water then undergoes pre-disinfection with sodium hypochlorite to reduce the initial microbial load and thus minimise biological growth along the various treatment stages, control water odour and taste, improve the coagulation and sedimentation process through oxidation of inorganic and organic substances, and eliminate algae. It is then fortified with aluminium polychloride and polyacrylamide and sent to the two clari-flocculators. The clari-flocculation treatment eliminates the suspended colloidal particles by aggregating them, thanks to the adding of aluminium salts, in larger particles that agglomerate and are then removed by precipitation. The water, which can now be used for industrial purposes, undergoes post-disinfection with chlorine dioxide and accumulated in a tank, before it is put into the water network that **brings it to the industrial clients and the four peripheral purifiers**. The purification treatment, which further purifies the water making it suitable for human consumption, occurs **in the four purifiers of Castel San Pietro, Mordano, Conselice and Sant'Agata sul Santerno** and includes the following phases: sand filtration, intermediate ozonisation, activated carbon filtration and final disinfection. Sand filtration is the most important phase for clarifying water, as it is the final physical barrier to prevent the passage of pathogens resistant to chemical disinfectants. The subsequent adding of nitrogen is aimed at the removal of smell, colour, taste, any traces of organic substances and metals. The filtration on activated carbon further refines the water removing the undesired substances of organic nature through a chemical-physical-biological process. The final disinfection, with chloride dioxide, inactivates the remaining pathogen microorganisms and the maintenance of microbiological quality of water up to the user. At this point the water is **put into the distribution network**.

NIP 1: The purification plant of Bassette in Ravenna

Regarding the three purifiers of **Romagna Acque, the NIP1 (New Purifier Plant)** was created in the late 1960s in the village of **Bassette**, to contribute to solving the issue of chronic shortage of drinking water, which has always been plaguing the territory around Ravenna. It is located on an area of about 72,000 m², completely fenced, partly occupied by plants and partly by forest areas (EN11).

The plant has a potential of **1,300 litres per second** divided on 4 lines that enable the treatment of about **900 litres per second** for a total of water produced around **78,000 cubic metres per day** (about **28.5 million potential m³ per year**).

The production cycle of drinking water includes: the **extraction of raw water** from the Lamone and Reno rivers and the Emilia Romagna Canal and, once purified, at the end of the treatment, **the water is put into Hera's distribution network**. The plant is structured for a physical-chemical treatment that includes refinement and disinfection, with the following phases: screening, oxidation, pH correction, clari-flocculation, chlorination at breakpoint, filtration on sand filters, filtration on granular active carbon filters, post-chlorination with chlorine dioxide, accumulation in two 16,000 m³ tanks in total.

The purification activity, understood as catchment and treatment of water, **does not generate major negative impacts on the ecosystems** in the territory of Ravenna and can always guarantee the vital minimum level of water in the rivers.

**NIP 2:
The purifier of the
Standiana**

Regarding on the other hand the **NIP2**, i.e. the **purifier of the Standiana**, just outside Ravenna, inaugurated in September 2015, it is a vital comprehensive intervention which resulted in the creation of the most advanced plant in Europe in the field, **which secured the redevelopment of the entire water management of Romagna**. The purifier uses a cutting-edge technology to obtain very high-quality water, starting from the water of the Emilia Romagna Canal, guaranteeing total security of supply also in periods of droughts. Given its innovative contribution, it is also the **most important among the investments** included in the multi-annual 2011-2023 plan of **Romagna Acque-Società delle Fonti S.p.A.**

The plant is the heart of a complex “comprehensive” intervention for the entire Romagna area, which is complemented with about 40 km of large interconnection pipelines connected to it. The start-up system of the purifier provides Romagna with a major quantity of water, at least **20 million potential cubic metres per year**, which are summed up to the 110 distributed on average today for a total of about **130 million cubic metres**, with a ratio between availability of resources and demand that is over 1.3, thus guaranteeing a security of supply that is **over 30% more than the possible requirement**. This enables Romagna Acque to further diversify the sources of supply reducing the current extraction by over 50% and enables a large part of the territory to have enough of the water resource also in the event of droughts.

The plant is powered with **water of the Po river coming from a diversion of the Emilia Romagna Canal** thanks to a specific diversion concession issued to Romagna Acque and through the realisation, by Plurima, a Romagna Acque subsidiary, of a specific infrastructural system for multiple uses of which it also oversees the operational management.

**A total investment
of 70 million
Euros**

The construction works of the New Purification Plant NIP2 lasted 2 years, from April 2013 to April 2015, preceded by a complex phase of planning and authorisations, which began in 2004 and ended in 2012. Over the 24 months of works, the building site of via Fosso Ghiaia experienced intense and constant working rhythms: 63 companies in total worked on it (41 of which based in Romagna) for a total of 26,240 man-days. On average, 41 workers went to work every day, with peaks of 83 workers working at the same time.

The total amount of the works was **32 million 900 thousand Euros**, to which about the same sum was added for the installation of the pipelines interconnecting the territory. The plant is in fact interconnected with the **network of Lugo, the NIP purifier of Ravenna** and the **Adriatic ridge of the Romagna Aqueduct**: the main areas served are therefore the **Lowland of Romagna, the territory of Ravenna and the Adriatic coast**, from Cervia to Cesenatico and even beyond. This brings the total investment to over **70 million Euros**.

Innovative and cutting-edge systems

The purifier is made with the most modern concepts and cutting-edge technology. The most important section of the plant is the **ultra-filtration**, i.e. **water filtration** through membranes with an outer porosity that is so small (0.04 micron) that they retain, apart from all suspended solids, also the bacterial load and spores of potentially pathogen organisms. The final passage on activated carbon allows for the retention of the last substances that have remained in solution in the water at the end of the treatment. The **process control** system is also modern, it is highly automated and equipped with remote checks that make it perfectly integrated with the remote monitoring system the company has in Capaccio. For the plant to work at full capacity, 12 workers are needed, between process controllers and maintenance teams. The new purifier therefore also provides **work and employment opportunities**, as well as high-quality mineral water.

The purification plant in Ravenna

Among the “historic” sources of supply, apart from NIP1 and NIP2, one must mention the **purification plant in Lugo**, located in the hospital area. It was built in the early 1980s to purify the raw water partly coming from the aquifer (two wells in Cotignola and one in Lugo) and partly from the industrial aqueduct of Conami in Imola, diverted from the Santerno and the CER. The plant is occasionally activated, in the event of years with droughts. It has a potential of **70-80 litres per second** and the potabilisation and purification operations take place through automated processes.

Considerations on the importance of industrial and civil uses and the difficulty in estimating their economic impact

This paragraph has illustrated the important role played by the water supply of the CER for the industrial sector and civil society. As with the actions carried out by the Consortium in the field of research and innovation examined in the previous paragraph, which are also very important in particular for the activity of farmers, this work does not include an economic assessment of the impact of these actions, given the lack of data and difficulty in reaching reliable estimates, even with a high degree of approximation. Such assessments will therefore be made in future works that can further study these aspects and provide an economic assessment of their impact.

2. A SHARED INFRASTRUCTURE

2.1. THE PERSPECTIVE OF THE STAKEHOLDERS

Stakeholder consultation

An important phase of the assessment of the externalities generated by the CER for the territory was the realisation of a stakeholder consultation.

The goal of the initiative has been to collect – from specific selected subjects – the assessments on the activities carried out by the CER, so as to reach a strategic and multi-industry assessment.

The technical group therefore selected the players (including Institutions, the Technical-Scientific world, Associations) capable, with their expertise and professionalism, to make a valuable contribution to create a shared map of the environmental, social and economic effects generated by the activities of the Consortium for the management of the Emilia Romagna Canal.

Therefore, it was decided to directly involve² some interlocutors who were given a questionnaire aimed at collecting an assessment of the importance of certain key subjects the CER focuses on.

The Stakeholders

The stakeholders contacted report to the following bodies and organisations:

- Emilia-Romagna Region;
- National Association of Reclamation and Irrigation Consortia – ANBI;
- Renana Reclamation and Irrigation Consortium;
- Agenzia Territoriale dell’Emilia-Romagna per i Servizi idrici e rifiuti (ATERSIR);
- Gruppo HERA;
- Bologna Canals (Chiusa di Casalecchio, Savena and Reno Canal Reclamation and Irrigation Consortia);
- Romagna Acque Società delle Fonti;
- University of Bologna (UNIBO)
- Autorità di Bacino del PO.

The following are the issues covered.

² This analysis resulted in the adoption of virtual forms of meetings through digital platforms that the state of emergency caused by the Covid-19 pandemic required, as the only ways to guarantee a fruitful exchange with the stakeholders involved.

2.2. THE STRATEGIC ISSUES IN THE PRESENT AND FUTURE SCENARIOS

The “external” point of view compared to the present and to future scenarios	The goal of this specific section of the study has been to analyse the “external” point of view of the selected subjects regarding the activity carried out by the Consortium on some strategic issues, both in relation to the present scenario and to prospective scenarios .
Functions of the CER	In this phase, the selection of the strategic issues was based on the paragraph “functions of the CER” which represents and describes the main activities carried out by the Consortium. The goal was to highlight the issues for which one recognises the primary role of the CER, considering both the current framework (the present), or rather the one for which the CER has hitherto been most recognisable, and the issues it is believed the CER must work harder on in the future. This type of assessment is also important in light of the evolution of the perceptions on issues related, for example, to climate change and ecosystem services, which are modifying or, at any rate, will require in the near future a radical change in the modes of management and intervention priorities.
The strategic areas of action analysed in the consultation	Specifically, the following areas of action have been identified as strategic (and therefore brought to the attention of the stakeholders): <ol style="list-style-type: none">1. <i>Irrigation supply for agriculture</i>2. <i>Water supply for multiple uses</i>3. <i>Technological investment and solutions for water saving</i>4. <i>Investment to recover water</i>5. <i>Investments in the distribution network</i>6. <i>Containing subsidence phenomena</i>7. <i>Improving the water and landscape habitats</i>8. <i>Improving water quality</i>9. <i>Generating ecosystem services</i>10. <i>Enhancing the dialogue with the Institutions and Communities to promote virtuous actions</i>11. <i>Research, culture and communication on the value of irrigation</i>12. <i>Research, culture and communication on climate change</i>
Scenarios: the present and the future	Comparing the present scenario with the future scenario provides in the first case – the present scenario – a vision of the commitment made hitherto by the CER in the territory, while in the second case – future scenario – it draws the attention to issues highlighted by the stakeholders on which the CER can address the programmatic lines for the near future.

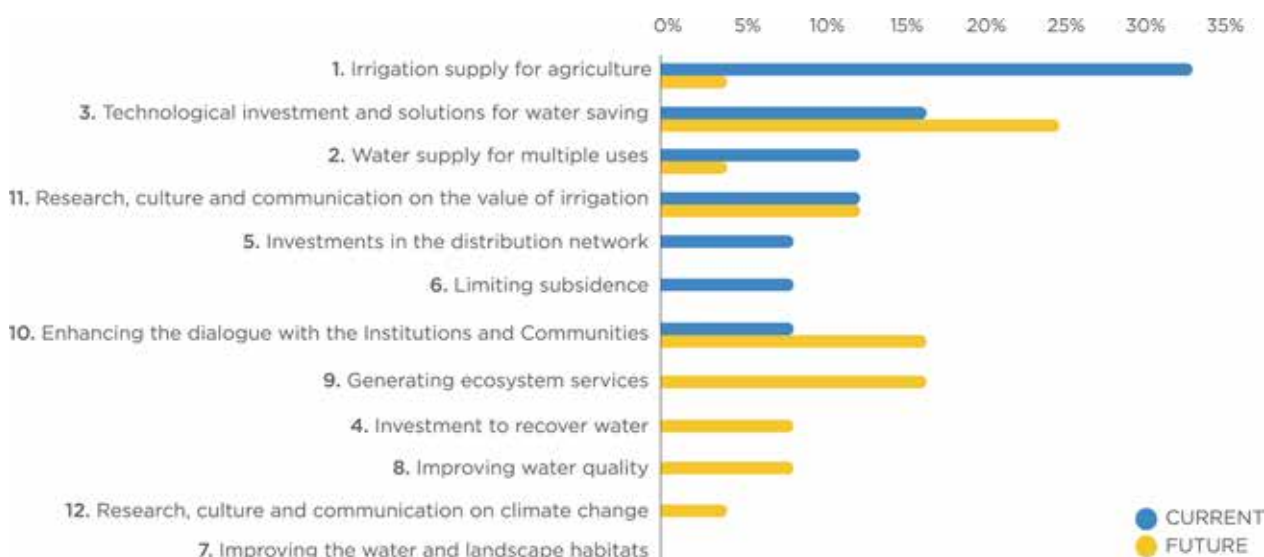
Irrigation supply for agriculture: the most recognisable sector for the CER

The results, shown graphically in figure 2.1, clearly show that, in the present scenario, the CER is mainly recognised for its role of provider of water across the territory: this emerges from the importance attributed by the stakeholders to item 1 “*Irrigation supply for agriculture*”, which is by far the issue on which all subjects agree as they acknowledge the importance of the function of water supply for the agricultural economy of Emilia-Romagna. This function is one of the major activities underlying the creation and very existence of the CER.

Water supply for multiple uses

Still regarding the present scenario, attention, albeit less, is drawn to item 2 “*Water supply for multiple uses*”, in that there is an acknowledgement of the role played by the Consortium on other fronts apart from providing water for irrigation uses (industrial, civil etc.). This comes as no surprise, given the closeness and knowledge of the stakeholders of these actions carried out by the CER across the territory.

Figure 2.1 – Current and future issues on which the Stakeholders assess the importance of the CER for the territory



Source: Nomisma

The vision for the future scenario

These issues, tied to the role of the CER as water supplier, significantly lose importance in the future scenario, not so much because of less attention from the stakeholders towards these aspects, but because they are considered in conjunction with the issue of climate change. This requires a more systematic approach and greater attention towards items 3 “*Technological investment and solutions for water saving*”, 4 “*Investment to recover water*” and 11 “*research, culture and communication on climate change*”.

In the near future climate change will require a shift in water management, as water will become increasingly scarce and, consequently, will become ever more valuable. In this respect the stakeholders are hoping for an increase in the investments in

research and technologies which will rationalise water use and make its uses more efficient, in a scenario in which this resource will become ever more important and central for our economic and social system.

“Dialogue with institutions and Communities” and alignment with the EU directives, the role of the CER to enhance in the future

The interviewed subjects, moreover, highlight the role of the CER in terms of *“Dialogue with Institutions and Communities to promote virtuous actions”* (10) and the advantage of a communicative and transparent governance in a view of collaboration and co-responsibility between bodies and institutions, in line with the European directives of the past two decades that require an ever greater effort to contain waste of water and effectively communicating the importance of the value of irrigation.

The recognised role of technological investment and solutions for water saving

Item 3 *“Technological investment and solutions for water saving”* recognises the role of the CER also in the present scenario regarding the investments for the creation of an interactive system for irrigation – IRRINET – which provides support and precise and personalised information to farms regarding the volumes of water to be used.

Guidelines for the promotion and communication of the ecosystem services provided

The issue of the *“Generation of ecosystem services”* (9), on the other hand, is attributed far less to the CER in relation to the present, highlighting more a sectorial vision of the benefits generated and tied mainly to agriculture, as is also apparent from the values included in the single environmental issues such as the *“Improvement of the water and landscape habitats”* (7) and the *“Containing subsidence phenomena”* (6). What is particularly surprising is the failure to recognise the commitment of the CER on this latter aspect related to the prevention of hydro-geological instability, on which the activity of the CER, on the other hand, has a major impact, as it prevents severe damage to civil society and to the economic system.

Ecosystem services are therefore one of the issues to which the stakeholders suggest paying greater attention in the future scenario, through the introduction of more suitable assessment systems featuring systemic approaches that are now indispensable and no longer tied to single issues, though important, such as the landscape, subsidence and habitats. Hence the great interest in highlighting the benefits that the CER’s works and activities bring to the territory, both environmentally and economically.

On this issue, moreover, one must note a perfect alignment with the priorities already set by the Water Management Plan of the hydrographic district, both regarding the current situation and regarding the future, which highlight the importance of an equal distribution of water and its interrelations with the environment and the economy.

Attention to climate change and adaptation actions (NBS)

The basic issues on which to work in the future represent the existing need on the territory, above all regarding the new climate phenomena to which we are gradually adapting. They automatically indicate the necessary inputs to enhance the resilience of the systems with the adaptation tools we are familiar with, such as the ecosystem services and the Nature-Based Solutions.

Consistency of the CER's priorities with the SDGs of the 2030 Agenda

The “roadmap” of inputs provided by the stakeholders represents the order of priorities coming from the SDGs of the 2030 Agenda, starting from governance all the way to operational actions aiming at capillary sustainability, on which year after year the structure of the CER aims to increase its commitment and improve its operation on the territory.

3. THE INFRASTRUCTURAL VALUE

Conditions for the value assessment

To give an economic value to the CER's infrastructure, one must introduce a methodological condition to meet.

From a strictly legal point of view, the CER's real estate property, as a legal subject, is limited to the building in Bologna where its headquarters are. The entire complex of works and plants is, on the other hand, registered at the Land Registry as State property, with all the characteristics this entails regarding legal status, alienability and the regime to which public property is subject. For the purposes of this study all of this has no practical importance, in that the assets studied have been built with state money, or at any rate public money, and with other sources of funding deriving from the CER's ability to put forward, manage and carry out interventions and activities.

State property and the "tangible" role of the CER

The great public works concerning water management and irrigation governance of the country are therefore cadastrally registered in the public domain of the state, but **in relation to the specific nature of the activities performed, they are fully managed by bodies of varying levels. In this respect the value is treated as if the infrastructure were the property of the Consortium.**

Results regarding assets managed effectively and new incremental values

This method provides us with **two useful facts.**

The first is that the CER oversees, on behalf of the public body in general, a set of works and infrastructure that provide a comprehensive service to the community (farmers, citizens, companies) and its management costs are partly sustained by it too through the contributions paid to the Reclamation Consortia under whose jurisdictions they fall.

The second is that the CER manages these works with a driver of skills that significantly increase its final result. For example, take the research, development and dissemination work that has nothing to do with strictly managing water and its regulation.

Below is a description and report of the value of the infrastructure managed by the Consortium for the Emilia Romagna Canal.

3.1. The functions and main infrastructural facilities of the CER

CER: the water motorway

From an infrastructural perspective, the Emilia Romagna Canal is often defined as a water motorway, that today can guarantee the water supply of one of the most productive areas in Italy, through a **path of about 135 km in total, with 7 pumping stations** that enable to deal with the unfavourable altitude.

Salvatonica di Bondeno (FE) the connection with the Po River

Powering the system is guaranteed through the **diversion on the hydraulic right of the Po River, in the village of Salvatonica di Bondeno (Ferrara)**, near the Cavo Napoleonico, an uncoated earthen canal, also called an attenuator of the Reno's floods and first vector of the Emilia Romagna Canal system.

Water supply of the Po River

The water supply of the Canal is **68 m³/s of the Po River** in the months going from May to September, and **25 m³/s** in the remaining months; it can also withdraw **1.5 m³/s from the Reno River** from April to September, and **2 m³/s** throughout the rest of the year.

"Volta Scirocco" barrier for the industrial establishments and the aqueduct of Ravenna

The Consortium, apart from supplying the main course through the diversion from the Po River, manages a mobile dam located in Volta Scirocco, which allows for the diversion from the Reno River to power the petrochemical area of Ravenna, various industrial plants, the irrigation utilities of the territories to the north of the city of Ravenna and the aqueduct of Ravenna.

Facilities managed by the CER

The CER Consortium manages or uses the entire facility, which includes:

- 5 lifting plants on the hydraulic right of the Reno: 135 km on the hydraulic right of the Reno River;
- 2 lifting plants on the hydraulic right of the Reno: 15 km on the hydraulic left of the Reno River;
- 6 diversions for multiple uses;
- companies and buildings.

Infrastructure related to water lifting

- Palantone Plant
- Sant'Agostino East Plant
- Sant'Agostino West Plant
- Cento Plant
- Crevenzosa Plant
- Pieve di Cento Plant
- Traghetto Plant

Companies and Buildings

- Headquarters of the Consortium for the Emilia Romagna Canal (directly owned)
- Marsili Farm
- Idice Farm

Infrastructure related to water transport

- Cavo Napoleonico
- Main course hydraulic left of the Reno River
- Main course hydraulic right of the Reno River
- Volta Scirocco mobile dam
- Branches for multiple use:
 - Selice-Santerno (Imola)
 - Senio-Lamone (Faenza)
 - Montone (East Forli)
 - Bevano Fiumi Uniti (Ravenna)
 - Ronco-Bevano (East Forli)
 - Bevano-Savio (West Cesena)

Below are more detailed descriptions of the infrastructural facilities listed above.

3.1.1. The CER, an upstream river: the infrastructure for lifting water

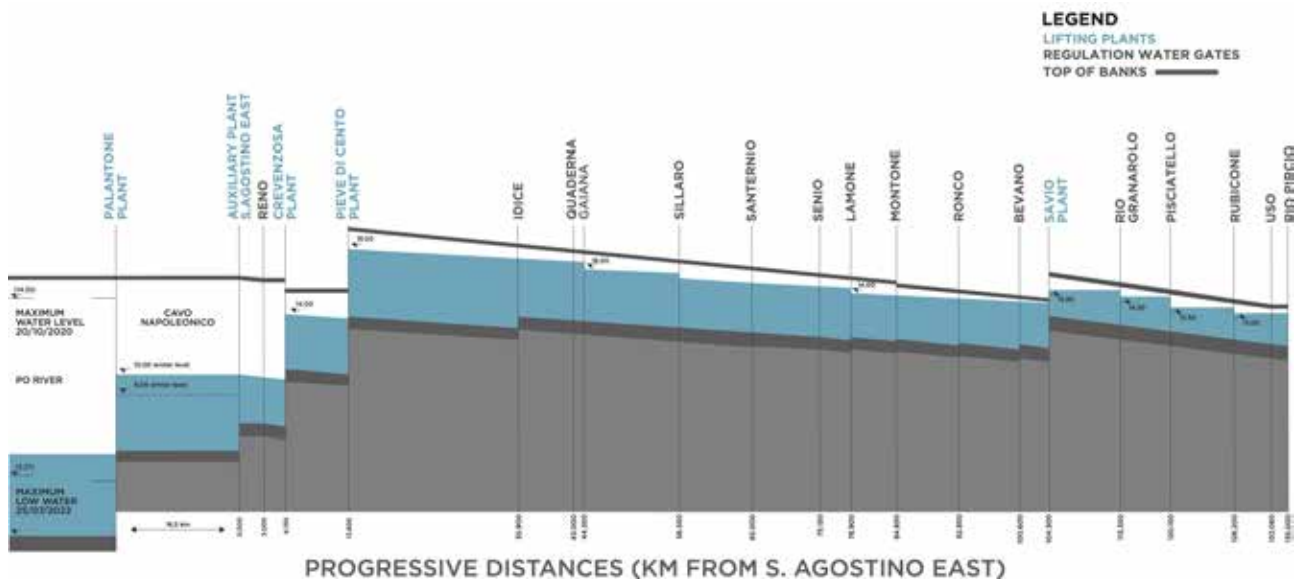
The lifting facilities

Water run-off within the Canal is provided by a series of pumping facilities placed along the course to overcome the unfavourable altitude, all thanks to a complex system that, based on the levels of the various sections of the canal, ensures the optimal supply of water to promote run-off.

Difference in level from 4 to 18 metres above sea level

The Emilia Romagna Canal, in fact, on average moves uphill (fig. 3.1): there is a shift from the level of free surface of the water of 4 m a.s.l. on the point of diversion from the Po River to 18 m a.s.l. Following the pumping of the Pieve di Cento plant, followed by very low slopes and decreasing volumes to a surface level of 14 m. a.s.l. And finally pumped by about 2 metres and end in the plains of the Rimini area.

Figure 3.1 – Longitudinal profile diagram of the Emilia Romagna Canal



The upstream “river”

The Emilia Romagna Canal can be deemed by all means an upstream river. The Po River, which brings water to the CER – along with its decisive asset of having water all year long – has the major inconvenience of being on the lowest point of the plain: in summer, its average level in the Bondeno section, where the system is born, is slightly above 4 metres a.s.l. To reach Romagna, **the water must go up 13–14 metres in altitude**. This obviously requires works for mechanical lifting (pumping), the costs of the plant and the electric energy to power it.

Diversion from the hydraulic right of the Po River

The main power supply of the Emilia Romagna Canal system is ensured through the **diversion from the hydraulic right of the Po River, in the village of Salvatonica of Bondeno (Ferrara)**, near the discharge work into the river attenuator of the floods of

the Reno River. This last work, created between 1951 and 1973 on the path of the former Napoleonic Cavo (project devised in the early 1800s with the ambitious goal of comprehensively restoring the confluence of the Reno River into the Po River), today has the two-fold function of spillway of the Reno's floods and first vector of the Emilia Romagna Canal system, thanks to its horizontal trend maintained by the bottom in the approximately 16-kilometre stretch between the Po River and the town of Sant'Agostino (Ferrara), near which the two intake pipelines of the CER system begin.

In particular, the entering the Attenuator by the water coming from the Po River takes place through the Palantone lifting plant.

PALANTONE PLANT

Main plant on the Po River.

Located in **San Biagio-Salvatonica** in the municipality of **Bondeno**, it is the **key plant** of the system that ensures the **water intake** from the Po River. It pumps water through **4 main electric pumps and 4 auxiliary ones** and feeds it into the Cavo Napoleonico.

Volume (m ³ /s)	Power (kW)	Prevalence (m)
68.00	5,490	6.00
Replacement Value (RV)		Current Value (CV)
22.209.200 €		13.325.300 €



The Sant'Agostino lifting plant

In Sant'Agostino, on the western bank of the attenuator, a lifting plant supplies water with a volume of about 7 m³/s.

It is 16.5 km long and first goes through the high plain of Ferrara from north to south; near Cento, a second plant lifts a volume of 4.5 m³/s for the Bologna territories on the hydraulic left of the Reno River.

Still in Sant'Agostino the main canal (CER) begins, dedicated – with a total length of 135 km, from the Cavo Napoleonico to the Adriatic Coast – to the water supply for the territories located on the hydraulic right of the Reno River.

EAST SANT'AGOSTINO PLANT

Plant on the hydraulic RIGHT of the Reno River

Auxiliary pumping plant whose pumps **only work when the water levels of the Cavo Napoleonico are lower than those of the CER** and starting point of the entire work.

Volume (m ³ /s)	Power (kW)	Prevalence (m)
7.50	378	2.50

Replacement Value (VN)	Current Value (VA)
2,200,200 €	1,647,700 €



WEST SANT'AGOSTINO PLANT

Plant on the hydraulic LEFT of the Reno River

It ensures the **prevalence for the outflow into the main course on the hydraulic left of the Reno River.**

Volume (m ³ /s)	Power (kW)	Prevalence (m)
8.00	486	3.00

Replacement Value (RV)	Current Value (CV)
2,417,300 €	1,286,900 €



The partition system of Crevenzosa. The partial diversion for the Riola and Botte canals of the Renana Reclamation and Irrigation Consortium

After underpassing the Reno River, the Canal continues from north to south until it arrives near the inhabited area of Galliera (Bologna) where, through the Crevenzosa partition and lifting plant, the volume is divided into two villages. One, up to a maximum of 13 m³/s flows out through the Riolo and Botte canals of the **Renana Reclamation and Irrigation Consortium** and enters the Reno, in the village of Bastia, through the new Beccara water gate; the remaining part (47 m³/s) continues on its path along the Emilia Romagna Canal.

CENTO PLANT

Plant on the hydraulic LEFT of the Reno River

It ensures the **prevalence for the outflow into the main course** on the hydraulic left of the Reno River.

Volume (m ³ /s)	Power (kW)	Prevalence (m)
4.00	244	4.00

Replacement Value (RV)	Current Value (CV)
1,121,400 €	664,600 €



CREVENZOSA PLANT

Plant on the hydraulic RIGHT of the Reno River

In **Coronella** in the municipality of Galliera (BO), at the **6th kilometre of the Emilia Romagna Canal**. It is the **second most important plant in terms of volume and prevalence**.

It ensures the **pumping of water up to 14 m a.s.l.** from which it then flows for 7.65 km until the next plant (Pieve di Cento).

Volume (m ³ /s)	Power (kW)	Prevalence (m)
50.00	3975	5.00

Replacement Value (RV)	Current Value (CV)
10,890,400 €	7,655,300 €



PIEVE DI CENTO PLANT

Plant on the hydraulic RIGHT of the Reno River

In **San Benedetto** in the municipality of **Castello d'Argile (BO)** the water is pumped up to a height of **18 m a.s.l.**

From here on the main course **flows for 90.5 km through gravity with decreasing volumes and levels** also thanks to an inner coating of the canal that **limits attrition and prevents the formation of vegetation**, up until the crossing of the Savio river (14 m a.s.l.), north of **Cesena**, where **the residual volume of 9m³/s is pumped once again** (Savio Plant).

Volume (m ³ /s)	Power (kW)	Prevalence (m)
50.00	3900	4.50

Replacement Value (RV)	Current Value (CV)
8,141,800 €	4,446,900 €



SAVIO PLANT

Plant on the hydraulic RIGHT of the Reno River

In Mensa in the Municipality of Ravenna the water is lifted from 14 to 15.9 m a.s.l. and flows into the final part of the canal for 30.7 km towards the Rimini territory up until km no. 135 where it connects with the Rio Pircio River and ends its course.

Volume (m ³ /s)	Power (kW)	Prevalence (m)
9.00	385	1.90

Replacement Value (RV)	Current Value (CV)
1,862,600 €	1,170,400 €



3.1.2. The infrastructure for water transport

The infrastructure for water transport

The water entered the Riolo and Botte canals and, subsequently, into the Reno serve, with the drawing of water from the same canals and the river, the lowest terrains of the Renana, Western Romagna and Central Romagna Reclamation and Irrigation Consortia. The diversion of the Reno River is made possible by a mobile dam, built long ago on the River in Volta Scirocco of Mandriole near S. Alberto (Ravenna), about 9 km away from the outlet, which allows for the retention and diversion through gravity of the water carried and the natural affluences, to avoid salt intrusions and therefore to carry out withdrawals under suitable conditions. Immediately upstream of the barrier are the diversion works that feed the urban and industrial aqueducts of Ravenna and the petrochemical plant of the Enichem company (formerly anic). The main volume, 47 m³/s, continuing its course along the CER, is lifted for the first time at 14.7 m a.s.l. through the Crevenzosa plant and, after 8 km, by a second plant to the east of Pieve di Cento, which further increases the altitude to 18.8 m a.s.l.

CANAL ON THE RIGHT OF THE RENO RIVER

The work begins from the Cavo Napoleonico in Sant'Agostino (FE) and stretches for 135 km along the eastern part of Emilia-Romagna until the intersection with the Rio Pircio River in the village of San Vito di Rimini (RN). Along the course there are also the works that enable the maintenance of the optimal water levels for outflow such as: Palantone, East Sant'Agostino, Crevenzosa, Pieve di Cento and Savio.

Maximum volume (m ³ /s)	Length (km)
60.90	135.00
Replacement Value (RV)	Current Value (CV)
607,535,500 €	356,357,000 €



CANAL ON THE LEFT OF THE RENO RIVER

With the intake work on the Cavo Napoleonico, this canal conveys water towards the Emilia territories going through the Land Reclamation areas of the Ferrara Plain and the Burana Land Reclamation. Along the course, the regular outflow of the water is also ensured by the two lifting plants of West Sant'Agostino and Cento.

Maximum volume (m ³ /s)	Length (km)
6.60	15.00
Replacement Value (RV)	Current Value (CV)
70,783,600 €	41,341,200 €



ACQUA CAMPUS NATURA - Volta Scirocco mobile dam

Located in Sant'Alberto di Ravenna, it is a mobile dam that enables the withdrawal of water from the Reno River and its conveyance through a channel for industrial uses (ANIC). Its importance is also tied to the creation of the Acqua Campus Natura in the Oasis of Volta Scirocco in which the estimated infrastructure is inserted.

Maximum volume (m ³ /s)	Length (km)
2.00	15.00
Replacement Value (RV)	Current Value (CV)
26,085,600 €	14,601,100 €



SPECIAL WORKS RIGHT-LEFT (Bridges, tanks, water gates etc.)

These are parts **connected to the canal** that enable the **optimal functioning** of the courses on the **right and left of the Reno River**, and **facilitate their maintenance**. These works may be water gates, trashracks, bridges, underpasses, tanks, diversions, water ditches and **anything that can be useful** for the functioning of the canal.

Maximum Volume (m³/s)	Length (km)
2.00	15.00
Replacement Value (RV)	Current Value (CV)
114,609,800 € (Right Reno)	68,586,000 € (Right Reno)
119,792,300 € (Left Reno)	71,682,300 € (Left Reno)



REMOTE CONTROL SYSTEM

This is an **important system** for the **automatic management** of the **functioning of the hydraulic parts**. The system can **centralise the information** on the **water levels** and one can know remotely what the hydraulic situation is and **plan the priority measures**.

Replacement Value (RV)	Current Value (CV)
516.000 €	165.700 €



3.1.3 The companies and buildings

CER HEADQUARTERS

Building made up of **three storeys**, about **300 sqm each**.

This is the headquarters of the **Second-Degree Irrigation Consortium** for the Emilia Romagna Canal, the body tasked with studying, implementing and using the irrigation works in the CER's irrigation district.

Surface (m²)	Work belonging to the CER
1,200.00	Via E. Masi, 8. Bologna (BO)

Replacement Value (RV)	Current Value (CV)
2,784,300 €	1,651,100 €



ACQUA CAMPUS - Research Area

Within the agricultural company activities related to irrigation experimentation are carried out (site of the ACQUA CAMPUS demonstration area).

The activity is **mainly focused on studying the most effective strategies and technologies for water saving in agriculture, to improve the quality of the yields and test innovative irrigation techniques.**

Surface (m²)	Property Rented (Ha)
12,500	Via Ronchi, 4, Mezzolara di Budrio (BO)

Replacement Value (RV)	Valore Attuale (VA)
1,239,614.00 €	680,490.00 €



ACQUA CAMPUS - Display Area

Along the Emilia Romagna Canal and near the Idice River is a demonstration area dedicated to "display water", a permanent exhibition of all the irrigation devices and instruments. This area features filters, drip and sprinkling irrigation systems, and the best irrigation machinery. One can also see the latest irrigation technologies and services, the phytodepuration techniques and the miniature models showing how the canal is managed.

Via Ronchi, Mezzolara di Budrio (BO)	Surface (sqm)
	15,072

Replacement Value (RV)	Current Value (CV)
61,600 €	31,600 €



There are also some secondary facilities for the ordinary function of the Consortium. In particular, there is the Guard House and adjoining building used as CER storage, located where the Emilia Romagna Canal underpasses the Reno after diverting water from the spillway of the Reno River's floods. These facilities cover a total surface of 150 m² with a Current Value of 167,100 € and a Replacement Value of 257,500 €. Finally, there is also the Traghetto Plant, which in the past was used as a lifting plant on the Po morto di Primaro. This facility is in Via Zenzalino SP7 km9 – Traghetto di Argenta (FE) with a Current Value of 175,400 € and a Replacement Value of 584,200 €. In the infrastructural works described, apart from the value monetised by the infrastructure, there are also the important roles, though not estimated, played by the various Acqua Campus seats described in the reports and related to experimentation, enhancement and other activities.

3.1.4 The modernisation interventions and the great maintenance activities

The CER is an infrastructure undergoing constant modernisation and maintenance

The CER is a sort of constant building site where the planning activities of new works, the daily management of the existing works and constant maintenance intertwine without interruption. In other terms, the CER is a body that has internalised both its operational and development function.

Table 3.1 includes the list of projects subject to funding up to the end of 2021: these include the works for which funding by the Italian Ministry of the Economy and

Finance was requested, worth 41.5 million €, and the works for which the type of state funding still needs to be identified, worth 26.6 million €, for a total of 68.1 million €. The investments and size of the works highlight a remarkable activity and efficiency, which is absolutely necessary in such an important context. The works under construction are located in various areas of the territory served and area aimed at increasing the efficiency of the services already present or to provide new ones.

As was already explained, these projects aim to obtain nearly total funding from the Italian State, but based on the idea, project and direct management of the CER, which therefore acts as a careful and skilful manager of public resources.

Table 3.1 – List of projects funded by the Italian Ministry of the Economy and Finance and eligible for funding (up to 12th December 2022)

No.	Project Title	Amount of state funding (millions €)	Total amount of the economic framework (millions €)	Progress as of 18/12/2020	Discount available in millions of Euros	Notes
1	"Palantone" lifting plant from Po: completion of the electro-hydraulic design equipment	18,500	18,500	Funded, in the execution phase	2,864	Funded with decree no. 3525676 on 27 th May 2019; contract stipulated on 26 th November 2020 and works' delivery on 16 th December 2020.
2	Stabilisation works and works to restore the efficiency of the first 3,310 Km) – Crevenzosa (pr. 6,050 Km)	7,530	7,530	Funded, in the execution phase	1,523	Funded with decree no. 3611934 on 29 th September 2019; contract stipulated on 20 th August 2020 and works' delivery on 8 th June 2021; it is a section of the project that was initially put forward, taken to insert it in project no. 3 (which meanwhile was funded and in the execution phase).
3	Redevelopment of the diversion works from the Emilia Romagna Canal in the Savena Sillaro section in the province of Bologna, with the realisation of a remote monitoring system	2,500	2,500	Funded, in the execution phase	0,414	Funded with decree no. DT 63545 on 5 th August 2020; contract stipulated on 26 th March 2021 and works' delivery on 4 th May 2021.
4	Functional completion of the shaft of the Emilia Romagna Canal: 2 nd extract of the construction of the main canal from the Rio Pirccio valley to the Fontanaccia final tank	6,478	7,200	Waiting for funding from the Italian Ministry of the Economy and Finance		Funding from the Italian Ministry of the Economy and Finance requested on 20 th July 2021. The executive planning shows an economic framework totalling 7,200,000 Euros, but because of the inclusion of project no. 3 (funded and in progress) reduced state funding was requested, equal to 6,478,000 € (with financial assistance for the missing amount of 722,000 €, taken from the Consortium's budget, subject to recovery from any auction rebates or other savings resulting upon completion of interventions).
5	Distribution for multiple uses of the CER's waters in the Senio Lamone area 2 nd lot 2 nd section 2 nd subsection	3,304	3,557	Waiting for funding from the Italian Ministry of the Economy and Finance		Funding from the Italian Ministry of the Economy and Finance requested on 17 th June 2021. A request was made for reduced funding equal to 3,303,975,86 € with financial assistance, to cover the remaining amount, under the consortium budget of the associated Consortium of Western Romagna, equal to 91,258.14 € paid by privates equal to 161,766 €, subject to recovery from any auction rebates or other savings resulting upon completion of interventions.
6	Distribution for multiple uses of the CER's water in the Bevano Savio area districts of S. Martino Cannuzzo	2,080	2,250	CBR executive project in progress		A request will be made for reduced funding equal to 2,080,000.00 € with financial assistance, to cover the remaining amount, under the consortium budget of the associated Consortium of Romagna, equal to 90,000 € and paid by privates equal to 80,000 €, subject to recovery from any auction rebates or other savings resulting upon completion of the interventions.
Italian Ministry of the Economy and Finance Total		40,392	41,537			
7	Stabilisation works and works to restore the efficiency in the Attenuator part (pr. 0,098 Km) – Reno (pr. 2,715 Km) of the Emilia Romagna Canal	7,980	7,980			The project has been momentarily inserted in the Dania database related to the Mipaaf, in pursuit of state funding under the Irrigation Investments National Fund Law 18/2020 – Budget Law 2021 (decree 30 th June 2021 no. 299915), but considering the timing of execution in the schedule, there is a shift towards the new planning of the 2020-2029 National Water Sector Interventions Plan: reservoirs section being issued.
8	Redevelopment and remote monitoring of the diversion works of the Emilia Romagna Canal along the main course	3,990	3,990			The project has been inserted in the Dania database related to the Mipaaf, in pursuit of state funding under the Irrigation Investments National Fund Law 178/2020 – Budget Law 2021 (decree 30 th June 2021 no. 299915), the deadlines for the submission and examination of the projects for this fund have recently been delayed.
9	Redevelopment of the course serving the territories on the hydraulic left of the Reno River	14,650	14,650			Executive project in the process of being assigned.
Total fundable projects relevant to the CER		26,620	26,620			
Total funded and fundable projects relevant to the CER			68,157			Source: CER Consortium

The amount of the maintenance work is about 400,000 Euros per year, and contributes to maintaining the Replacement Value / Current Value ratio high

The same maintenance work is an important element of the CER's activity, and proof of the system's good health, and every year it requires major spending both for ordinary activities (ranging from managing banks and floodplains, to reparations inside the lifting plants) as well as for more serious interventions.

The amount of the maintenance work is about 400,000 Euros per year, and contributes to maintaining the Replacement Value / Current Value ratio high. The commitment of the CER in terms of management and maintenance is what enables a series of such complex works and delicate infrastructure to always be perfectly functional.

In the great public works there are maintenance activities that cannot be delayed that, if not performed with care and regularly, do not only undermine the daily efficiency of the good and, consequently, of the service provided, but lead to permanent damage over time.

For example, it would be impossible to replace the provision of 400,000 Euros for maintenance activities with an aggregate contribution deferred over time, which in this specific case can be quantified as 2 million Euros every 5 years, given that it would not yield the same results and would be ineffective. Therefore, the management activity requires taking care of these assets in a constant and well-planned manner.

3.1.5 The multiple uses

Multiple uses: projects and funding

The CER Consortium has long been interested in enhancing its catchment area towards extra-agricultural uses, also in favour of non-associated subjects, to optimise management and improve the territory's water availability.

To this end, the CER has obtained the approval and funding of many important projects of water transport for multiple uses, featuring the prevalence of irrigation use. From a technical point of view, the interventions performed can be in short transversal branches, pronounced in the two directions, north and south, from the main course of the CER, creating a sort of "herringbone" across the territory". The transport lines bring water to the minute transport networks, specialised in agricultural and civil-industrial distribution. All of this in the form of piped lines completely underground and therefore with minimum environmental impact.

The CER is also majority shareholder within the company PLURIMA S.p.A., established with Romagna Acqua Società delle Fonti S.p.A. with the aim of funding multiple-use works.

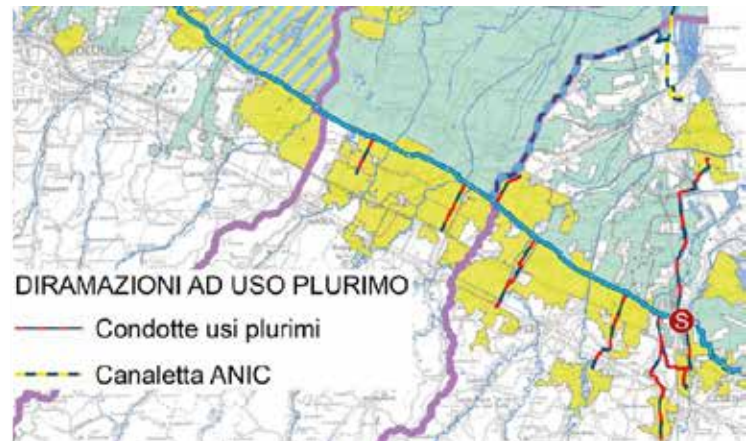
MULTIPLE USES

"Herringbone" diversions that bring water to transport networks for both agricultural and extra-agricultural uses.

They are present in the following sections:

- Selice-Santerno (Imola)
- Senio-Lamone (Faenza)
- Montone (East Forlì)
- Bevano Fiumi Uniti (Ravenna)
- Ronco-Bevano (East Forlì)
- Bevano-Savio (West Cesena)

Replacement Value (RV)	Current Value (CV)
113.448.800 €	89.178.400 €



3.2 THE OVERALL VALUES

The assessments

In the sheets shown previously there were descriptions of the infrastructure and works managed by the Second-Degree Reclamation Consortium for the Emilia Romagna Canal which, as stated at the beginning, does not own these works, as they belong to the State.

The assessment covered in this chapter, however, aims to highlight the economic value of this infrastructure, to reach a sort of estimate of the "asset" value of the infrastructure managed by the Consortium. The approach selected, in fact, is based on counter-factual logic, meaning that the aim is to understand what would happen if there were no CER performing the function of supplying water to its territory of competence, and consequently what would be the economic damage for the economy and civil society. These assessments are useful if put in relation with the economic value of the CER's physical infrastructure, meaning the building cost of the plants and facilities, so as to reach a quantification of the investment necessary to build a work as large as the Emilia Romagna Canal, capable of guaranteeing the positive externalities highlighted in this study. It is a sort of cost-benefit analysis: through counter-factual logic, so in the hypothetical absence of the CER, one estimates the economic commitment to be made to build all the infrastructure headed by the CER, to take stock and compare the economic value of the benefits that the CER infrastructure guarantees to the territory in which it supplies water.

Table 3.2– Asset value of the infrastructure managed by the Second-Degree Reclamation Consortium for the Emilia Romagna Canal

	Replacement Value (R.V.)	Current Value (C.V.)
INFRASTRUCTURE FOR WATER LIFTING		
PALANTONE PLANT	22,209,200 €	13,325,300 €
SANT'AGOSTINO EAST PLANT	2,200,200 €	1,647,700 €
SANT'AGOSTINO WEST PLANT	2,417,300 €	1,286,900 €
CENTO PLANT	1,121,400 €	664,600 €
CREVENZOSA PLANT	10,890,400 €	7,655,300 €
PIEVE DI CENTO PLANT	8,141,800 €	4,446,900 €
SAVIO PLANT	1,862,600 €	1,170,400 €
THE INFRASTRUCTURE FOR WATER TRANSPORT		
CANAL ON THE HYDRAULIC RIGHT OF THE RENO	607,535,500 €	356,357,000 €
CANAL ON THE HYDRAULIC LEFT OF THE RENO	70,783,600 €	41,341,200 €
VOLTA SCIROCCO MOBILE DAM	26,085,600 €	14,601,100 €
SPECIAL WORKS ON THE HYDRAULIC RIGHT OF THE RENO	114,609,800 €	68,586,000 €
SPECIAL WORKS ON THE HYDRAULIC LEFT OF THE RENO	119,792,300 €	71,682,300 €
REMOTE MONITORING	516,000 €	165,700 €
COMPANIES AND BUILDINGS		
CER HEADQUARTERS	2,784,300 €	1,651,100 €
MULTIPLE USES		
	113,448,800 €	89,178,400 €
TOTAL	1,104,398,800 €	673,759,900 €

Source: Nomisma with Praxi data

The estimate of the asset value

The sheets presented in this chapter include the economic values of the single plants, reprocessing the assessments made for insurance purposes by the consultancy company Praxy S.p.A. on behalf of the Second-Degree Reclamation Consortium for the Emilia Romagna Canal. In fact, these assessments provide not only an estimate of the Current Value, meaning the economic value of the work considering the degree of wear and tear, but above all of the Replacement Value, or reconstruction value, i.e. the cost of the work if the decision was made to rebuild it. This latter type of value is the most interesting for the purposes of this analysis, because of the counterfactual logic we have chosen to adopt.

The Replacement Value, however, is an underestimation of the real reconstruction value, given that it does not take into account the planning costs sustained to build the work, nor does it take into account the costs of the land expropriated to install the plants that make up the entire infrastructure of the Emilia Romagna Canal. A

rough estimate of these costs indicates that the Replacement Value would be higher by at least 15-20% than the value obtained, thus highlighting the great economic commitment required for the creation of the CER.

Based on the analysis of the summary values indicated in table 4.2, one can note that the infrastructure to transport water makes up the greatest economic value, with 552 million Euros in the present assessment, and 938 million in the replacement assessment. By analogy, one should add to this category the infrastructure serving multiple uses (civil, industrial etc.), which is worth 89 million Euros in the present state, 113 million in the event of reconstruction.

The value of the water lifting infrastructure is lower, namely 27 million Euros of Current Value, which doubles in the case of Replacement Value (54 million Euros).

The residual share includes the companies and buildings necessary for the CER's administrative and research activities, which in total are worth 2.5 million Euros in their current state, 4.3 million Euros in the case of reconstruction.

In total, the asset value of the CER's infrastructure is equal to 674 million Euros in terms of Current Value. If the CER did not exist and one wished to build it, the cost would be equal to 1.1 billion Euros. This is therefore the value of the infrastructure that guarantees the water distribution on the territory of Romagna with all the benefits it entails, both in economic terms which mainly benefit the agricultural sector, and in environmental terms thanks to the ecosystem services provided, and which will be examined in detail in the rest of the document.

4 THE AGRICULTURAL VALUE

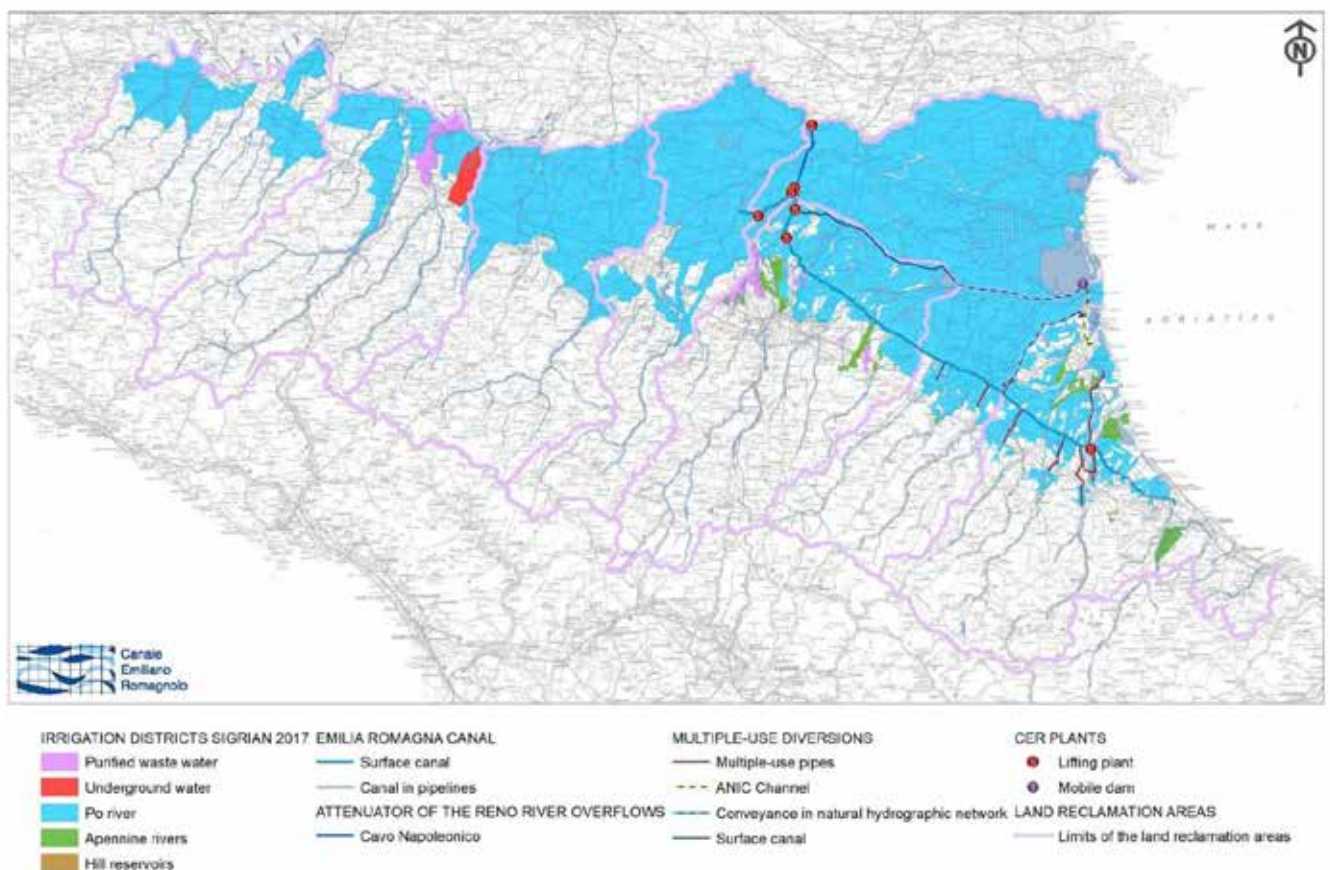
4.1 THE ROLE OF WATER ON THE TERRITORY

4.1.1 The characteristics of the water system and the water districts of the Emilia Romagna Canal

The Po River as the main source of irrigation of the area served by the CER

The main surface water available in Emilia-Romagna comes from the Po River and its tributaries on the right of the river. The largest Italian river, supplied by a catchment area of about 70,000 km² in closure section in Pontelagoscuro (FE), is the main source of irrigation for agriculture of Emilia-Romagna, followed, by order of importance, the resources withdrawn from other Apennine watercourses that are not tributaries of the Po River, the reuse of purified waste water, water lifted from underground and the hillside storage reservoirs.

Figure 4.1 - Chorography of the irrigated districts in Emilia-Romagna based on the source of supply



Source: study by the CER Consortium based on SIGRIAN data, 2017

The surfaces of the irrigated districts divided based on the sources

The following are the surfaces of the irrigated districts divided based on the source of supply (tab. 4.1). These assessments refer to the year 2017, whose irrigation season was deemed significant because of the contribution made by the water system of the Emilia Romagna Canal to support the region during a period of prolonged drought, with the absence of major rainfall from October 2016 to September 2017 and high temperatures recorded starting from the month of June (Source: Arpae - Hydro-Weather-Climate Report Emilia-Romagna 2017).

Table 4.1 – Surfaces (in hectares) of the irrigated districts managed by the Land Reclamation Consortia of Emilia-Romagna divided based on the source of supply

Source of supply	Territorial surface ⁽¹⁾	Equipped surface ⁽²⁾	Irrigated surface ⁽³⁾
Po river and tributaries on the hydraulic right	761,442	615,047	237,203
Apennine rivers with final discharge in the Adriatic Sea	13,305	9,511	1,409
Purified waste water	12,413	8,309	515
Groundwater	5,730	3,575	364
Other (water in the bottom of the canals as it is not used by farmers)	240	159	86
TOTAL	793,130	636,601	239,577

⁽¹⁾ Territorial surface: dominated geographical surface, indicated by the relevant Irrigation Body

⁽²⁾ Equipped surface: part of the dominated area on which there are public works used for irrigation activities.

⁽³⁾ Irrigated surface: part of the equipped area on which irrigation activities were carried out in the year of reference (2017).

Source: study by the CER Consortium based on SIGRIAN data, 2017

The CER for irrigation needs and production development of 5 land reclamation areas

In this context, the Emilia Romagna Canal transports water from the province of Ferrara to the province of Rimini, thus playing a pivotal role for the agricultural development of the territory it goes through and of the economic fabric in a broader sense.

Regarding the agricultural industry, the CER supports the irrigation requirements of five associated land reclamation areas. Below are the surfaces of the irrigated districts supplied by the water system of the Emilia Romagna Canal (tab. 4.2).

Table 4.2 - Surfaces in hectares of the irrigated districts covered by the CER's water system

Land reclamation area	Territorial surface	Equipped surface	Irrigated surface	Irrigated/equipped incidence
Burana Reclamation and Irrigation Consortium	20,031	19,028	1,057	5.55%
Renana Reclamation and Irrigation Consortium	78,782	69,202	17,141	24.77%
Pianura di Ferrara Reclamation and Irrigation Consortium	27,071	23,101	9,248	40.03%
Western Romagna Reclamation and Irrigation Consortium	68,856	32,681	16,723	51.17%
Romagna Reclamation and Irrigation Consortium	53,550	30,394	14,488	47.67%
TOTAL	248,290	174,406	58,657	33.63%

Source: study by the CER Consortium based on SIGRIAN data, 2017

Irrigated surface as an expression of water requirement tied to the presence of irrigated crops

The incidence percentage of the irrigated surface compared to the equipped surface indicates the water requirement of the irrigated crops grown. The high incidence value witnessed in the districts of Romagna and Ferrara supplied with water by the water system of the Emilia Romagna Canal are proof of the strong presence of hydro-demanding crops such as orchards and open field horticultural crops.

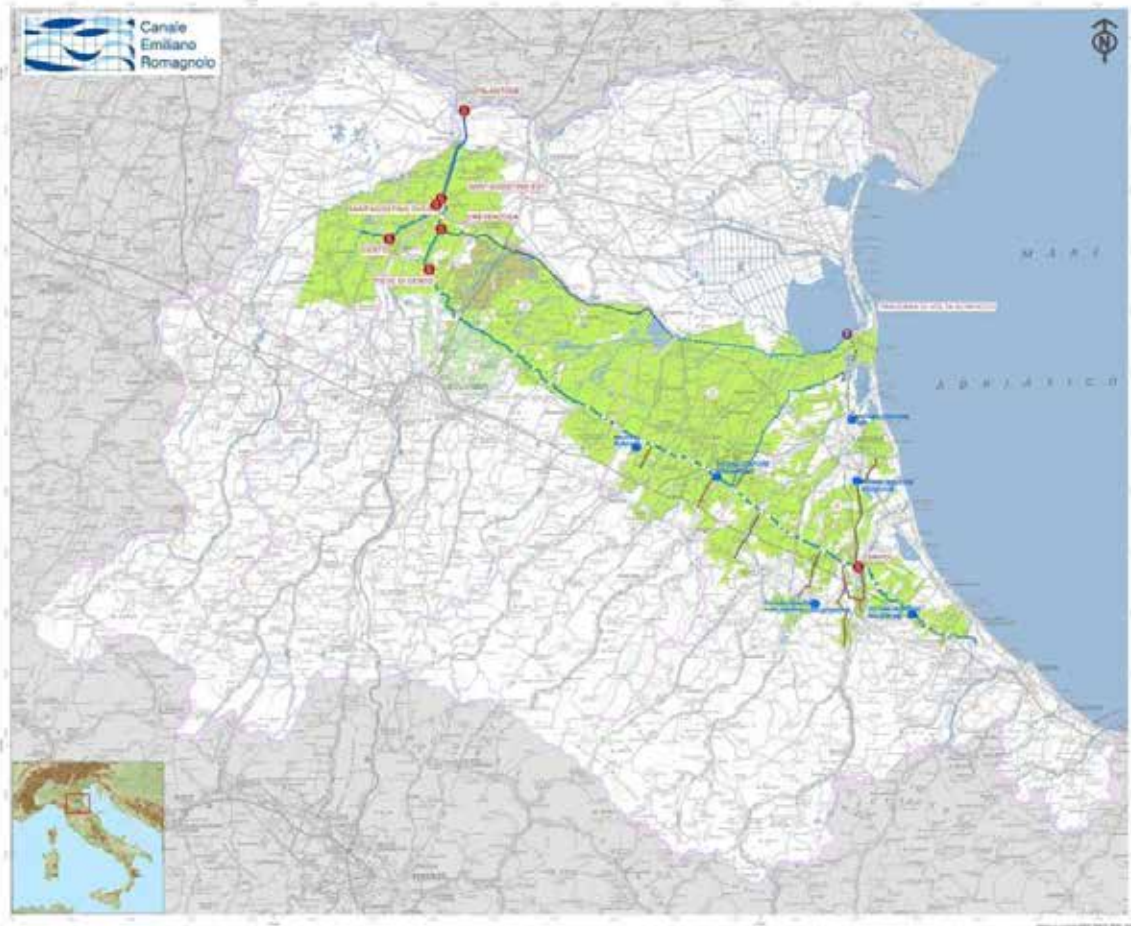
Equipped surface for extensive crops

Vice versa, a low incidence or the ratio between irrigated and equipped surfaces is the result of the prevalent presence of extensive crops and resorting to “rescue irrigation”, by taking water directly from the land reclamation consortia’s canals, whose amount of water has increased during the irrigation season (canals for mixed use, discharge and irrigation).

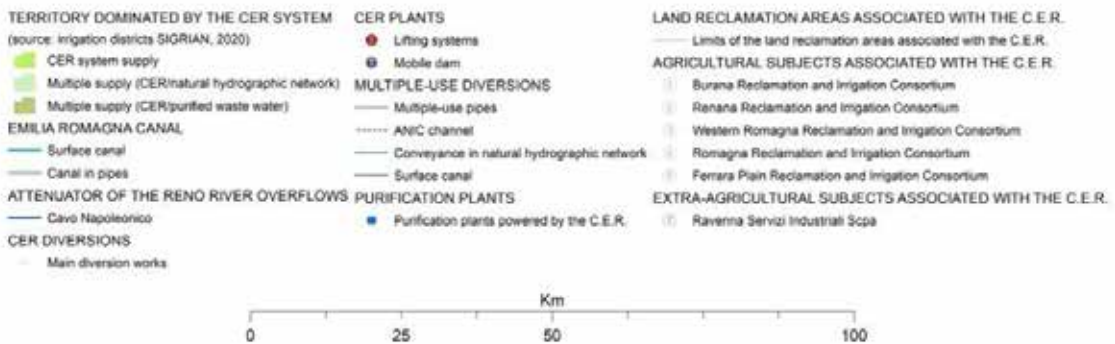
Irrigation system and investments for a high-quality water system

Then, by assessing in detail the modes of distribution in the irrigated districts of Emilia-Romagna, one can clearly note that the availability of quality water secured by the CER has over time favoured the investments to build consortia infrastructure for water pressure distribution, such as rural and multiple-use aqueducts, which are more efficient than land reclamation canals, in that they substantially do not have losses during transport, and can also guarantee the quality of the resource by preventing potential external contaminations.

Figure 4.2 - Chorography of the area and water system of the Emilia Romagna Canal



AREA AND WATER SYSTEM OF THE EMILIA ROMAGNA CANAL



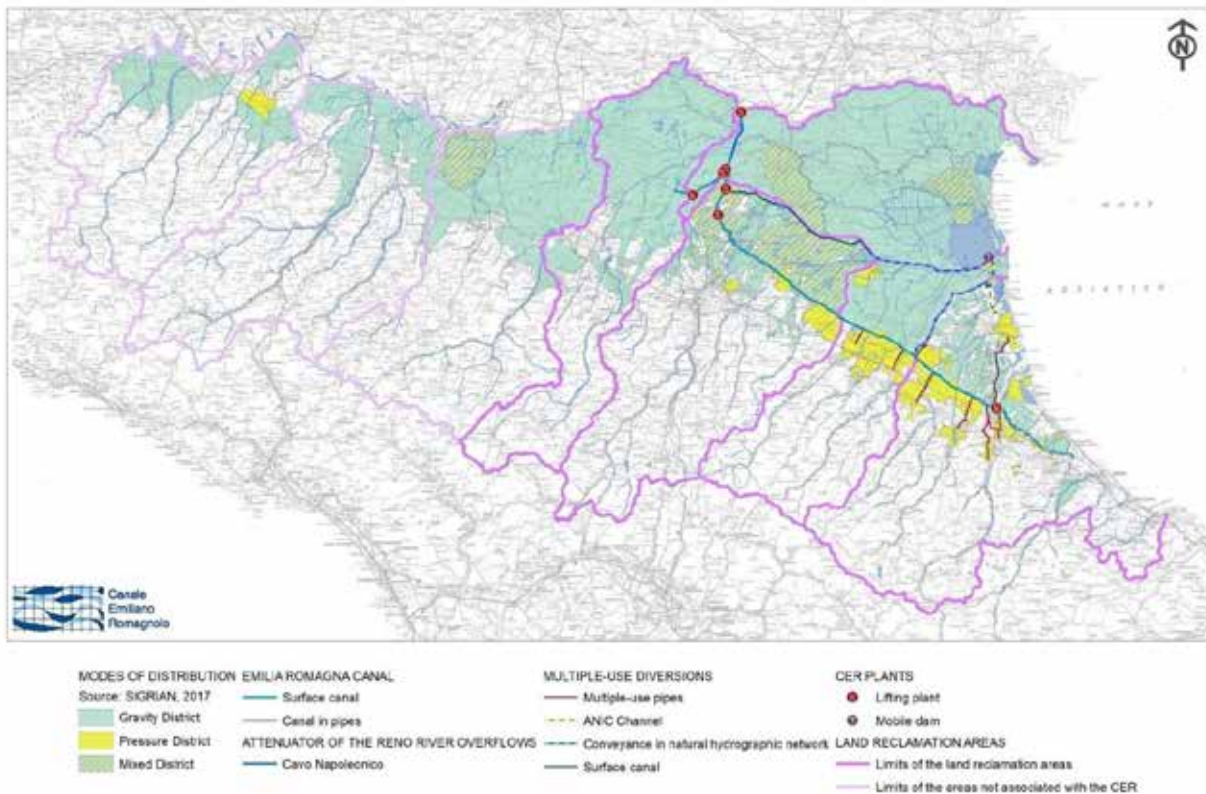
Source: study by the CER Consortium based on SIGRIAN data, 2020

Figure 4.3 - Chorography in hectares of the irrigated districts in Emilia-Romagna based on the modes of distribution

CER Associate	Land Reclamation Consortium	Irrigation system	Equipped surface
Consortia not associated with the CER	Piacenza Reclamation and Irrigation Consortium	Gravity district	43,238
	Piacenza Reclamation and Irrigation Consortium	Pressure district	3,500
	Parmense Reclamation and Irrigation Consortium	Gravity district	30,058
	Emilia Centrale Reclamation and Irrigation Consortium	Gravity district	82,773
	Emilia Centrale Reclamation and Irrigation Consortium	Mixed district	15,371
Consortia associated with the CER	Burana Reclamation and Irrigation Consortium	Gravity district	113,062
	Renana Reclamation and Irrigation Consortium	Gravity district	22,721
	Renana Reclamation and Irrigation Consortium	Mixed district	49,533
	Renana Reclamation and Irrigation Consortium	Pressure district	7,578
	Ferrara Plain Reclamation and Irrigation Consortium	Gravity district	173,425
	Ferrara Plain Reclamation and Irrigation Consortium	Mixed district	28,123
	Western Romagna Reclamation and Irrigation Consortium	Gravity district	18,586
	Western Romagna Reclamation and Irrigation Consortium	Pressure district	14,190
	Romagna Reclamation and Irrigation Consortium	Gravity district	15,193
	Romagna Reclamation and Irrigation Consortium	Pressure district	19,250

Source: study by the CER Consortium based on SIGRIAN data, 2017

Figure 4.3 - Chorography of the irrigated districts in Emilia-Romagna based on the modes of distribution



Source: study by the CER Consortium based on SIGRIAN data 2017

4.1.2 The prevalent types of irrigation crops and the related agro-industrial supply chains

The availability of water has positively influenced the crop diversity and production and environmental characteristics of the industry

Agriculture, together with the land reclamation of swampy areas, is undoubtedly the human practice that has contributed the most to modifying and shaping the structure and landscape of the plain of Emilia-Romagna. In particular, the availability of water and its irrigation use has played a pivotal role in differentiating the territory based on the varieties added to it, thus influencing the production and environmental characteristics of the territory. The water system of the Emilia Romagna Canal and the related infrastructure have thus outlined the current regional agricultural structures, thus providing a major enhancement to those most suited to fresh and industrial horticulture, viticulture, grains and industrial crops.

The picture of the agricultural use of soil

The starting point to analyse the agricultural activities and the related agro-industrial supply chains must be based on the spatial distribution of the agricultural crops grown in the area supplied with water by the water system of the Emilia Romagna Canal. The most detailed and suited source of information for this is the “Agricultural use of soil” database, drawn up every year by the Second-Degree Reclamation Consortium for the Emilia Romagna Canal in collaboration with Arpae and the Agriculture Department of the Emilia-Romagna Region.

Assessment instruments: from the AGREA crop plans to water requirements (IrriManager software)

This is a geographical information base that indicates the AGREA³ crop plans and the requirements of the irrigation crops based on the water budget model used by the IrriManager software, prepared by the CER based on real pedological and weather-related information. The AGREA crop plans are overseen and integrated also through the photointerpretation of satellite images (iColt Project, Hydro-Weather-Climate Arpae), so as to guarantee the coverage with cadastral map lot details for the entire regional UAA.

Georeferenced analyses of the crops for detailed assessments of the CER area

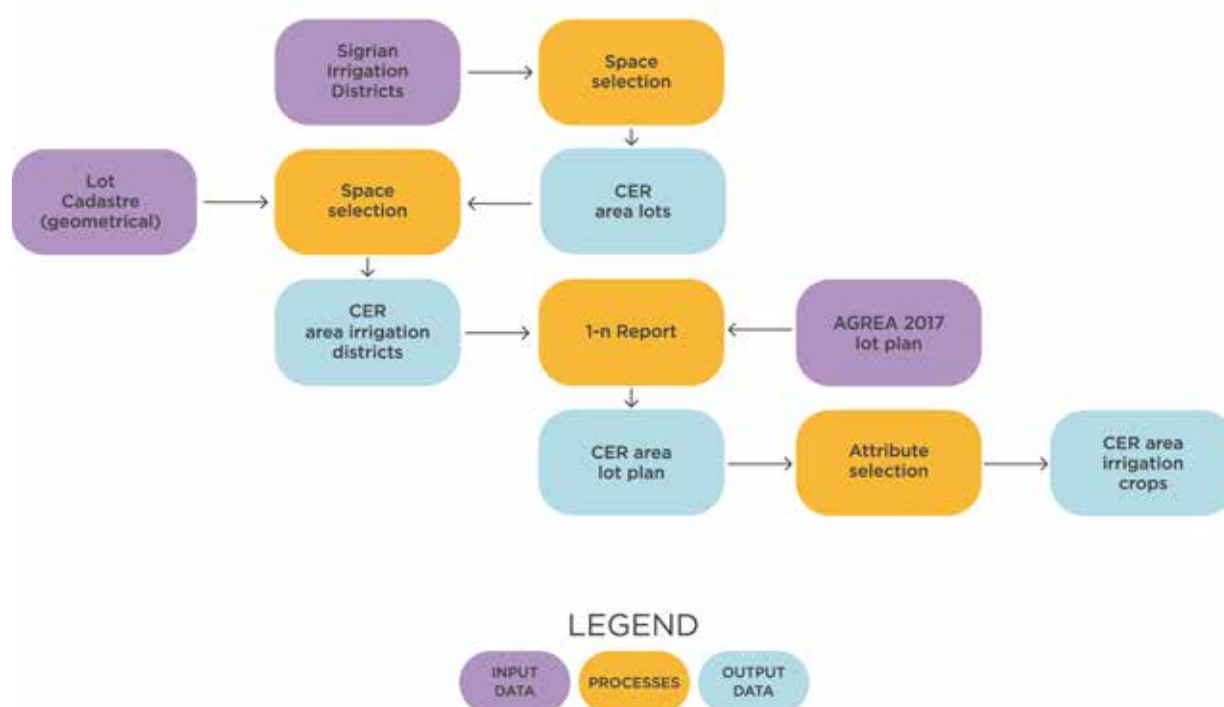
Through a geostatistical analysis carried out in a G.I.S.⁴ environment, the information coverage of agricultural use of the soil helped identify the only surfaces planted with crops located within the area supplied with water by the water system of the Emilia Romagna Canal, thus assessing its incidence and importance.

The following is the conceptual framework of the processes used.

³ AGREA, the Regional Agency for the Provisions in Agriculture, is the Regional Paying Agency that provides aid, premiums and contributions to the set of professionals in the field of agriculture that are envisaged by the EU, national and regional provisions.

⁴ The Geographic Information System (GIS) is a computerised information system that allows for the obtaining, recording, analysis, view, return, sharing and presentation of information coming from geographical data.

THE VALUE OF THE EMILIA ROMAGNA CANAL



Situation in the 2017 irrigation season: 190 thousand hectares of agricultural crops, of which 107 thousand irrigated

Regarding the 2017 irrigation season, deemed important because of the indispensable contribution guaranteed by irrigation, also rescue⁵ and self-supply⁶ irrigation, to support the struggling agricultural crops because of the absence of major rainfall and the high temperatures recorded at the beginning of summer, there was an assessment of the total area planted with crops in the area dominated by the system of the Emilia Romagna Canal, which was 189,285 Ha⁷, of which 106,813 Ha⁸ of irrigated crops.

Situation in the 2017 irrigation season: fruit crops and the wine industry

Among the fruit crops, those that occupy the largest surface are, from largest to smallest, stonefruit (peach tree, apricot tree, cherry tree, plum tree), with 9,141 Ha, and pome fruit (pears and apples), with 5,677 Ha. In terms of surface the actinidia (kiwifruit) crop is also remarkable (1,833 Ha), with the record reached by Italy as the largest producer in the world, with production occurring mostly in the provinces of Ravenna and Forlì-Cesena. The regional range of fruit cultivated is then

⁵ "Rescue irrigation" is the irrigation practice made necessary by certain unexpected climate conditions that can undermine the unit income of the current crop.

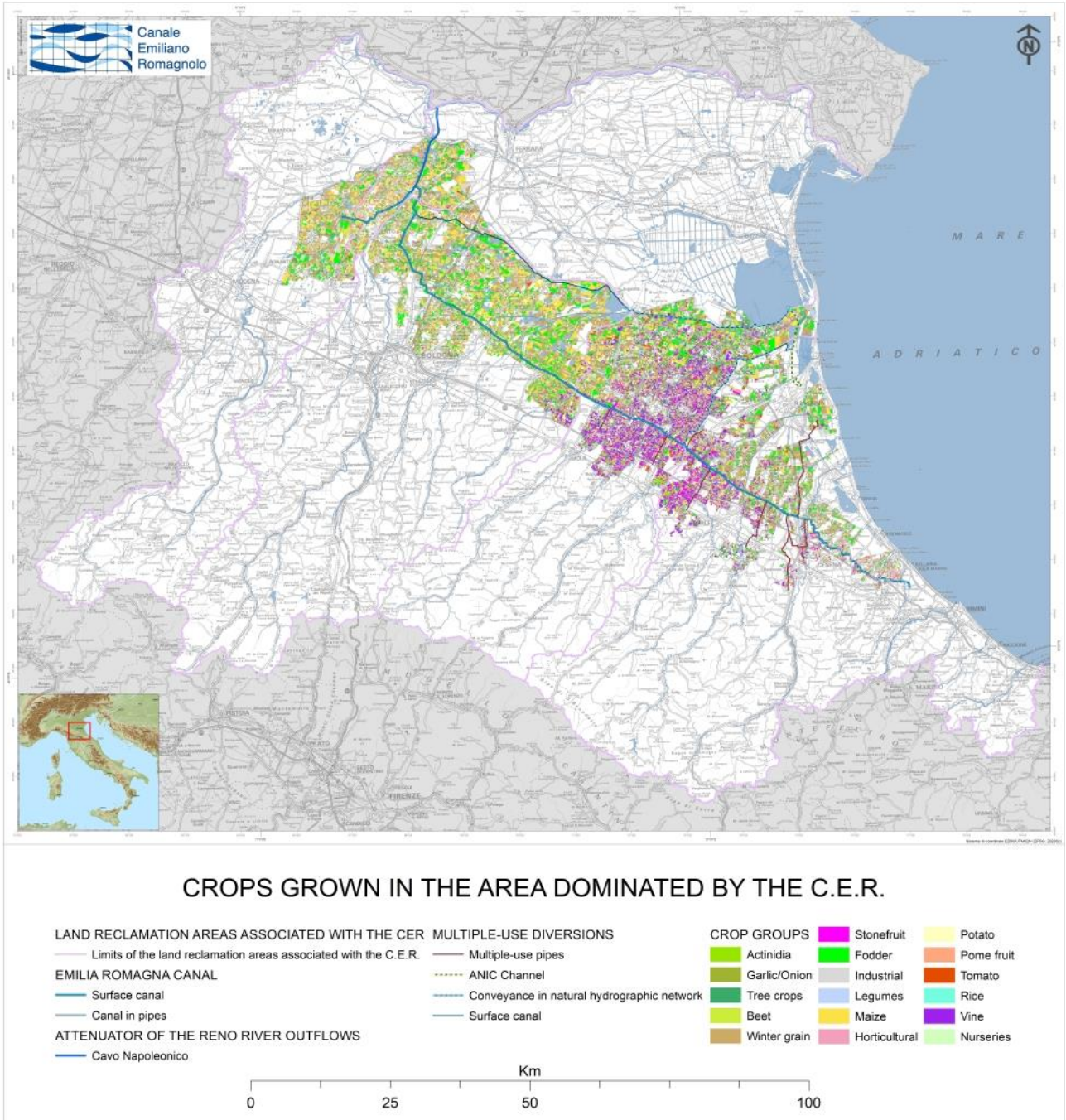
⁶ "Self-supply" indicates the withdrawal of water for irrigation purposes carried out by farmers "autonomously", meaning without the use of organised irrigation infrastructure of consortia (self-supply normally occurs through the pumping of company wells or mobile collections from a natural hydrographic network).

⁷ AGREA data 2017. Tares, uncultivated land in general, and set-aside areas are not considered.

⁸ All agricultural crops that normally require artificial water administration with the purpose of meeting the natural water deficit of the plants throughout the entire vegetation cycle were considered irrigated crops.

complemented with the lotus (persimmon tree), cultivated on 376 Ha. Wine growing also plays a major role, with its surface reaching 13,081 Ha in total.

Figure 4.4 - Crops grown in the area supplied with water by the CER's water system



Source: study by the CER Consortium based on AGREA data, 2017

Table 4.4 - Surfaces (in hectares) of fruit and wine growing crops in the area dominated by the Emilia Romagna Canal system

Fruit/wine growing crops	Surface (Ha)	Food processing	Fresh consumption	Not specified
Actinidia (kiwifruit)	1,832.713	-	-	-
Apricot tree	1,215.755	-	-	-
Cherry tree	112.88	-	-	-
Lotus or persimmon tree	375.994	-	-	-
Apple tree	1,462.253	10.144	733.587	718.522
Pear tree and quince	4,215.181	470.863	1,951.730	1,792.586
Peach tree	2,122.513	258.873	1,863.640	-
Nectarine tree	4,097.406	-	-	-
Plum tree	1,593.111	0.176	-	--
Walnut tree	264.151	0.666	253.151	10.335
TOTAL ORCHARDS		740.722	4,802.108	2,521.443
Table grape vine	4.115	-	-	-
Wine grape vine	13,065.900	-	-	-
Other vines	10.708	-	-	-
VITICULTURE TOTAL	13,080.723	-	-	-

Source: study by the CER Consortium based on AGREA data, 2017

Fruit sector

The main destination of fruit is the fresh market, in which Italy is a global leader when it comes to certain crops (peach tree, pear tree), thanks to Emilia Romagna's contribution to production. The fresh fruit produced in the region is traditionally characterised by high quality standards. In this situation, major economic benefits can be traced back to the improvement of the goods and the quality of the final products thanks to irrigation.

The processing industry

The fruit plants provide raw material also to the processing industry, which features three different business areas: fruit juices, nectars and a larger range of products that include syrup fruit, jams and marmalades. In terms of processed volumes, the industrial destination of the fruit has however heavily fallen over the years and, today, it is a far smaller commercial channel than the fresh market.

Wine making industry

The wine vine too is an economically important crop for the territory, as is shown by the fact that the Emiliano Romagnolo vineyard is the fifth largest nationwide in terms of planted surfaces, with about 50,000 Ha (Source: The agri-food system of Emilia-Romagna, 2019). In the territory covered by the analysis, the surface planted with vines amounts to 13,066 Ha (AGREA data, 2017).

Vines support a high-quality supply chain, where CDO wines account for about 60% of the regional production. In particular, in recent years native grape varieties (Trebbiano, Sangiovese, Albana) have generated increasing interest compared to international ones, thus strengthening the close bond of wine with the territory

where it is produced. Regional wines therefore seek a high-quality image, which is the foundation for the product's marketing, especially on foreign markets.

Apart from quality wines, **in the territory of the CER there are important productions among what are known as "table wines", which use large quantities of irrigation water**, quantities that are far higher compared to the quality supply chain, in which the role of irrigation is more modest. In this situation, water is one of the main factors that influences the vegetative behaviour of the vine, for which a correct management of the resource affects not only the production result on the ground (yield per hectare), but improves the final quality of the grape, thus contributing to the achievement of the commercial objectives.

Irrigated horticultural crops: 13,000 Ha divided into 20 productions

Horticultural crops cover a surface of over 13,000 Ha, divided into 20 productions. Onions (1,982 Ha), tomato for food processing (1,825 Ha) and pea (1,455 Ha) are the most widespread irrigated horticultural crops on the territory. The offer is complemented by a wide range of other horticultural crops for fresh market, including bean, cauliflower and spinach, cultivated on surfaces with very diverse sizes, although all feature a regular use of water. What is remarkable is also the total volume of the productions from seeds, to which about 20% of the irrigated horticultural crops is allocated.

The frozen food industry

The water provided by the CER is also important for horticultural crops intended for the frozen food industry.

Frozen vegetables, owing to specific characteristics, require an industrial approach in all the phases of the production process, including the agricultural part. **The range of frozen vegetables includes, among others, artichokes, carrots, green beans, peas, and spinach.** The final quality of the frozen product is guaranteed by the selection of the raw material on the ground and by overseeing every single phase of the crop's management, starting from the soil and seeds, as well as when and how the harvest is carried out, and in the end entering the product into the processing line. Thus, freezing plants are at the centre of large production basins particularly suited for horticulture, as the shorter the time between harvest and freezing, the better the quality of the product.

In recent years, above all in Romagna, there has been the rise of major production hubs for the processing and freezing of vegetables (e.g. Orogel soc. Coop agr. in Cesena), which resulted in an enhancement of the vertical integration between agricultural production and processing industry.

Table 4.5 - Surfaces in hectares of vegetable crops grown in the area dominated by the Emilia Romagna Canal system

Vegetable crops	Total	Vegetable garden	Seed production
Garlic and shallot	25.092	24.085	1.006
Asparagus	54.312	54.312	-
Cauliflower and cabbage	293.783	58.504	235.280
Cucumber	145.093	3.303	141.791
Onion and chive	1,982.584	1,812.835	169.750
Watermelon	130.823	129.542	1.281
Bean and green bean	409.973	389.167	20.807
Industrial green bean	589.068	-	-
Fennel	31.401	26.746	4.656
Strawberry	87.286	87.286	-
Lettuce	351.128	249.035	102.092
Melon	174.638	172.627	2.011
Pea	2,143.797	-	-
Tomato for food processing	1,825.367	-	-
Tomato for fresh consumption	25.881	24.976	0.905
Spinach	296.442	230.135	66.307
Pumpkin and zucchini	451.732	416.059	35.672
Other (leafy) vegetables ⁹	431.660	120.338	311.322
Other vegetables ¹⁰	893.688	625.673	268.015
Potato	2,804.281	-	-
TOTAL VEGETABLES	13,157.029	4,284.419	1,360.895

Source: study by the CER Consortium based on AGREA data, 2017

Potato production

To complement the picture created for vegetables, among the irrigated crops of the territory one must also mention tubers, in particular the potato (2,804 Ha). Potatoes have a wide range of uses, both in terms of fresh consumption and as raw material for the processing industry. In the field of the fresh market there are high quality productions that are deeply rooted to the territory, for example the Controlled Denomination of Origin (CDO) of the *Primura* variety, which is above all present in the province of Bologna. Territoriality guarantees the differentiation of products, while innovation enables the productions to move away from the concept of commodity and adopt that of functional product. The brands *Selenella™* e *Iodì™* are part of this rationale, whereby their products feature important trace elements for human nutrition, which shows that water availability for irrigation is a necessary and fundamental condition for high-quality productions.

The sugar beet

In the territory studied a major role is also played by industrial irrigated crops, chief among them the sugar beet (10,917 Ha). Historically the sugar beet supply chain has had a major economic importance, albeit far smaller today (currently the only active plant in Emilia-Romagna is in Minerbio, in the province of Bologna). On the other

⁹ Swiss chard, chicory, endive, parsley, radicchio, and arugula.

¹⁰ Beet, brassica carinata, brassica rapa, thistle, artichoke, carrot, chives, eggplant, bell pepper, leek, radish, scorzonera, and celery.

hand, the cultivation of the sugar beet to produce a hybrid seed lately has grown significantly owing of the favourable pedoclimatic conditions and the remarkable availability of water in the first phases of the vegetative development, so much so that it made the territory of this study one of the most productive in the world when it comes to this crop (4,007 Ha).

Soya

Another remarkably large industrial crop is soya (7,451 Ha), mainly intended for use as feed in animal farming. The production system based on processed and preserved meat and cold cuts has historically been the driver of the demand for this crop by the zootechnical industry professionals.

Table 4.6 - Surfaces in hectares of industrial irrigated crops grown in the area dominated by the Emilia Romagna Canal system

Industrial crops	Total	Industry/feed	Seeds
Sugar beet	10,917.745	6,910.396	4,007.348
Soy	7,450.877	6,924.313	526.564
Coriander	422.138	-	397.573
Basil	62.503	5.994	56.509
Bamboo	40.329	23.826	-
Hemp	16.275	0.499	15.776
TOTAL OF INDUSTRIAL CROPS	18,909.867	13,865.028	5,003.770

Source: study by the CER Consortium based on AGRE data, 2017

Grains and in particular maize

The extension of the irrigated surface in the area overseen by the Emilia Romagna Canal is complemented by grains, maize in particular. This crop usually takes advantage of irrigation as a common practice because it leads to an increase of production in the field without affecting the final quality.

The irrigated crops intended for fodder, alfalfa and permanent polyphytic grasslands

The list of irrigated crops also includes various productions (maize, pea, soya, clover) intended to be used as fodder, as well as alfalfa and permanent polyphytic grasslands. In the case of alfalfa, irrigation has positive effects on the production volumes above all in the first years of implantation, but, in general, it is not financially sustainable in the subsequent years.

Rice cultivation

In the municipalities (in the province of Bologna) of Molinella, Malalbergo and Castel Guelfo there is also a rice cultivation (seed rough rice) with Italy being the largest producer in the EU.

Greenhouse and nursery productions

The picture is then complemented by the greenhouse and nursery productions: ornamental lawn rolls, fruit, vegetable and flower greenhouses and nurseries for a total of 745 Ha.

Table 4.7 - Surfaces in hectares of irrigated grain, rice and fodder crops grown in the area dominated by the Emilia Romagna Canal system

	Surfaces (Ha)
MAIZE	
Maize	14,486.447
FODDER CROPS	
Alfalfa, ryegrass	17,864.416
Maize, as fodder	9,513.270
Pea, as fodder	26.430
Permanent polyphytic grasslands	184.467
Soya, as fodder	9.783
Clover, as fodder	7.096
RICE	
Seed rough rice	134.719

Source: study by the CER Consortium based on AGREA data, 2017

Table 4.8 - Surfaces (in hectares) of greenhouse and nursery crops in the area dominated by the Emilia Romagna Canal system

Greenhouses and nurseries	Surfaces (Ha)
Lawn rolls (turf)	67.982
Greenhouses	90.455
Flower nurseries	22.322
Fruit nurseries	254.629
Vegetable nurseries	14.820
Other nurseries	204.364
Greenhouses	90.455
TOTAL	745.027

Source: study by the CER Consortium based on AGREA data, 2017

Water of the CER to increase productivity on the ground and for high quality standards

For an agriculture such as that of Emilia-Romagna, water is an important resource not only to guarantee productivity increases on the ground, but also to maintain high quality standards of the products. In this respect, it must be noted that some of the irrigated productions intended for the industry and cultivated in the area covered by the analysis have been the object of agreements, deals and interprofessional framework contracts¹¹ that envisage from the primary system the adoption of the correct cultivation practices (including also irrigation) that are necessary for agricultural production to meet the quality requirements of the industry and trade.

¹¹ For example: the framework contract for the sale of potatoes for fresh consumption signed by OP, Cooperative, Fruitimpresa and Ascom; the framework contract for the tomato for food processing of Northern Italy, signed by OP and the associations of the processing industries. Moreover, there is an agreement for the seed industry, shared by Organizzazioni Professionali agricole, organizzazioni cooperative, Assosementi.

Some observations on the data on the irrigated cultivation surfaces

By comparing the surfaces of the irrigated crops obtained through a geostatistical analysis of the coverage of agricultural use of the soil with the data declared by the relevant Reclamation Consortia in the districts supplied with the water of the Emilia Romagna Canal, there is a major discrepancy.

More specifically, regarding the 2017 data of the SIGRIAN system¹², which is the official reference for monitoring the use of irrigation water in agriculture at national and EU level in accordance with Ministerial Decree Of the Italian Ministry of Agricultural, Food And Forestry Policies 31/07/2015, in the districts covered by the Emilia Romagna Canal there are far smaller irrigated surfaces compared to the total surfaces planted with irrigated crops in the same territories.

Table 4.9 - Surfaces (in hectares) of irrigated crops in relation to irrigable crops in the area dominated by the Emilia Romagna Canal system

Reclamation Consortium	Type of distribution	Territorial surface	Equipped surface	Irrigated surface 2017 (a)	Irrigable crops 2017 (b)	irrigated/irrigable incidence (a/b)
Burana Reclamation and Irrigation Consortium	Gravity district	20,031	19,028	1,057	7,689	14%
Renana Reclamation and Irrigation Consortium	Gravity district	17,099	14,884	2,405	6,381	38%
	Pressure district	8,369	7,578	2,966	4,069	73%
	Mixed district	53,315	46,740	11,770	22,047	53%
Western Romagna Reclamation and Irrigation Consortium	Gravity district	51,504	18,491	10,207	23,324	44%
	Pressure district	17,352	14,190	6,516	10,108	64%
Romagna Reclamation and Irrigation Consortium	Gravity district	27,586	12,581	5,345	9,832	54%
	Pressure district	25,964	17,813	9,143	11,960	76%
Ferrara Plain Reclamation and Irrigation Consortium	Gravity district	27,071	23,101	9,248	11,403	81%
TOTAL		248,290	174,406	58,657	106,813	55%

Source: study by the CER Consortium based on SIGRIAN data, 2017

¹² The SIGRIAN (National Information System for the Management of Water Resources in Agriculture) is the database created and managed by CREA-PB (Council on Research in Agriculture and Agricultural Economics Analysis – Centre of Policies and Bioeconomics, former INEA) and is the reference for the monitoring of irrigation volumes available to all municipalities and relevant bodies on the matter of water for agriculture, in accordance with Ministerial Decree MIPAAF 31/07/2015. The territorial information system, consisting of a geographical and alphanumeric component, is constantly kept up to date by the competent irrigation bodies across the territory, including the Reclamation and irrigation Consortia, the Regions and Autonomous Provinces.

The reasons behind the variation of the data

The difference between the data indicates that, although 2017 was a particularly dry agricultural year, only a part of the potentially irrigated crops was irrigated with the water transported by the Emilia Romagna Canal system. The reasons behind this are mainly the following:

1. some perennial fodder crops are grown in unwatered fields. This is the case, for example, of the alfalfa, for which irrigation is financially advantageous in relation to the yield of the production only initially just after the implantation;
2. some varieties of grain maize are grown in unwatered fields, especially in the territories of Romagna, in relation to the pedological conditions and the water availability of the land;
3. the old peach tree implantations, with precocious varieties, are still grown on the Romagna plain; the old vineyard implantations are grown in unwatered fields, to obtain greater alcohol content at the cost of a lower yield per hectare;
4. the practice of water self-supply is still very common, especially through the pumping of company wells or drawing water with mobile structures from the natural hydrographical network that escapes the control of the Reclamation Consortia, in that they are not controlled by Consortia's water transport and distribution.

Self-supply from underground bodies of water

Regarding this last point and by analysing the data of the ISTAT census (2011) concerning the sources of water supply, a high percentage of supply (33%) still depends on underground bodies of water. This data must be highlighted because of the possible repercussions related to drawing groundwater which, as described below, may result in a worsening of phenomena related to subsidence. One must however underline that the only ISTAT data available is dated 2011. In the meantime, many infrastructure projects have enabled the sustainability of irrigation in many areas of the region. This is particularly important in Romagna, where many farmers were able to benefit from new reservoirs and distribution plants aimed at making irrigation more efficient. The next census will allow for the provision of a quantitative estimate of this phenomenon.

Relation between wells and extensive productions

By more carefully analysing the spatial distribution of the incidence of the irrigated surfaces compared to the total irrigated crops, one can note that resorting to irrigation through self-supply is generally more pronounced in the districts that are more dedicated to extensive productions, with a lower density of consortia's irrigation works, meaning where water distribution occurs through the use of mixed-use reclamation channels (discharge and irrigation).

Distribution system with pressure pipes and a decreased use of wells

Vice versa, in the districts where the water of the CER is distributed through pressure pipes and company delivery groups, resorting to self-supply is far less common. In this case, in fact, the high availability of quality water (it does not lose quality along the way) throughout the entire irrigation season (generally from March to October), makes it financially disadvantageous to pump water from wells or other sources, with

the restoration of groundwater and the consequent slowing of subsidence phenomena and the salt wedge entering the Adriatic coastal strip.

4.2 THE LAND VALUE OF THE IRRIGATED AREAS IN EMILIA-ROMAGNA

The “legacy” of the CER The Emilia Romagna Canal is the longest hydraulic work for irrigation purposes in Italy. As was stated multiple times, the CER Consortium oversees its functioning and maintenance, and oversees the activity of the private subjects in the territory of its competence. The functions carried out by the Consortium concern hydraulic safety (water pumps, drainage canals), the management of the water intended for irrigation (plants and irrigated networks), the participation in urban planning works, as well as the protection of the environmental and agricultural heritage. There are multiple benefits provided by this work to the territory, including the increase in value of the land served by a greater availability of water. The data, in fact, shows how much importance is given in Emilia-Romagna to the difference between “*irrigated*¹³” land and “*non-irrigated*” land. The rest of the paragraph illustrates the analyses that quantify the increase in value of an irrigated land compared to a rainfed land.

4.2.1 The analysis methodology

Average Agricultural Values analysis The analysis is carried out by comparing the Average Agricultural Values¹⁴ (AAV) for irrigated and non-irrigated land regarding the six provinces on which the CER is active, meaning the 670 thousand hectares of UAA referring to the provinces of Ferrara, Modena, Bologna, Forlì-Cesena, Ravenna and Rimini. The Average Agricultural Values were introduced by art. 16 of Law No. 865/1971 essentially for the use regarding expropriation procedures for public use of non-building land concerning a specific territory and with certain characteristics, and in particular to determine the additional expropriation compensation foreseen for owners who are small growers/farmers and stakeholders and for tenants/colons of the expropriated land. Following Constitutional Court ruling no. 181 of 10th June, 2011, the previous criteria for calculating the expropriation indemnity were superseded: the quantification of the indemnity, which was pegged to the AAV (consisting of a series of tables in which the broad prices of various types of land with certain characteristics were reported) was declared unconstitutional, as each property holds specific peculiarities and difficult to frame in static schemes such as the AAV tables were, which basically reported average prices that might not correspond to the real market value. In each province, the Average Agricultural Values are determined every year, by 31st January, by the Provincial Expropriation Commission regarding the single agricultural regions,

¹³ Irrigated land with its own or leased water, both if in the rotation the crops require irrigation and if irrigation is not indispensable.

¹⁴ In the field of single agricultural regions, reference is made to the values of the land deemed free from binding agricultural contracts, based on the types of crops grown and detected in the previous calendar year. The Values are indicated in Euro per hectare.

based on the single types of crops grown and detected in the previous calendar year. The values, in Euros per hectare, are published in the Official Regional Bulletins (ORB).

This is the process adopted to determine the Average Agricultural Values.

Study flow and research of the working group



Stages of the working group



The calculation of the average increase generated by the availability of water in a productive agricultural territory

The following quantities were calculated:

- The value of the average price (in Euro/Ha) of the quality of the crop considered, in terms of weighted average of all the values of the same crop, irrigated and non-irrigated, in different Agricultural Regions, coming from the 2019 AAV tables of each province; each province in fact has different Agricultural Regions with different prices – based on the characteristics of the territory itself – which have been put together to have a comprehensive provincial view).
- the percentage increase between the same crop as irrigated and dry;
- the average of the percentage increases of the same crop for the entire area served by the CER (weighted average of the single percentage increases between the provinces of Ferrara, Bologna, Modena, Ravenna, Rimini and Forli-Cesena);
- in the cases where the data is missing for a given province and a given crop quality, the missing data was obtained with proportions based on similar characteristics between provinces (owing to territory proximity and similar agricultural activities).

In short, therefore, the analysis mentioned had the goal of determining the average percentage increase of the value generated by the water availability of a productive agricultural territory.

4.2.2 The results

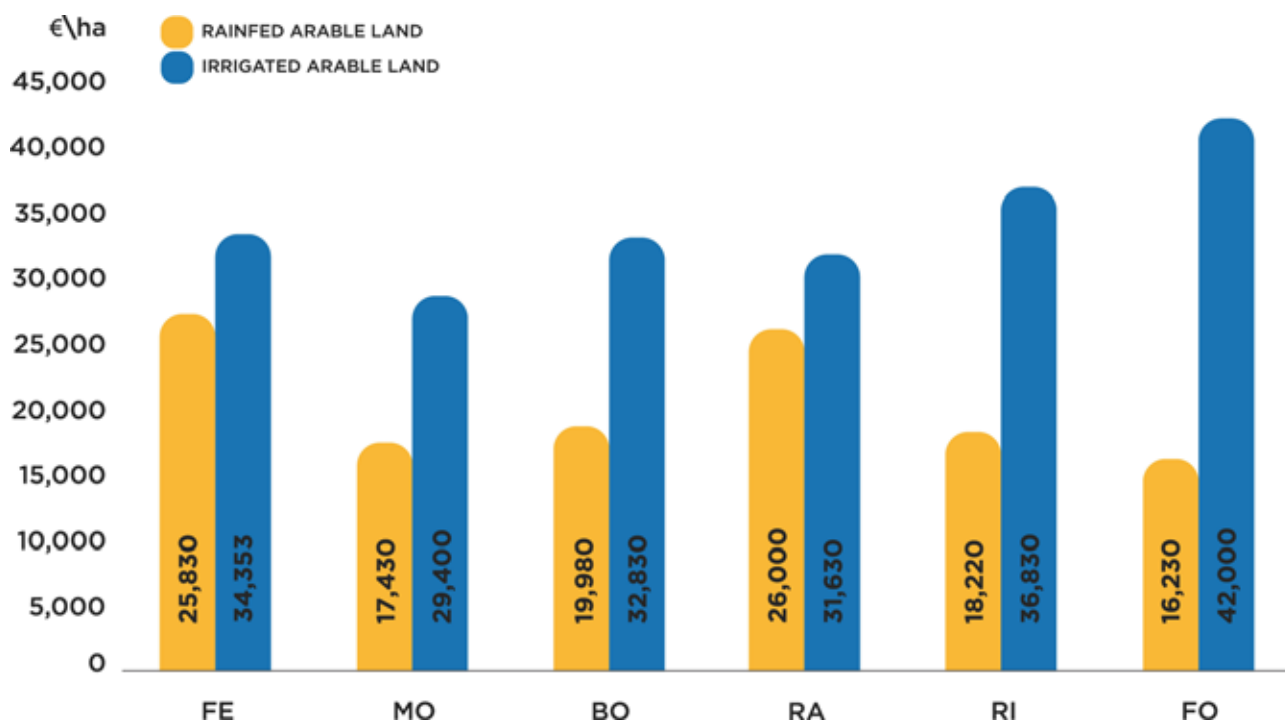
The increase in value of the irrigated land (Euro/Ha) generated by the CER

As already mentioned, the analysis considered the main use classes of the soil (*arable land, orchard, vineyard, meadows and pastures*) in the provinces that were part of the study, namely Ferrara (1), Modena (2), Bologna (3), Ravenna (4), Forlì-Cesena (5) and Rimini (6). The values obtained are the result of the average of the values of the single crops in the agricultural regions in which the provinces were divided, from which then the total percentage increase between irrigated and non-irrigated crop was obtained (fig. 4.5).

The most significant data refers to the AAV of the **arable land** crops, which was around 20,000 Euros per hectare, with a maximum in Ravenna (26,000 Euros/Ha) and a minimum in Forlì-Cesena (16,230 Euros/Ha), while for **irrigated arable land** crops it was around 34,500 Euros per hectare, with a maximum in Forlì-Cesena (42,000 Euros/Ha) and a minimum in Modena (29,400 Euros/Ha). The presence of irrigation heavily influences value, introducing a difference between irrigated and non-irrigated equal to 14,500 Euros/Ha.

Table 4.10 shows the increases in percentage values of rainfed and irrigated soil referring to the type of use, namely arable land, vineyard and orchard.

Figure 4.5 – Difference between Average Agricultural Values of irrigated arable land and rainfed arable land



Source: Nomisma on data of the Official Bulletin of the Emilia-Romagna Region – Average Agricultural Values

Table 4.10 – Average Agricultural Values and increases in percentage values of irrigated land compared to rainfed land based on type of use of the soil and Province

		FE	MO	BO	RA	RI	FO
ARABLE LAND	Dry	25,830	17,430	19,980	26,000	18,220	16,230
	Irrigated	34,353	29,400	32,830	31,630	36,830	42,000
	Variation % irrigated/dry	33	69	64	22	102	159
ORCHARD	Dry	29,025	29,220	34,500	30,630	36,000	23,500
	Irrigated	38,700	36,675	36,167	34,720	41,400	27,500
	Variation % irrigated/dry	33	26	5	13	15	17
VINEYARD	Dry	26,500	34,980	34,980	33,890	31,640	27,420
	Irrigated	41,870	55,600	55,600	35,180	40,499	42,000
	Variation % irrigated/dry	58	59	59	4	28	53

Source: Nomisma

The increase in value of the irrigated land (in %) generated by the CER

In percentage terms, the average increase in irrigated and rainfed **arable land** varies from a minimum of 22% in the province of Ravenna to a maximum of 159% in the province of Forlì-Cesena. When it comes to the **orchard**, the increase is lower, as it ranges from 5% in the province of Bologna to 33% in the province of Ferrara. Somewhere in the middle is the average increase of the **vineyard**, as it ranges from 4% in the province of Ravenna to 59% in the province of Modena. These figures unequivocally show to what extent the irrigation of an arable land is a “rewarded” factor in economic terms within the territory studied in this report. Regarding the meadows and pastures it is hard within these areas to carry out assessments on the possibility that they may change in value owing to the presence or absence of irrigation, also because, based on the AAV analyses of the agricultural regions, there is hardly ever a specification of the value variations of meadow or pasture that is irrigated or non-irrigated.

The ANBI values and study

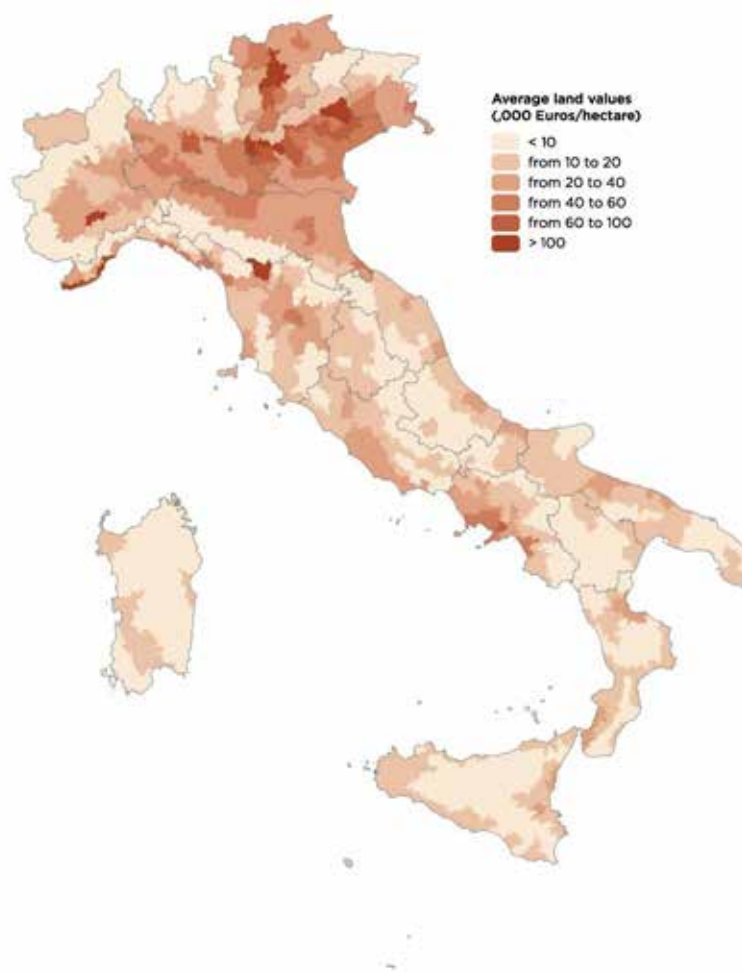
The data obtained, albeit extremely prudential, is in line with what was indicated in a study conducted by ANBI¹⁵ with the University of Trieste on irrigation in Italy as an important economic factor and on the impact it has on food production, despite the values shown being lower in terms of percentage compared to what was indicated above: **research in fact highlights that irrigation is essential for the survival of the Italian agricultural systems, making a major contribution to the agricultural value and therefore to the income stability of the rural company, decreasing the risks related to a meteorological trend that is ever more affected by climate change.**

¹⁵ The National Association of Consortia for the Management and Safeguard of the Territory and Irrigation Water - ANBI, which represents all Reclamation Consortia and other bodies that operate within Emilia-Romagna in the field of protecting the soil and managing water.

The CREA values and study

Then, referring to the CREA data¹⁶ on the year 2017-2018 on the Average Values of the land in Italy (indicated in their publication titled *Indagine sul mercato fondiario in Italia, Investigation on the Land Market in Italy*, edited by Andrea Povellato and Antonella Tantari), confirms the traditional bipolar structure of the land market whereby 60% of the national land property is concentrated in the regions of the North. In this macro-area the land values are stable at around 35,000 Euros/Ha with almost 43,000 Euros/Ha in the regions of the Northeast and 26,000 Euros/Ha in those of the North West, prices that are not too different from those examined for the purposes of our assessment (fig. 4.6). This result was obtained also thanks to irrigation and the water availability that the CER infrastructure is able to guarantee on the territory of its competence. Without this supply, the land value of this land would severely decrease, in the terms and proportions that have been described in this paragraph.

Figure 4.6 – Italy: average land values based on territory (2018)



Source: Crea-Pb, Data base of land values

¹⁶ The Council on Research in Agriculture and Analysis of Agricultural Economics – CREA, is the main Italian research body dedicated to the agri-food supply chains with legal personality under public law, supervised by the Ministry of Agricultural, Food and Forestry Policies (MIPAAF).

4.2.3 The total value increase related to irrigation

Overall values

With reference to the investigated territory, the aim was to calculate an overall piece of data of the value increase generated by the presence of water.

As stated at the beginning of the paragraph, the UAA taken into consideration consists of 670 thousand hectares of surface belonging to the provinces where the CER is active, meaning Ferrara, Modena, Bologna, Ravenna, Forlì-Cesena and Rimini.

The values of the land in each province were assessed based on the possibility or lack thereof of irrigation and reference was made to the AAV provided by the Italian Revenue Office and the ISTAT data regarding the crops in the years going from 2017 to 2019.

By adding the value increase due to irrigation in each of the six provinces and for each type of land examined (arable land, orchards, vineyards) the result is a total value of 6.7 billion Euros (Tab. 4.11a).

To obtain a value increase of the irrigated land solely concerning the equipped surface of the CER, equal to 174 thousand hectares, an average calculation was carried out, as in this field there was no specific data with the distinction between surfaces divided into the provinces they were part of and into type of irrigated land. Therefore, the increase in value calculated for the entire UAA of the six provinces examined (670 thousand hectares) was readjusted over the 174 thousand hectares of the CER's **equipped surface**, based on the hypothesis that the latter may feature a division into types of irrigated and rainfed land that is similar to all 670 thousand hectares, thus obtaining an **increase in value due to irrigation equal to about 1.7 billion Euro** (Tab. 4.11b). This rough calculation is absolutely prudential, given that the share of irrigated land on the CER's equipped surface is far higher than the share of irrigated land present in the entire UAA of the six provinces.

By applying the same process to the **territorial surface**, meaning the entire surface of competence of the CER that can potentially be irrigated (equal to 248 thousand hectares), one may obtain **an increase in land value due to irrigation equal to about 2.5 billion Euros**.

These assessments enable one to estimate the economic value that irrigation can generate in terms of land value, with which one can determine what is known as agricultural value. The following paragraph includes the proposal of an alternative approach to reach an estimate of the agricultural value, analysing the amount of agricultural production reached every year exclusively due to the water supply guaranteed by the Emilia Romagna Canal in its territory of competence.

Table 4.11a – Estimate of the increase in value of the agricultural land due to irrigation in the UAA of the six provinces in which the CER is active

Provinces	Total UAA (arable lands, orchards, vineyards, meadows and pastures) (Ha)	increase in value due to irrigation (billion €)
Ferrara	179,040	1.911
Modena	120,312	1.157
Bologna	159,082	1.884
Forlì-Cesena	72,530	0.798
Ravenna	104,641	0.538
Rimini	35,178	0.380
TOTAL	670,784	6.667

Source: Nomisma

Table 4.11b – Estimate of the increase in value of the agricultural land due to irrigation in the equipped UAA and in the territorial UAA of the CER

Equipped UAA of the CER	(Ha)	174,406
Territorial UAA of the CER	(Ha)	248,290
Increase in value due to irrigation in the equipped UAA of the CER	(billions €)	1.734
Increase in value due to irrigation in the territorial UAA of the CER	(billions €)	2.468

Source: Nomisma

4.3 THE VALUE OF IRRIGATED AGRICULTURAL PRODUCTION

Estimate of the value of the agricultural production related to water supply

This paragraph seeks to obtain an estimate of the agricultural production directly connected to the water supply of the Emilia Romagna Canal which, thanks to the associated Reclamation Consortia, enables farmers to have at their disposal water to use for hydro-demanding crops. To obtain this estimate simulations were carried out through statistical models that reproduce the current state of agricultural production achieved with the water resource that is in fact available, and subsequently assess how this production would change by eliminating each time a given amount of water, thereby eventually reaching the extreme condition of no water being provided by the CER. This would lead to measuring the agricultural production differential, which precisely indicates the agricultural production ascribable to the supply of the Emilia Romagna Canal.

4.3.1 The methodology adopted

The economic models of mathematical programming in the agricultural sector

To estimate the value of the agricultural production related to the water supply of the CER an economic model that provides the most accurate representation of the reality observed was used. In the field of agricultural economics there is a large variety of models to simulate this value, the most used are: mathematical programming models, econometric models, monetary assessments (hedonic prices, contingent valuation), ABM (agent-based modelling). In this study we opted for mathematical programming, which is by far the most used model in the literature (Graveline, 2016).

The economic models of mathematical programming used in agriculture illustrate the choices of rational agents (farmers) whose aim is to maximise utility, expressed through a function called utility function, which may be either linear or non-linear (Naylor e Vernon, 1969).

The estimate of the utility function

Utility is generally calculated through revealed preferences, meaning by observing the choices made by the agents in reality. The revealed preference theory, developed by Samuelson (1938), is based on the assumption that, with the other variables being equal, an agent chooses a certain basket¹⁷ over another based on his or her preference: it is therefore necessary to identify an objective function (the utility function) that reproduces this choice. Another technique to estimate the utility of farmers is the direct one, through interviews, which is normally more expensive and time-consuming. The identification of this function is fundamental to illustrate the behaviour of the farmer: it is in fact used in the model and can be interpreted as a mathematical description of human behaviour.

The “normative” models

The mathematical programming models can be divided into two main categories: normative models and positive models. Normative models are older – they have been used for over 50 years in the field of agricultural economics (Buysse et al., 2006) – and are used above all if there is little data available, but it is not guaranteed that they will give a precise image of the situation observed (for example, the distribution of the crops examined in the study). These models take on an a priori objective/utility function, which provide the conditions that represent the best possible allocation of the inputs (Graveline, 2016).

¹⁷ In economics the term “basket” indicates a general set of resources that an agent can acquire or may have.

The “positive” models

The second category includes the positive models, which are more recent: they start from the assumption that the choice made by the agent (meaning the observed choice) is in fact the optimal one and this information is used as a stringent tool to calibrate the model. Calibration is a procedure whereby one can identify the utility that guarantees that the model is as similar as possible to the reality observed, thus making it useful for policymakers as they are often interested in seeing the effects of a policy starting from the real situation, rather than an ideal one.

The economic agent of the model can be, like in reality, the single farmer or stakeholder or a homogeneous group of farmers based on the specific characteristic deemed useful for the study (for example one can group together the agents that use the same source of water supply or one can refer to homogeneous groups created for agricultural statistics purposes). This agent in reality makes a choice on the mix of crops to practice, on time, on the investment and application of the water necessary for production. In the model this complex choice is often reduced to a decision on the mix of crops to which average values of costs, production, water requirements etc. are attributed.

The evolution: towards “Positive Mathematical programming” (PMP) models

The utility function that determines this choice can be defined as single-attribute, meaning that it considers a single attribute (normally profit) relevant, or as multi-attribute; the former, though widely used, has been criticised by various authors for not being very representative of the behaviour of farmers (Ajzen, 1991; Bartolini et al., 2007; Gómez-Limón et al., 2016). Therefore more complex models have been developed in which utility is described by various attributes including for example profit, risk, socio-cultural habits, etc. (Pérez-Blanco et al., 2015). This approach is based on the Theory of Planned Behaviour (Ajzen, 1991) and the Multi Attribute Utility Theory developed by Keeney e Raiffa (1993) and which was later further developed (Bergevoet et al., 2004; Gocsik et al., 2014; Läßle e Kelley, 2013).

The advantages of the “PMP” models

During the same decade Howitt (1995a) introduced a new type of model, the Positive Mathematical Programming (PMP) models, which though having a single-attribute function, meaning that it considers the expected profit as the only relevant attribute, can consider the effect of all the other attributes on the choice of the agent. This ability is due to the interpretation of the mathematical process of calibration, which in this model allows for a perfect reproduction of the reality observed of the area studied, which, on the other hand, is not guaranteed with multi-attribute models. The calibration of the PMP models is however also a source of heavy criticism concerning the theoretical foundation of this result, which is not easily justifiable (Heckeley et al., 2012). Please see annex 1 for further technical information regarding model theory. In the specific case of this study the original PMP introduced by Howitt (1995) is applied, which uses a quadratic utility function in the cost, whose mathematical formulation can be found in annex 1.

4.3.2 The area examined

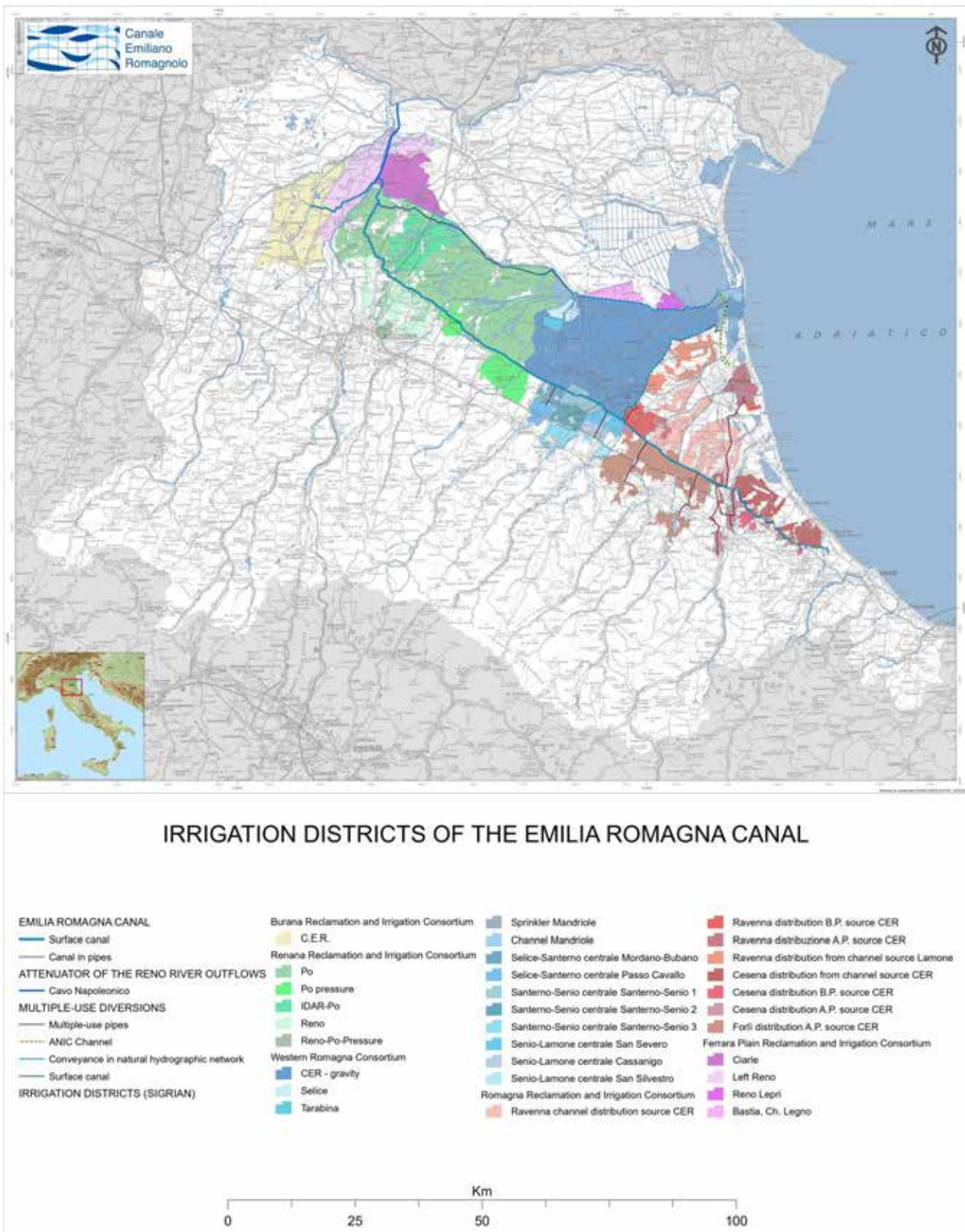
**The area studied: 31
macro districts,
250,000 hectares,
43% of irrigated soil**

The CER's area of competence includes the provinces of Modena, Bologna, Ferrara, Ravenna, Forlì-Cesena and Rimini. The territory stretches across a flat area that is historically rich in water thanks to the many rivers flowing down from the Apennines, which are however not enough to sustain agriculture. Therefore the CER was built, which sustains the irrigation sector with the water of the Po River. Despite this wealth of resources, climate change is taking a toll on the sustainability of the sector and the irrigation infrastructure is ever more central for its survival. The area studied is divided into 31 Macro Districts (figure 4.7), which are used as economic agents in the simulation model.

These macro districts feature areas that withdraw irrigation water from the source and/or infrastructure itself and are used by the various Reclamation Consortia active in the territory as disaggregation units to collect large amounts of data. The territory analysed stretches for nearly 250,000 hectares, of which about 43% are irrigated.

Since the estimation described in this paragraph focuses on the value of the agricultural production tied to water supply, only the irrigated area has been used in the simulation model. Moreover seed crops, even if irrigated, were not considered in the analysis owing to a lack of data.

Figure 4.7 – Area studied: the CER’s macro districts

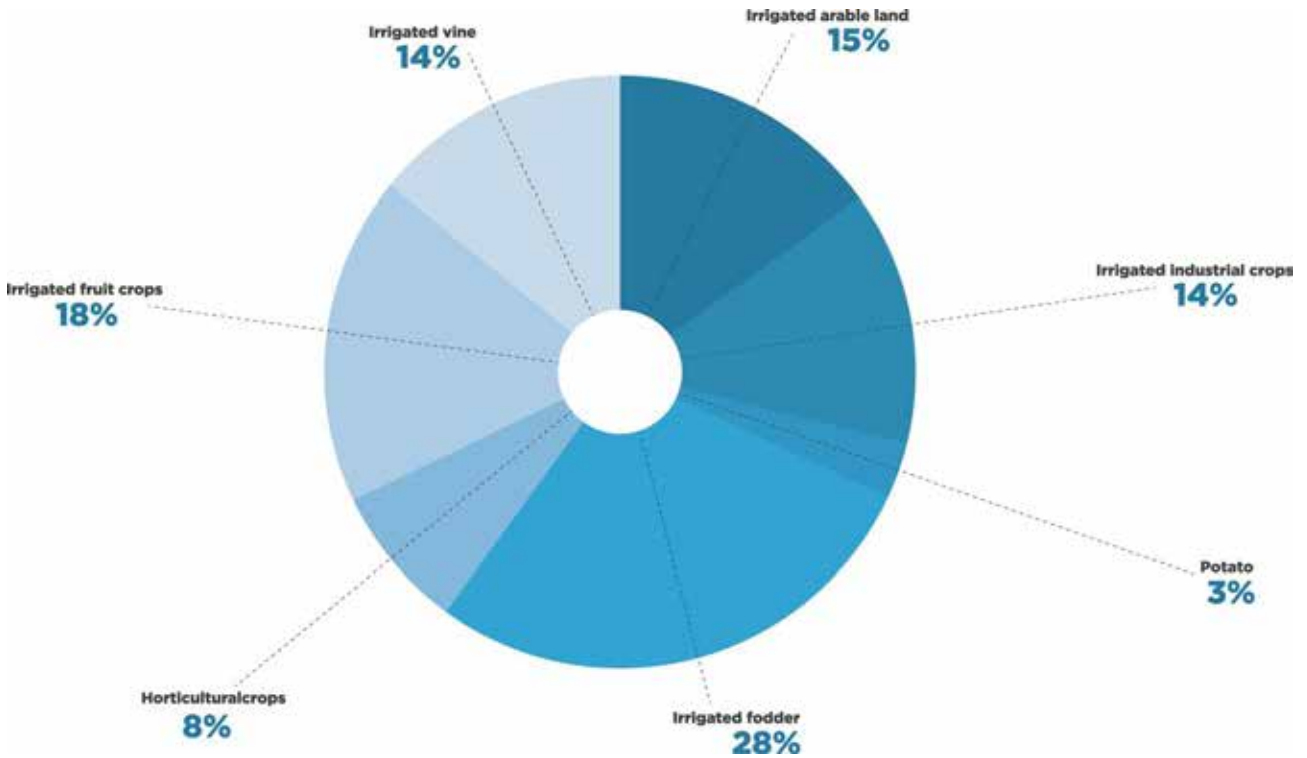


Source: CER Consortium, 2021

**The area studied:
crop distribution**

The irrigated area studied is mostly used for extensive crops of arable, industrial and fodder land (57%), with the remaining territory planted with vegetable crops and permanent crops (vines and fruit trees), as shown in figure 4.8. Specifically, the main irrigated crops are: alfalfa (18%), corn (15%), vine (14%), fodder corn (10%), beet (7%), soya (7%), peach tree (6%).

Figure 4.8 – Irrigated crops in the CER’s territory



Source: CER Consortium

4.3.3 The data available

**The data for the
construction of the
model**

The data used for the construction of the model is presented in table 4.12. The data related to prices and production is available from various sources, but the decision was to opt for as much homogeneity as possible, meaning to use the same source if it was available: in particular the RICA database for costs and prices (INEA, 2020) and ISTAT data for the average productions (ISTAT, 2019). If there was a lack of information, other sources were used. In particular, for information related to the production and costs of non-irrigated crops that was not available in the RICA and ISTAT databases, data from the CER was used.

Table 4.12 – Data used and source

Data	Source	Year of reference	Disaggregation	Unit of measurement
Surface	CER, 2021	2017	Lots, grouped based on the irrigated district	Ha
Specific costs	CER, 2021; RICA, 2020	2008 – 2016	NUTS 2 (Region) and CER area	€/Ha
Prices	RICA, 2020	2008 – 2016	NUTS 2 (Region)	€/kg
Production	CER, 2021; ISTAT, 2019	2008 – 2017	NUTS 3 (Province) and CER area	Kg/Ha
Water requirements	CER, 2021; Regione Emilia-Romagna, 2016	2003 – 2017	Irrigated district (CER data), NUTS 2 (Region) (ER region data)	m ³ /Ha
Labour Costs	Pérez-Blanco et al., 2016; Regione Emilia Romagna, 2010	2014	NUTS 2 (Region)	€/hour
Transport and irrigation efficiency	CER, 2021	2017	Fee and irrigated district	%

4.3.4 Assumptions, results and scenarios

How the simulations work

To calculate the agricultural production attributable to the CER's water supply, simulations were carried out in which there is a 1% decrease in the availability of water in every step until one reaches 100% less water, meaning the absence of water for irrigation.

After every reduction the economic agent once again allocates the land at their disposal with the mix of crops that maximise its utility function. The utility function that describes the behaviour of the agent is the one identified during the calibration procedure presented in the previous section.

The adaptation strategies: intensive, extensive and super-extensive

During the simulation the agent is forced to modify their initial crop choice in that the availability of water decreases: this process in reality can lead to three different adaptation strategies, called intensive, extensive and super extensive regulation (Koundouri, 2004). These are done through deficit irrigation (intensive regulation), the replacement with a crop that is less hydro-demanding (extensive regulation) and the replacement with a crop that can grow in dry conditions (super extensive regulation). Most of the agro-economic models present in the literature reduce the complexity of these strategies to merely the extensive and super-extensive regulations, in that intensive control is often impossible to simulate owing to a lack of data¹⁸. Also in this application only the last two adjustment strategies were considered in that no information was found regarding production functions of the area studied for the various species grown.

¹⁸ To enable intensive regulation the production functions of every crop in every area considered in the model would be necessary. The introduction of a production function also entails an increase in the complexity of the model (a second variable is added apart from the allocation of the surface, namely the quantity of water) and the need for a much larger number of agents in that the disaggregation necessary to obtain a precise production function is very low (it in fact depends on the composition of the soil and climate factors that can be very different also within a very short spatial distance).

Scenarios for the simulations

The simulations have the calendar year as the time interval of reference, meaning that each simulation hypothesises the behaviour of the farmers in a given year in relation to a specific quantity of water available for irrigation. This assumption does not count for the “water shock” hypothesis, meaning the sudden lack of water provided by the CER, in which the lack of water occurs at the beginning of the year taken into consideration, without the possibility of making any changes to the mix of crops grown. In this case the seasonal crops have already been planted and the sudden lack of water influences the production of irrigated crops. The rainfed alternatives are limited owing to structural problems of the PMP models, which cannot insert many rainfed alternatives. Therefore the following were taken into consideration: wheat, sunflower and legumes. Regarding the permanent crops their extension cannot be decreased/increased in that the timeframe of the model is the short term (calendar year), so no major disinvestments are allowed. For the permanent crops there was data concerning rainfed crops, namely apple tree, pear tree, peach tree and vine; the other permanent crops (actinidia, plum, cherry tree, persimmon tree and apricot tree) were not replaced in the absence of water, and their production values were cancelled in the event of water shortage.

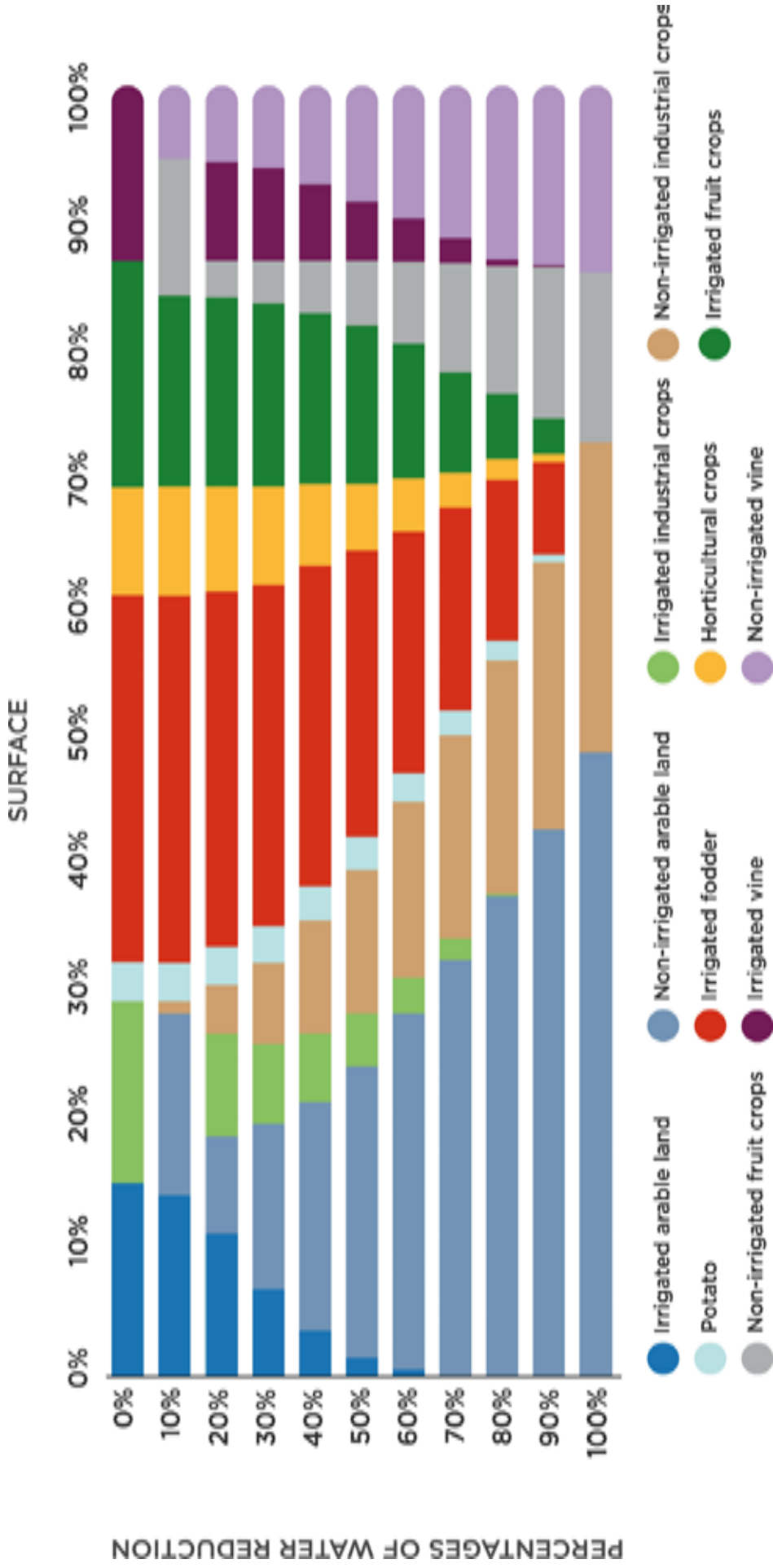
The variations in crop allocation in the event of water shortage

Figure 4.9 includes the changes in surface allocated for every crop group, deriving from a progressive 10% decrease in water availability. The result is aggregated for all the macro districts considered.

The graph indicates various effects: irrigated arable land and industrial land are the first crops to be replaced with the rainfed alternatives, while the vegetable, fodder and potato crops (which do not have a rainfed alternative) are the last to be replaced.

Moreover, the permanent crops (fruit and vine crops) are replaced with the respective crops without irrigation, except some for which rainfed crops are not an option (actinidia, plum, cherry tree, persimmon tree and apricot tree): they are eliminated, therefore there is a light decrease of the fruit crop surface.

Figure 4.9 - Impact of the decrease in water availability on the crop groups grown



Source: Nomisma data from various sources

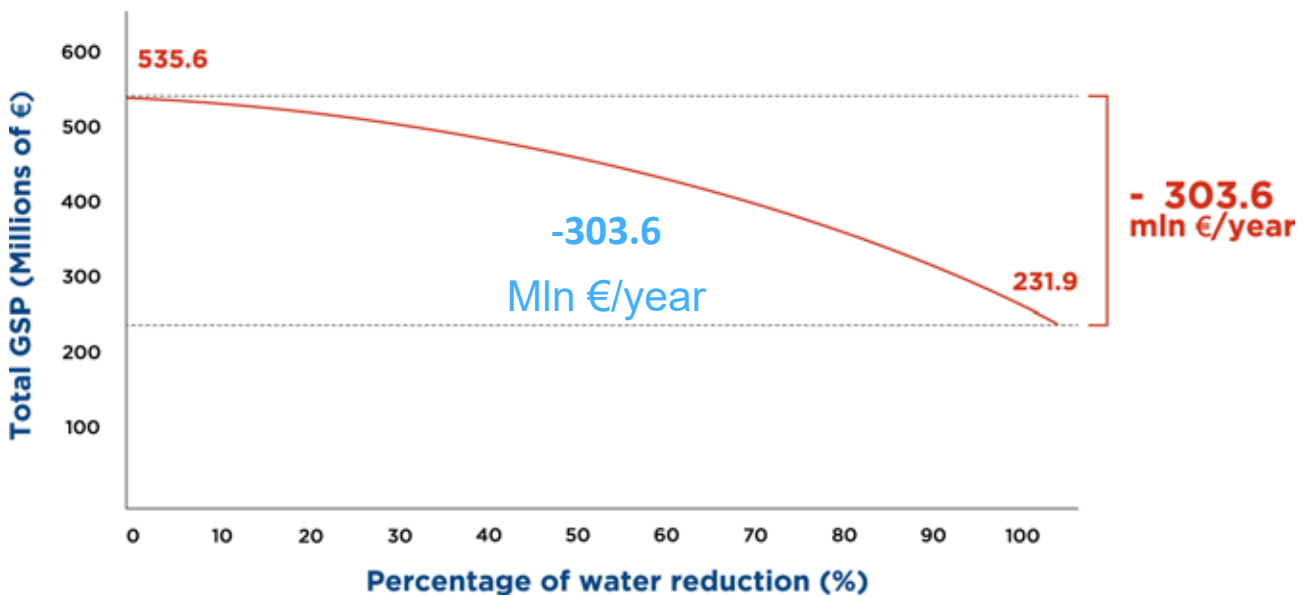
The effect of water reduction in terms of GSP loss

Figure 4.10 indicates the effect of the reduction in irrigation water in terms of Gross Saleable Product (GSP), meaning the monetary value of agricultural production before production costs. By analysing the curve of the graph one can note that the GSP reduction occurs quite gradually in the first part of the simulations (in which water availability is still large), while the loss increases in intensity as the water deficit becomes increasingly severe, until it reaches complete lack of water.

The conclusion reached by analysing the graph is that **the CER's water supply contributes to determining over half of the GSP** produced in the area of competence of the CER: at the end of the simulations, there in fact a **303.6 million Euro reduction per year in GSP** out of a total of 535.6 million Euros, meaning 56% of the entire gross saleable product. Given that in 2020 in Emilia-Romagna vegetable productions amounted to 2,378 million Euros in GSP, the conclusion is that **the water provided by the CER contributes 12.8% of the vegetable production of the entire region**.

Moreover, given that the volume of water made available by the CER is equal to about 278 million cubic metres per year, the 303.6 million Euros of GSP are equal to a yield of 1.09 Euros in GSP for every cubic metre of water.

Figure 4.10 - Impact of the decrease in water availability on the Gross Saleable Product



Source: Nomisma data from various sources

The effects on total and contract labour

Water shortage would result in effects not only in terms of agricultural production that would disappear, but also at a social level and in terms of employment, because loss in production would at the same time lead to a loss in labour that would no longer be used to this purpose.

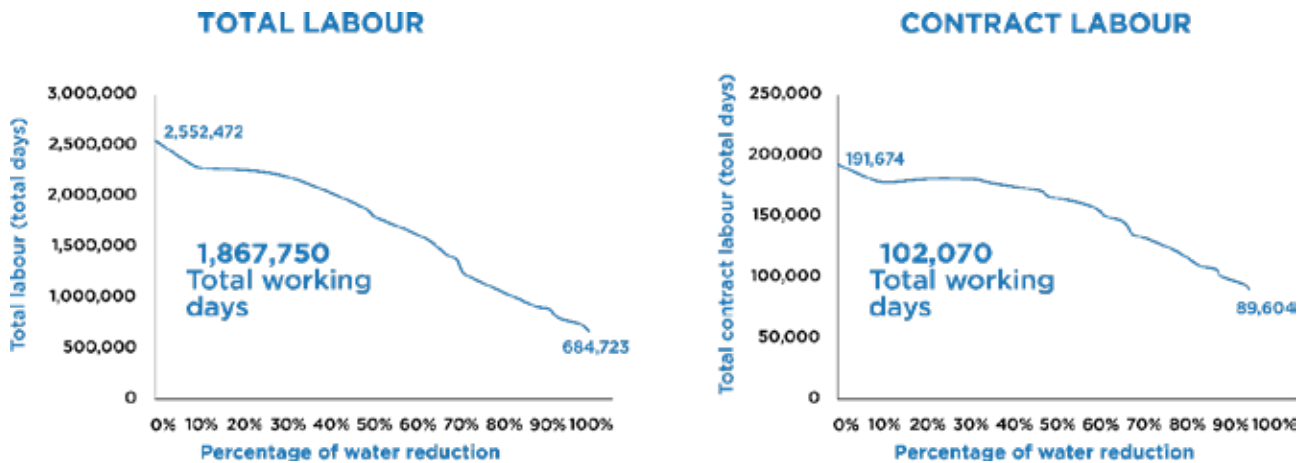
Graph 4.11 shows the impact of the reduction in water availability in terms of total and contract labour. In the case of full water availability, the quantity of contract labour accounts for 7.5% of the total labour (191 thousand days of work out of a total of 2.5 million days). This data was taken from the RICA database and is a precautionary estimate of the quantity of contract labour necessary for the grown agricultural crops.

The curve analysis shows a greater initial decrease (up to 10% less water), a momentary stability/minor decrease and then a second greater reduction (from 35% less water in the case of total labour, from -50% for contract labour). The irregular behaviour is not unusual in single-attribute models such as the PMP in which the expected profit defines the behaviour of the agent.

By analysing the quantity of work necessary for the single crop groups (figure 4.12), one can note that in the case of full availability of water it is the fruit crops that require the greatest effort (over one million days of work per year), followed by vegetable crops and vine crops, both with over half a million days of work. In the extreme case of no water availability, fruit crops would experience a decrease in working days equal to 73% and vines equal to 88%, while vegetable, fodder and potato crops would experience a maximum loss in labour, in that for these crop groups there is no rainfed alternative. The only crop groups that show an increase in the quantity of work are arable and industrial crops, which are incidentally the crop classes that take up the lowest amount of labour in the case of full water availability.

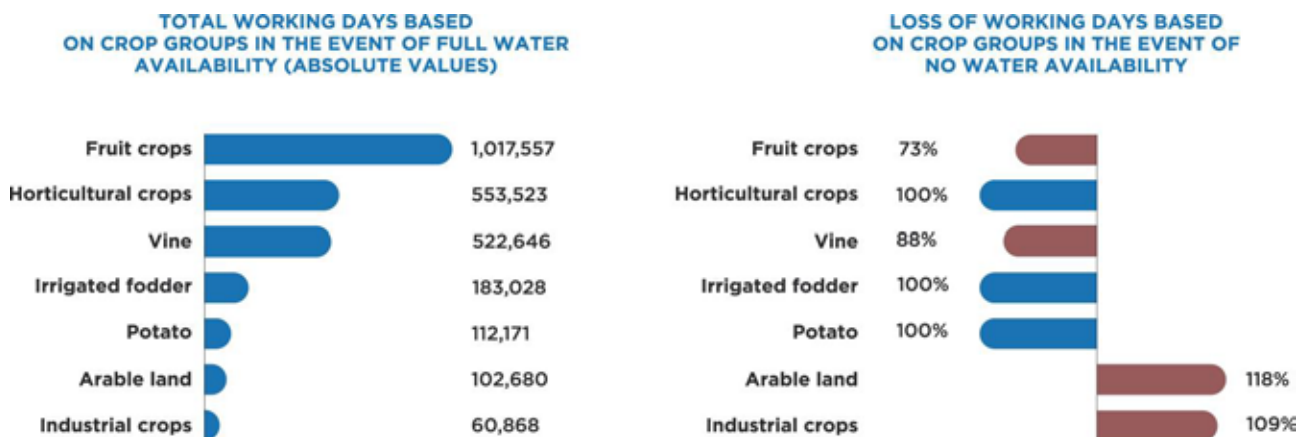
As a whole, in the event of there not being any water provided by the CER there would be a total loss in labour equal to over 1,800,000 working days per year, of which about 100,000 for contract labour, meaning seasonal workers, the most fragile part of the working force in agriculture. By turning these numbers into economic values, the loss in total labour is equal to 160 million Euros per year, of which **8.8 million attributable to contract labour alone** (figure 4.13). As was already mentioned, this is a precautionary estimate, the loss in contract labour may be even higher, given that, according to ISTAT data, in Emilia-Romagna in the agricultural sector the employment of employed staff amounts to over 6 million working days per year.

Figure 4.11 - Impact of the reduction in water availability on the quantity of labour force expressed in working days



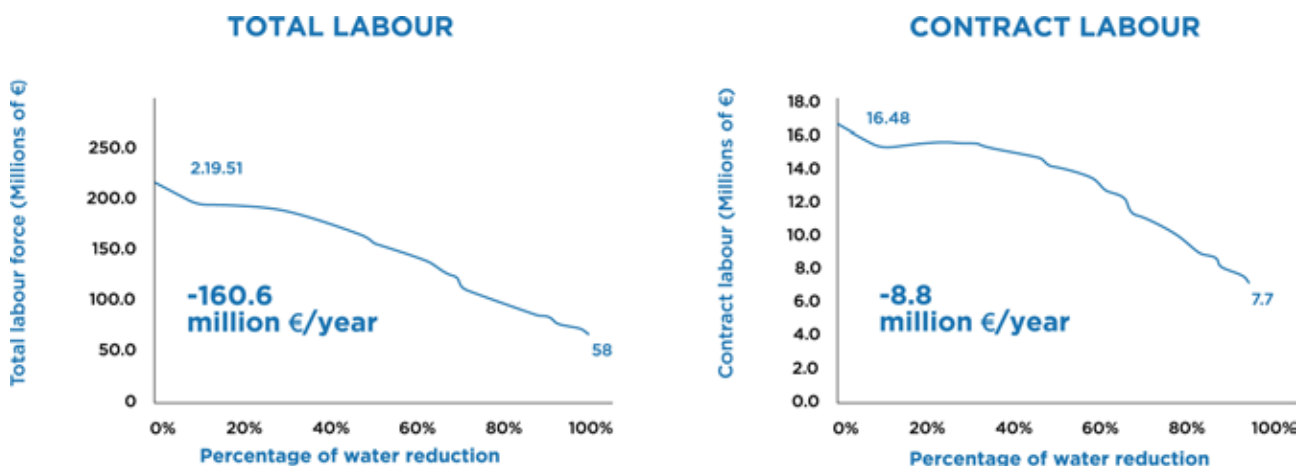
Source: Nomisma data from various sources

Figure 4.12 - Quantity of total labour (expressed in working days) based on crop groups in the case of full water availability and impact of the complete reduction of water availability



Source: Nomisma data from various sources

Figure 4.13 - Impact of the decrease in water availability on the value of labour

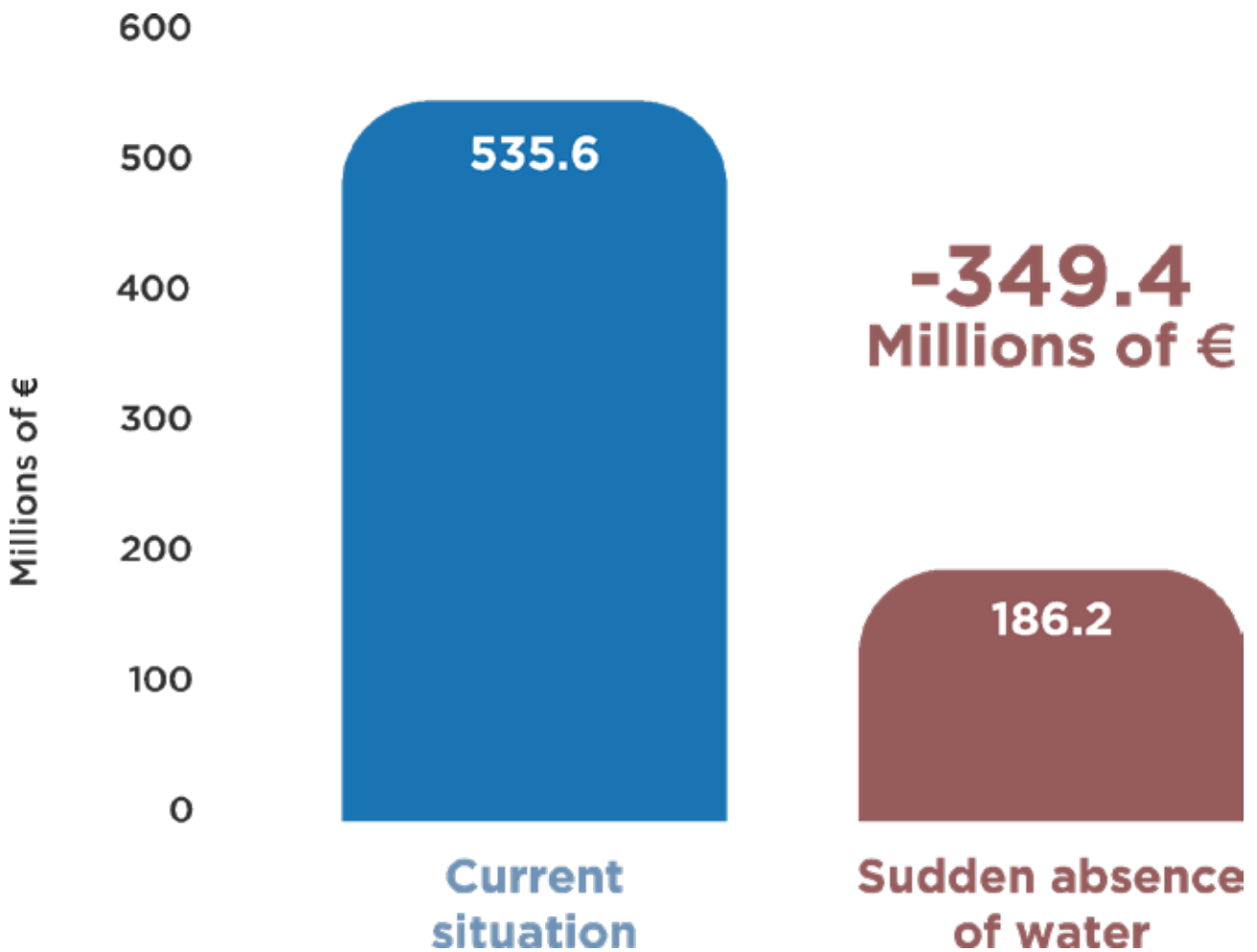


Source: Nomisma data from various sources

Water shock and effects in terms of GSP

When it comes to the second scenario, concerning the case of sudden water shock, figure 4.14 shows the effect in terms of GSP. In this case one can note that the impossibility to adapt results in a greater GSP loss, equal to 349.4 million €/year, equal to 45.8 million €/year more compared to the hypothesis with an adaptation (figure 4.11). This result is particularly relevant to consider the importance of adaptation strategies that allow for a decrease in the economic impact of the environmental events that can partly be anticipated, such as the case of extreme drought.

Figure 4.14 - Impact of the sudden lack (water shock hypothesis) of water availability on the Gross Saleable Product (GSP)



Source: Nomisma data from various sources

Over 50% of the GSP depends on irrigation

For a more precise analysis of the results, one must specify that the simulation considers the possibility for farmers to partially modify the crop mix throughout the year and therefore adapt it to water availability.

The results of the PMP model show that irrigation is a vital practice for over half of the GSP and that the absence of irrigation would lead to a substantial change in the agricultural landscape of the area of the CER.

The simulation put forward in this chapter is useful for obtaining an estimate of the agricultural production tied to the quantity of water made available thanks to the Emilia Romagna Canal. For a complete analysis, one must also note that, with the absence of water supply attributable to the CER, farmers would not be left completely without water, they could at least in part resort to other sources obtainable through self-supply, a method that is already present in the territory concerned. Therefore, the actual loss in agricultural production would be lower than the one shown in the simulation, but with all the negative externalities that withdrawals from wells and aquifers would entail, first and foremost subsidence and land collapsing, as was illustrated at length in chapter 5 on its environmental and ecosystem value.

5.1 THE ECOSYSTEM SERVICES: THE THEORETICAL APPROACH

The ecosystem services

This section includes the introduction of the concept of Ecosystem Services and the internationally recognised and shared scheme to classify and measure the benefits guaranteed by the ecosystems to human beings.

The second paragraph includes a description of the environmental benefits deriving from the functions performed by the CER, while the third paragraph includes an economic quantification of these benefits, through the relevant scientific literature.

5.1.1 The ecosystem services

What are ecosystem services?

Ecosystem services are defined as the “multiple benefits provided by the ecosystems to *human beings*” (Millennium Ecosystem Assessment, 2005). The safeguard and restoration of the ecosystem services, in order to guarantee the key role for life on earth and human welfare, are among the priorities identified in the Strategies on biodiversity both at a national and EU level.

Although the concept of ecosystem service has ancient origins (Marsh, 1864), it has become more relevant in the past fifty years, going from a prevailing interest in the ability of ecosystem services to increase public attention towards the biodiversity conservation, to a progressive involvement of economic decision making mechanisms and strategic planning (Gómez-Baggethun et al., 2010). In this perspective, giving the right economic value to ecosystem services allows for a better management and maintenance of the ecosystems that provide them, through the creation and implementation of suitable conservation and compensation mechanisms and instruments.

The *Millennium Ecosystem Assessment* (2005), the largest and most in-depth collection of information hitherto acquired on the state of the ecosystems in the world, classified ecosystem functions into four categories described in table 4.8. These categories are sometimes reduced to three, integrating services supporting habitats into other categories (normally into availability). This is the case, for example, of the *EU Common International Classification of Ecosystem Services* (CICES version 5.1) (<https://cices.eu/>).

The ecosystem services: benefits provided to humanity

One can therefore note that the ecosystems provide humanity with a great variety of services and advantages and, nevertheless, their real value – in the long run – is not “accounted for” in the economic projections of society. While on the one hand the demand for ecosystem services has been growing greatly ever since 1960, at the same time in the past 50 years humans have modified the ecosystems with a speed and force that had never been witnessed before. The growing need for food, freshwater, timber, fibres and energy sources is resulting in an irreversible biodiversity loss across the entire planet, and it has been estimated that 60% of the ecosystem services of the world have by now been undermined.

Table 5.1 – Categories of Ecosystem Services

Categories	Ecosystem functions	Ecosystem services
SUPPORTING <i>(services supporting habitats)</i>	It includes the services that allow for the formation of all the indispensable elements for the growth and development of natural organisms, so as to guarantee the conservation (on site) of biological, genetic and evolutionary process-related diversity.	Oxygen production
		Control of the nutrient cycle
		Habitat conservation
		Biodiversity conservation
PROVISIONING <i>(supply services)</i>	This includes all the consumption goods and resources deriving from the ecosystems (both natural and semi-natural) which humans resort to to meet their needs.	Food
		Raw materials
		Freshwater
REGULATING <i>(regulation services)</i>	This includes benefits deriving from the control of the ecosystem processes, such as regulating the climate, air quality, water purification, hydro-geological instability phenomena, etc.	Gas control
		Climate control
		Water control
		Soil control
		Protection from hydro-geological instability
		Pollination
		Habitats for biodiversity
CULTURAL <i>(cultural services)</i>	Natural ecosystems contribute to maintaining human health because they guarantee opportunities to reflect, for spiritual enrichment, cognitive development, recreational and aesthetic experiences. Therefore, this category includes intangible services such as beauty of the landscape and its fruition (tourism), the welfare generated by outdoor activities (walks and sport), the importance of historical elements and those with which the local community identifies.	Inspiration for culture, art, educational and spiritual values, sense of identity
		Aesthetic values
		Recreational values

Source: Millennium Ecosystem Assessment (2005)

Fields of application and methods

Therefore, it has become vital to introduce the concept of ecosystem services in decisions on the management and planning of the territory, for local governments to control the pressures that threaten the ecosystem and the way it functions, to improve its effectiveness and “build” a governance model based on instruments that can preserve and/or implement these services, such as forms of monetary contributions.

Traditional methods are unable to quantify the value of the ecosystem services as key elements for human welfare. That is why new instruments and approaches are being developed, which entail in the way they can be applied the use of sustainability indicators and of the ecosystem service categories as vital analysis elements.

Assessment models: “The Economics of Ecosystems and Biodiversity” - TEEB

These new assessment models include the “Economics of Ecosystems and Biodiversity” (TEEB), an initiative promoted by the UN Environment Programme and co-ordinated by the TEEB office in Geneva, Switzerland. “TEEB for Agriculture & Food” (TEEBAgriFood) includes various research projects focused on the comprehensive assessment of agriculture and food systems along their value chains, assessing the most important externalities. The goal pursued by TEEBAgriFood is that the assessment methods used are integrated and adapted to local communities, to best inform the “policy-makers” (TEEB, 2015).

This type of assessment models ensures that the material interactions between the environment, the economy, society and health, as well as agricultural production and household consumption are taken into consideration.

5.1.2 The eco-agri-food systems

The agricultural system of reference: eco-agri-food system

The territorial context analysed in this study is an agricultural system indicated by the scientific literature as eco-agri-food. Within this context, agricultural production makes a major contribution to meeting the food-related needs of human beings, but at the same time it directly and indirectly influences the natural resources. Agricultural activity, in all its forms, requires an intensive use of ecosystem services (land, water, biodiversity), which are the true raw materials useful for production. Therefore, agriculture can make a major contribution to the maintenance, improvement or degradation of soil quality and all related ecosystem services. For example, the need to eradicate certain diseases or accelerate development processes drives many farmers to make heavy use of chemicals that undermine (sometimes irreparably) the soil’s biodiversity. Conversely, regenerative agricultural techniques (for example biodynamic, integrated pest management and organic) favour the maintenance not only of soil fertility, but also of biodiversity.

Agricultural production and externalities

Agricultural production generates positive externalities if it increases the related ecosystem services, or negative ones if it spoils them, thus generating direct costs or benefits to the consumer. However, although there is a value to these externalities, it is hard to quantify it, because it is not a good/service that is traded on the market and therefore it does not have a reference price.

For example, a cost associated with agricultural production is the quantity of greenhouse gas emissions produced (the estimate varies between 11% and 15% of all global emissions, source: Intergovernmental Panel on Climate Change 2014); vice versa, a benefit generated by agriculture is employment: there are 1.5 billion people employed in the world in this sector, thus making it one of the most important economic activities in the world.

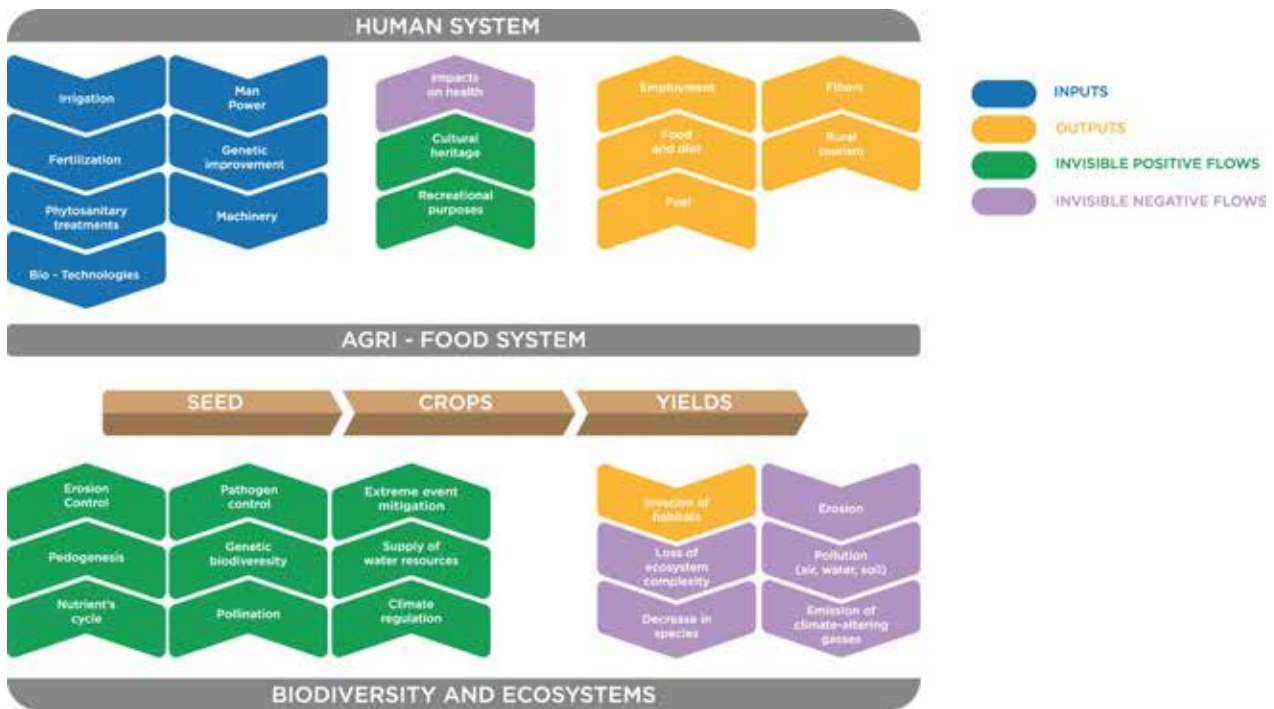
A further example is the importance of evapotranspiration from Amazonian rainforests. This phenomenon allows for the formation of clouds that, when they reach the Andes, generate rainfall on the La Plata basin, a breadbasket of South America. The value of the production of this agricultural economy is of enormous value and heavily depends on the rainfall cycles. However, the value of evapotranspiration from Amazonian rainforests for agricultural production is neither recognised nor quantified.

The structure of the TEEBAgriFood

TEEBAgriFood makes all costs and benefits visible, providing a universal and comprehensive assessment framework. Some of these benefits are economically visible, i.e. accounted for based on the market prices, while others are economically invisible and require a series of assessment techniques to estimate their prices, which are in fact called “shadow” prices.

An important goal in the TEEBAgriFood assessment framework is to guarantee that the associated flows and stocks are made explicit. The intermediate flows, meaning those that contribute to the production of a good or service and its final value, are often invisible, meaning that they are usually ignored in the decision-making process. For example, the pollination process is an intermediate flow that contributes to the agricultural yield, but it does not have an economic value, in that it merges with the final price of the agricultural product that it contributed to generating.

Figure 5.1 – Ecosystem services in the eco-agri-food systems



Source: TEEB, 2015

The four flows mapped in the TEEBAgriFood framework

Therefore, given that many intermediate flows are incorporated in the final flows, often including the ecosystem services, it is important to recognise and account for these intermediate flows separately. The four main types of final and intermediate flows mapped in the TEEBAgriFood framework are:

- ✓ **Production and consumption of agricultural and food products:** these elements are relevant when it comes to understanding the added value of food processing and distribution. They are economically visible, therefore recorded both in physical terms (quantity) and in monetary terms (income and added value), and are measured in the national accounts. The recommendation is that said flows are recorded based on type of good (for example maize, rice, beef etc.) and suitably classified based on the type of company (for example type of production practice, range of sizes of the farm etc.).
- ✓ **Agricultural and food inputs:** they are important to understand the food value chain, including all the “intermediate” resources, meaning those used for food production (for example water, energy, fertilisers, pesticides and medication for animals). There are major differences in the resources employed as inputs between alternative production systems for the realisation of the same product (for example between intensive and extensive production systems); consequently the environmental and financial costs are different, take for example water (natural application through rainwater or irrigation), fertilisers (for example through natural inputs such as compost or artificial ones) and pesticides (biological control of parasites or industrial pesticides).

- ✓ **Ecosystem services:** agricultural production favours the creation and safeguard of certain ecosystem services, for example climate control through carbon sequestration, soil conservation (for example preventing subsidence) and maintaining strictly aesthetic and cultural elements (rural culture, landscape value etc.). As these ecosystem services are generally not traded on the market, as they are considered public goods, their generation by the agricultural activities is not included in the calculation of the agricultural production's value, nor is their increase or decrease highlighted by specific economic values.

- ✓ **Residual flows:** they include various pollutants (greenhouse gas emissions, excessive nitrogen or phosphorus emissions), harvest losses, waste water and food waste along the eco-agri-food value chain. Residues are flows of solid, liquid, and gaseous matter and energy that are discarded, discharged, or emitted by plants and households through production, consumption, or accumulation processes (TEEB, 2015). These residual flows are some of the most severe negative externalities in that they affect human welfare and the overall functioning of the eco-agri-food systems; recording and measuring them is therefore vital. Food waste can easily be measured in tonnes; however, for a more precise analysis, it must also be indicated in calories, nutrients and economic value. The poorer the communities where the harvest losses occur, the more harvest losses are detrimental: the inability to preserve the resources in the long run through storage and/or refrigeration owing to a lack of means leads to a vicious cycle through which agricultural producers, following crop failure, witness their small income decrease and their level of poverty rise.

5.2 THE ENVIRONMENTAL BENEFITS GENERATED BY THE ACTIVITY OF THE CER

5.2.1 The ecosystem services within the CER framework

The ecosystem functions performed by the CER

The hydraulic management functions of the surface water performed by the CER (water supply, regulation and distribution) lead to major consequences concerning environmental safeguard in all its areas of competence.

The territorial context and landscape functions

In the rural plain territory, also in the areas with a widespread and vital production capacity, there is the presence, sometimes marginal, of **pre-existing landscapes of interest**, such as historical agricultural and territorial signs and arrangements, traditional agrarian arrangements, and a rich network of historical infrastructural elements that still connote it (canals, elements of centuriation, historical centres and roads, etc.). The CER allows for the economic sustainability of the Associated Reclamation Consortia and, indirectly, the reclamation of the plain that has shaped the territory and generated the structure of the current landscape.

The rural territory and ecological networks

There are also areas of the rural territory with lower agronomic prestige, less artificialisation of the crop structures and greater natural and environmental values, which are identified in the territorial planning in the “**ecological networks**” (at a local, provincial, national and European level, such as the Rete Natura 2000), aimed at preserving the remaining biodiversity present (protected areas, wetlands, nature and ecological protection areas). Within this framework the **waterway system** plays an important role: when it comes to protecting biodiversity and enhancing ecosystems, it is a pillar of the ecological networks. In the Emiliano-Romagnola plain the ecological network consists of various types of wetlands, woods and thickets, grasslands, hedgerows and hedge rows, waterways (elements that are sometimes recognised thanks to specific values such as being Sites of Community Importance or Special Protection Zones) and is an opportunity to rebuild and enhance natural and semi-natural elements that have disappeared or are residual.

The CER guarantees the presence of water by favouring the preservation of the landscape and nature

The presence of water in plains, guaranteed by the activity of the CER also during the drought seasons, clearly contributes to the **formation and preservation of the typical landscape of the cultivated plain**, as well as that of areas of high **naturalistic value related to water, such as wetlands and areas near canals** (Cavazza et al., 2017). At the same time, the survival of the habitats present is guaranteed, both in agricultural areas and natural ones.

The CER and its research, experimentation and technical assistance on irrigation and water saving activity

These ecosystem services, although they derive from the irrigation activity guaranteed by the CER, compete with it at the same time, above all during the periods of droughts, which are ever more frequent and intense.

To preserve these vital ecosystem services, **the CER for nearly sixty years has been carrying out an intense research, experimentation and technical assistance on irrigation and water saving activity.** This started with the goal of making available for farmers not only water supply but also all the necessary information for a correct, economical and not wasteful use of water. This activity is mainly performed as part of European projects (Horizon 2020, Horizon Europe and PRIMA Med.) and projects of the Emilia-Romagna Region (operational groups of the EIP, RDP 2014-2020).

The ecosystem services of the CER based on the MEA categories

Below are the main services provided by the ecosystems present in the plain area of competence of the CER and influenced by its activities. These ecosystem services are presented using the categories of the *Millennium Ecosystem Assessment* (2005) described above.

Table 5.2 a – The Ecosystem Services provided by the CER – Supply Services

Supply services	Actions of the CER and benefits
Availability of agricultural resources	The control and water availability activities of the CER provide the resources for the development, not only of most of the irrigation agriculture of the area studied (whose value was calculated in the previous chapter), but also by the proliferation of natural ecosystems that provide products and services to society, thanks to the return flows of the agricultural activity.
Raw material availability	The CER's activities have a positive impact on the availability of products deriving from its agricultural activity (by-products, soil conditioners, fuel etc.) which can be used as inputs for other activities. The ecosystems and biodiversity provide many plants used in the medical field and some raw materials for the pharmaceutical industry.
Freshwater availability	The CER guarantees a water availability that is not only used for the agricultural activities, but also by non-agricultural users. The CER, moreover, contributes to redistributing the water and creating new ecosystems, for example through the return flows of agriculture and the losses from the canals that generate new natural areas. The activities of the Consortium, moreover, provide surface water that helps preserve the groundwater present across the territory and counter saline intrusion in the aquifers along the coastline.

Table 5.2 b – The Ecosystem Services provided by the CER – Cultural Services

Cultural services	Actions of the CER and benefits
Aesthetic value	The CER's activities of maintaining "green" infrastructure and historical infrastructure, financing research, communication and dissemination activities (conventions, activities in schools, guided tours) are the essence of this specific ecosystem service. In the territory of the CER there are natural sites, oases and protected wetlands that survive thanks to the CER's (and the associated Consortia's) activities of water control that are now an integral part of the landscape. The CER is also a historical institution with a great cultural value, in particular concerning the infrastructure that has now acquired a historical value. It has an important archive and a library, cultural heritage, available to citizens and scholars.
Physical and mental well-being	The role nature plays in maintaining physical and mental health is ever more recognised, In the plain territory the Consortium ensures the management of the canals and the banks which, in turn, allows for the safe use of adjacent green areas, maintaining the agri-eco-food system and the typical agricultural landscapes protected in the Plans in force (for example: landscape of the historical plain reclamations; Centuriation landscape etc.).
Sense of belonging to a place	The CER's activity provides the necessary water for growing the typical products of the area (CDO and IGP, such as the Bologna potato or the Medicina onion) which contribute to generating among the local population a sense of identity and belonging to the territory.
Tourism	The ecosystems and biodiversity play an important role for many types of tourism, with major economic advantages for many regions. Ecotourism can also spread awareness among people on the importance of biodiversity and thus contribute to strengthening other ecosystem services. The CER's activity of water supply and control allow for the maintenance and enhancement of the agri-eco-food system, with positive externalities in terms of tourist attraction. In the territory this translates into the chance to engage in forms of ecotourism and agritourism, to participate in dissemination activities and opening to the public historical sites and artefacts (including those of the Reclamation Consortia under certain institutions, for example the detention basins of Campotto, Bassarone and Vallesanta and the historical plant of Bagnetto).

Table 5.2 c – The Ecosystem Services provided by the CER – Services supporting the habitats

Habitat supporting services	Actions of the CER and benefits
<p>Habitat preservation for animal and plant species</p>	<p>The habitats provide everything that plants and animals need to survive: food, water and shelter. Every ecosystem nurtures various habitats that can be vital for a species' life cycle. Migratory species, including birds, fish, mammals and insects, all depend on different ecosystems during their movements. In this specific analysis the CER's water supply activities contribute to creating a landscape where water is abundant, clean (thanks to phytodepuration) and made available to migratory animal species. In the CER's territory, all natural sites, oases and protected wetlands are considered part of this ecosystem service: Rete Natura 2000, provincial ecological networks, natural protection areas, shelters for migratory birds, the park of the Delta of the Po River, Punta Alberete, Valle della Canna etc.</p>
<p>Biodiversity maintenance</p>	<p>Genetic diversity is the variety of genes in animal and plant populations, it is what distinguishes species from one another, thus providing the foundation for the development of crops and livestock. Some habitats have an exceptionally high number of species, which makes them genetically more diverse than others and are known as "biodiversity hotspots". In the case of the CER, its activities (water supply and control, Second-Degree Reclamation Consortium) contribute to maintaining the vitality of the habitats. In the territory studied, biodiversity is concentrated in the wetlands, because the rest of the territory is very anthropised (human settlements and agricultural crops). The CER provides water to surfaces with specific hydraulic functions (such as the detention basins of land reclamation), which therefore acquire natural value; moreover, there are other prestigious protected areas that are indirectly served by the Consortium with its activities (for example Siti Natura 2000 with priority habitats for the European Union).</p>

Table 5.2 c – The Ecosystem Services provided by the CER – Regulation Services

Regulation Services	Actions of the CER and benefits
Mitigation of extreme events	Ecosystems and living organisms create defences against natural disasters (floods, storms, landslides etc.), thus preventing potential damage. For example, wetlands can contain the effects of floods. In the territory in which the CER operates they perform regulation and diversion activities of the Po and Reno Rivers. In an indirect manner, through the co-associated reclamation Consortia, the CER contributes to the continuity of the drainage and hydraulic defence activities.
Subsidence prevention	Subsidence is the (natural and/or anthropic) phenomenon of downward vertical movement of the ground. If it has an anthropic origin, it is mainly caused by the extraction of fluids from underground, such as water, hydrocarbons or gas. In the territory of the CER this phenomenon is heavily monitored, in that in the past 50 years a major downward vertical movement of the plain area of Emilia-Romagna was observed. Given the importance of the phenomenon, paragraph 5.3.4 includes an in-depth study accompanied by some estimates.
Local climate and air quality	Trees provide shade and influence rainfall and water availability both at a local and a regional level. Trees or other plants also play an important role in regulating air quality, removing pollutants from the atmosphere. The CER's activity, in particular its control and Second-Degree Consortium functions, indirectly contribute to maintaining the reclamation work of another marshy area, prone to diseases, in an agri-eco-food system. Moreover, the presence of water in the canals generates positive effects on the air temperature of the surrounding areas in the hot periods, thus guaranteeing an improvement of the local micro-climate.
Carbon dioxide (greenhouse gas) absorption from the atmosphere	The ecosystems regulate the global climate by absorbing greenhouse gases. As the trees and plants grow, they remove carbon dioxide from the atmosphere, storing it in their tissues. Thus the forest ecosystems provide a carbon storage service. Biodiversity too plays an important role by improving the ability of the ecosystems to adapt to the effects of climate change. In the CER's territory, the annual crops have a minor impact on this ecosystem service, while perennial crops (for example fruit trees and re-forested areas) have a greater impact.
Biological control	The ecosystems are important for the control of parasites and diseases transmitted by carriers that attack plants, animals and people. This happens through the activities of predators and parasites such as birds, bats, flies, wasps, frogs and fungi, which carry out a natural control activity. The CER makes a contribution in maintaining this ecosystem service: the CER, the land reclamation activities and the farmers that are part of a consortium have changed the environment to enhance the presence of species that contribute to the control of parasites and diseases.
Maintaining soil fertility	The activity of the CER enables the provision of superficial water resources from the Po River, thus avoiding the overexploitation of the groundwater. Soil fertility is essential for the growth of plants and agriculture: well-functioning ecosystems provide the soil with the necessary nutritional substances to support the plants' growth. The CER and the Reclamation Consortia under other institutions maintain a fertile and complex eco-agri-food system that, without their activities, would become a hardly arable swamp (and not available for other extra-agricultural activities). One can deem virtually null the issue of erosion prevention in that the CER is located on a plain area.
Pollination	Insects and wind pollinate the plants and trees, which are vital for fruit, vegetable and seed production. Pollination is an ecosystem service that is mainly provided by insects, as well as by some birds and bats. Specifically, all the CER's activities (water distribution and control, Second-

Degree Reclamation Consortium) are connected to this service: the CER is in fact an excellent eco-agri-food system where the crops, plants and pollinating insects benefit from one another.

5.3 THE ESTIMATE OF THE ECOSYSTEM SERVICES PROVIDED BY THE CER

5.3.1 The Total Economic Value (TEV) theory for the economic assessment of ecosystem services

The assessment of the Ecosystem Services

The economic assessment of the Ecosystem Services is a process that consists in the monetary quantification of the value of the benefits generated by a specific ecosystem.

The approach that is normally used in the literature to assess the ecosystem services refers to what is known as the Total Economic Value (TEV), which can be defined as the sum of the values of all the services generated by the natural capital (rivers, forests, seas etc.), both in relation to the present and the future (Robinson, 2001; Dziegielewska, 2009; Barbier et al., 1997; Dosi, 2000). Some Ecosystem Services can be treated as any other good or service sold on a given market, to which one must therefore assign a value based on the demand or based on the importance given to the service. A monetary value can easily be given to these services, because of the analogy with what happens with any other good or service that is traded between a producer and a consumer.

Table 5.3 - The components of the Total Economic Value and the associated techniques for the monetary quantification of the Ecosystem Services

Components of the total economic value	USE VALUE			NON-USE USE	
	Direct use value	Indirect use value	Option value	Existence value	Bequest value
MEASUREMENT METHODS	Direct market techniques	Indirect market techniques	Non-market techniques	Participatory assessment	
	When an exchange value can be determined	There is an estimation of the costs avoided of potential damage or replacement costs (engineering alternatives), or the costs that a subject sustains to enjoy a service (travel costs, hedonic price).	Through direct interviews one evaluates the willingness to pay to maintain a certain Ecosystem Service or the willingness to be compensated for any reduction of this service.	It includes the collective definition of values, by including the opinions of experts (expert knowledge) and/or local players (local knowledge).	

Source: Bräuer 2003, MEA 2005

The Total Economic Value (TEV) categories

At the same time, there are other types of ecosystem services to which one cannot directly attribute a monetary value because they cannot be considered goods to be sold on a given market. Therefore, to economically quantify these services, one must apply specific assessment techniques that can vary depending on the type of service.

The Total Economic Value (TEV) is divided into two macro categories: “Use Value” and “Non-use Value”.

“Use value”

“Use value” refers to the (current or future) consumption of a given good or ecosystem service. When there is a “direct” use by humans the term used is direct value of use: it is used for all supply services (for example water supply) and for all goods or services that do not entail consumption *per se* (for example, enjoying a view for those who live in a given territory or tourists who go there to enjoy the view). On the other hand, an “indirect” type of use indicates the use of a good or Ecosystem Service takes place in an indirect way, meaning that it does not derive from direct consumption but rather refers to the effects generated on other goods or services: for example the benefits deriving from control services, for example the drainage of the river waters, which prevents the flooding of a given territory.

The “Use value” category also includes the “option value”, which identifies a use that is not current but future. The individual does not currently use the good/service but is nevertheless willing to pay a given sum to have the chance in the future to benefit from this good/service. The definition of option value is tied to the concept of risk aversion: since people are unsure about the future supply of the good/environmental service, they are willing to pay today a sum of money today that guarantees them the chance to use it in the future.

“Non-use value”

The second category with which the Ecosystem Services are assessed is the “non-use value”: it refers to the “Existence value” based on the awareness of individuals that the good considered exists and continues to exist, even if they will never use it (one can be willing to pay for the preservation of the Amazon forest even if one will never visit it, but simply because one judges positively its existence). The value of non-use category also includes the “Bequest Value”, which derives from the fact that those who make the assessment is willing to pay a certain sum for future generations to continue enjoying the good or service in question.

The assessment methods used by economists usually simultaneously quantify the use and non-use values, as it is hard to consider these two types of value separately (Freeman, 2003).

5.3.2 The commonly used methods to assess the Ecosystem services

Methods to assess the market in the absence of a market

The goods and environmental services provided by the ecosystems are not easy to assess. Some environmental resources, owing to their very nature, lack a free trade market in which one determines the optimal prices and quantities. For example, there is no exchange market for clean water courses or for biodiversity, for which one cannot identify a market price.

To determine the monetary value of the environmental resources without a market, various assessment methods have been developed in the economic literature. The following are the most important.

Surrogate markets

The surrogate (or replacement) market method entails estimating the value of an environmental good (which has no market) by considering the impact and externalities it has on the value of a market good, which is therefore quantifiable.

There are two assessment methods based on this concept: hedonic prices and the travel cost technique.

Hedonic prices

Hedonic Price method

The typical application is the real estate market: through an econometric analysis, one calculates the relation of the price of the properties both with the structural characteristics of the properties (size, conditions of use etc.) and with the environmental and context characteristics, so as to assess the effect of the latter in determining the price.

This method is often hard to apply because of the difficulties in collecting the data.

Travel cost

Travel Cost Method

It is based on revealed preference theory: the basic hypothesis is that the travel time and cost sustained by the visitors to reach a place are the “access price” to the site itself. Every individual has a different travel cost, which varies together with the kilometres and expenses connected to the travel. By aggregating all this information one can estimate the aggregate market demand for the access/availability of an environmental resource.

The method is mostly used to estimate the benefits generated by areas with a great recreational value and high public use.

Preventive expenditure

The preventive expenditure method is based on the costs generated by the expenses aimed at reducing environmental damage (air pollution, water contamination, landslides etc.). The environmental value is calculated based on what people are willing to spend to prevent the decay of natural resources.

Contingent valuation method

The contingent valuation method aims to estimate the economic value of environmental goods through an investigation on the population that reveals the preferences of consumers. The method is based on the simulation of a hypothetical or contingent market, to estimate the willingness to pay for the maintenance of a

given natural resource (Loomis et al., 2000). This method therefore aims to assess the Willingness To Pay (WTP), meaning the maximum value that individuals are willing to pay to enjoy a good or resource.

Benefit Transfer

The Benefit Transfer is a valuation technique that consists in transferring the information and estimates on the value of one or multiple natural resources calculated by a given number of scientific studies on other territorial areas similar to the one being studied. This instrument is a process entailing the research, analysis and selection of the results obtained from previous studies on the same issue, but in different geographical areas, though similar.

The Benefit Transfer method was applied to the present study, based on what is described in the following paragraph.

5.3.3 The Benefit Transfer method to assess the ecosystem services provided by the CER

The Benefit Transfer application

The first step to apply the Benefit Transfer technique was to identify a selection of studies that covered socio-economic and environmental contexts that were similar to those in which the Consortium for the Emilia Romagna Canal is active.

The selected studies and the creation of a dBase

The studies were selected following thorough research on the relevant existing literature and a consultation of various public databases (for example, the database of Davis University, in California: <http://buvd.ucdavis.edu/>). All the studies taken into consideration were inserted in a database of reference, which included information regarding: authors, title, year of publication, country, characteristics of the population, environmental risk factors, types of environmental goods and services assessed, climate change scenarios (if recorded), stressors, type of study (primary/secondary source), assessment method, timeframe of reference, unit of measurement of the willingness to pay, discount rate (if recorded and available), assessed ecosystem services, abstract and value/range of values of the willingness to pay (WTP) measured in convertible units (for example: Euros per person per year, Euro per house etc.).

The creation of this database allowed for the filtration and selection of the most relevant papers for the Emilia Romagna Canal case study.

The fundamental steps in the selection of the studies useful for the estimation were the following:



Step 1

Initial screening of the scientific literature

In the first screening phase 1,093 studies were selected, based on the following criteria:

- Only studies (journals, reports, books, working papers) whose analysis focus were ecosystem services as defined by The Economics of Ecosystems and Biodiversity (TEEB) international programme
- Only studies that assessed ecosystem services based on the Total Economic Value (TEV) Theory method

Only studies that dealt with ecosystem services regarding water availability and/or assessed contexts in which agricultural production (eco-agri-food systems) was present.

Step 2

Identification of the relevant studies for the CER case study

Starting from the selection of 1,093 studies deriving from Step 1, a stricter selection was carried out based on the following criteria:

- 1) Only studies that take into account territorial contexts in which there are agricultural activities. Consequently studies focusing solely on water availability were excluded.
- 2) Only studies that cover territorial contexts in which there is at least one of the Ecosystem Services identified as relevant to the Emilia Romagna Canal in table 5.2.

The application of these criteria led to the selection of 61 scientific studies.

Step 3

Further selection of the studies

In the third phase the scientific studies were further selected based on the following criteria:

- 1) Only studies published on journals, reports, books and working papers; conference papers were left out.
- 2) Only studies that reached an economic assessment of the ecosystem services in terms of annual value were considered, while studies that offered a capitalised value were left out. This choice was based on the goal of avoiding further elements of uncertainty such as the choice of a suitable discount rate to annualise a capitalised value.
- 3) Only studies conducted in the past 20 years were considered, i.e. between 2002 and today.

Table 5.4 illustrates the 17 studies chosen through the selection process.

Table 5.4 – List of studies selected for the economic assessment of the Ecosystem Services with the Benefit Transfer method

Authors	Title	Year	Country
Bielski, S., R. Marks-Bielska, A. Novikova, and B. Vaznonis	Assessing the Value of Agroecosystem Services in Warmia and Mazury Province Using Choice Experiments	2021	Poland
Aziz, T., and P. Van Cappellen	Comparative Valuation of Potential and Realized Ecosystem Services in Southern Ontario, Canada	2019	Canada
Polizzi, C., M. Simonetto, A. Barausse, N. Chaniotou, R. Kankanen, S. Keranen, A. Manzardo, K. Mustajarvi, L. Palmeri and A. Scipioni	Is Ecosystem Restoration Worth the Effort? The Rehabilitation of a Finnish River Affects Recreational Ecosystem Services	2015	Finland
Galioto, F., Marconi, V., Raggi, M., Viaggi, D.	An Assessment of Disproportionate Costs in WFD: The Experience of Emilia-Romagna	2013	Italy
Dachary-Bernard, J. and T. Rambonilaza	Choice experiment, multiple programmes contingent valuation and landscape preferences: How can we support the land use decision making process?	2012	France
Martin-Lopez, B., M. Garcia-Llorente, I. Palomo and C. Montes	The Conservation against Development Paradigm in Protected Areas: Valuation of Ecosystem Services in the Doñana Social-Ecological System (southwestern Spain)	2011	Spain
Jenkins, W. A., B. C. Murray, R. A. Kramer and S. P. Faulkner	Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley	2010	United States
Wilson, S. J.	Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature	2010	Canada
Southgate, D., T. Haab, J. Lundine and F. Rodriguez	Payments for Environmental Services and Rural Livelihood Strategies in Ecuador and Guatemala	2010	Guatemala, Ecuador
Thompson, J. and M. Anielski	Economic Activity and Ecosystem Services in the North Saskatchewan River Basin	2010	Canada
Troy, A. and K. Bagstad	Estimating Ecosystem Services in Southern Ontario	2009	Canada
Batker, D., I. De la Torre, M. Kocian and B. Lovell	The Natural Economy of the Nisqually Watershed	2009	United States
Wilson, S. J.	Ontario's Wealth, Canada' Future: Appreciating the Value of the Greenbelt's Eco-Services	2008	Canada
Wilson, S. J.	Lake Simcoe Basin's Natural Capital: The Value of the Watershed's Ecosystem Services	2008	Canada
Alberini, A.; P. Rosato; A. Longo; and V. Zanatta	Information and Willingness to Pay in a Contingent Valuation study: The Value of S. Erasmo in the Lagoon of Venice	2004	Italy
Travisi, C.M., and P. Nijkamp	Willingness to Pay for Agricultural Environmental Safety: Evidence From a Survey of Milan, Italy, Residents	2004	Italy
Carlsson, F., P. Frykblomb and C. Liljenstolpec	Valuing Wetland Attributes: An Application of Choice Experiments	2003	Sweden

Source: Nomisma

Step 4

Value Transfer for the economic assessment

The selection process of the scientific literature therefore led to the selection of 17 studies used to obtain the estimates of the value of the ecosystem services provided by the Second-Degree Reclamation Consortium for the Emilia Romagna Canal.

To obtain these estimates one must transfer the results obtained from these studies to the specific case of the CER. For the transfer of the values the following data concerning the territory of competence of the CER was used:

- **248.239** hectares of territorial surface (source: CER);
- **1.458.378** inhabitants (source: ISTAT);
- **654.540** inhabitants (source: ISTAT).

Moreover, the values estimated by the 17 studies were converted into Euros through the corresponding exchange rates, and were updated through consumer price indices of the various countries.

To transfer the estimates obtained from the 17 scientific studies to the CER case study, the entire surface of competence of the CER was taken into consideration, not only the equipped part, given that the environmental benefits are not just limited to the irrigable surface, but also include the more extended area of 248 thousand hectares, which indicates a sort of potential environmental value.

Table 5.5 – List of studies selected for the economic assessment of the Ecosystem Services with the Benefit Transfer method

Type of soil use	Surface		Values per hectare (€)			Total values (Millions of €)		
	Hectares	Percentage	Minimum	Average	Maximum	Minimum	Average	Maximum
Permanently irrigated lands	170,151	68.5%	59	260	413	10.004	44.254	70.249
Permanent crops	36,495	14.7%	59	596	1134	2.146	21.766	41.386
Discontinuous urban fabric	18,722	7.5%	0	0	0	0.000	0.000	0.000
Continuous urban fabric	8,144	3.3%	0	0	0	0.000	0.000	0.000
Bodies of water	5,558	2.2%	194	1723	3861	1.077	9.577	21.461
Wetlands	4,308	1.7%	455	4694	11584	1.960	20.225	49.907
Shrubby and/or herbaceous vegetation	1,568	0.6%	243	727	1263	0.381	1.140	1.980
Forests	1,160	0.5%	3397	3972	4521	3.941	4.609	5.245
Non-irrigated arable land	1,147	0.5%	59	228	413	0.067	0.262	0.474
Waterways	985	0.4%	194	1553	2955	0.191	1.529	2.910
TOTAL	248239	100.0%				19.767	103.361	193.612

Source: Nomisma

Division of the CER's territory for the purposes of the economic assessment

For the purposes of the economic-environmental assessment, the territory managed by the CER was divided into 10 types of soil use indicated in table 5.5, based on the Corine Land Cover¹⁹ classification: more than two thirds are permanently irrigated land (170 hectares), 14.5% is dedicated to permanent crops (36 thousand hectares), 10.8% includes urban areas with different degrees of soil exploitation (26 thousand hectares, of which 18 thousand of discontinuous urban fabric and 8 thousand of continuous urban fabric), 2.2% includes water bodies (5 thousand hectares), 1.7% wetlands (4 thousand hectares), while the remaining area of the territory includes

¹⁹ <https://land.copernicus.eu/pan-european/corine-land-cover>

herbaceous vegetation, forests, non-irrigated arable land and other water bodies (nearly 5 thousand hectares, equal to 2% of the total area).

As was already stated, the selection process only considered scientific studies that examined territorial contexts in which there is at least one of the Ecosystem Services deemed relevant to the Emilia Romagna Canal and listed in table 5.2.

Regarding the ecosystem service related to the availability of agricultural resources (table 5.2), there is no risk of repeating the economic assessment with what was said in chapter 4 on agricultural value, due to the fact that this category includes agricultural products not traded on the market, while in chapter 4 the agricultural value was calculated as the value of the GSP (gross saleable product), meaning the agricultural production sold on the market. It is clear that this specific ecosystem service is of little importance within the set of services considered, among which the control services and services supporting the habitats certainly play a vital role.

Moreover, with the Benefit Transfer method one cannot assess the single ecosystem service, it provides economic values regarding the totality of ecosystem services that a given scientific study examines. The selected scientific studies provide the values of the ecosystem services divided based on type of soil use according to the Corine Land Cover categories. Hence the reason why the surface of competence of the CER was divided into these categories, with the goal of attributing an economic value to each category to then reach a total economic value through the aggregation of the values of each type of soil use²⁰.

Therefore, for each of the 10 types of soil use present in the territory of the CER, within the 17 studies selected, the minimum, average and maximum economic unit values were obtained, and then the respective total values (minimum, average and maximum values) were obtained by multiplying the unit values of each type of soil use by the corresponding surface.

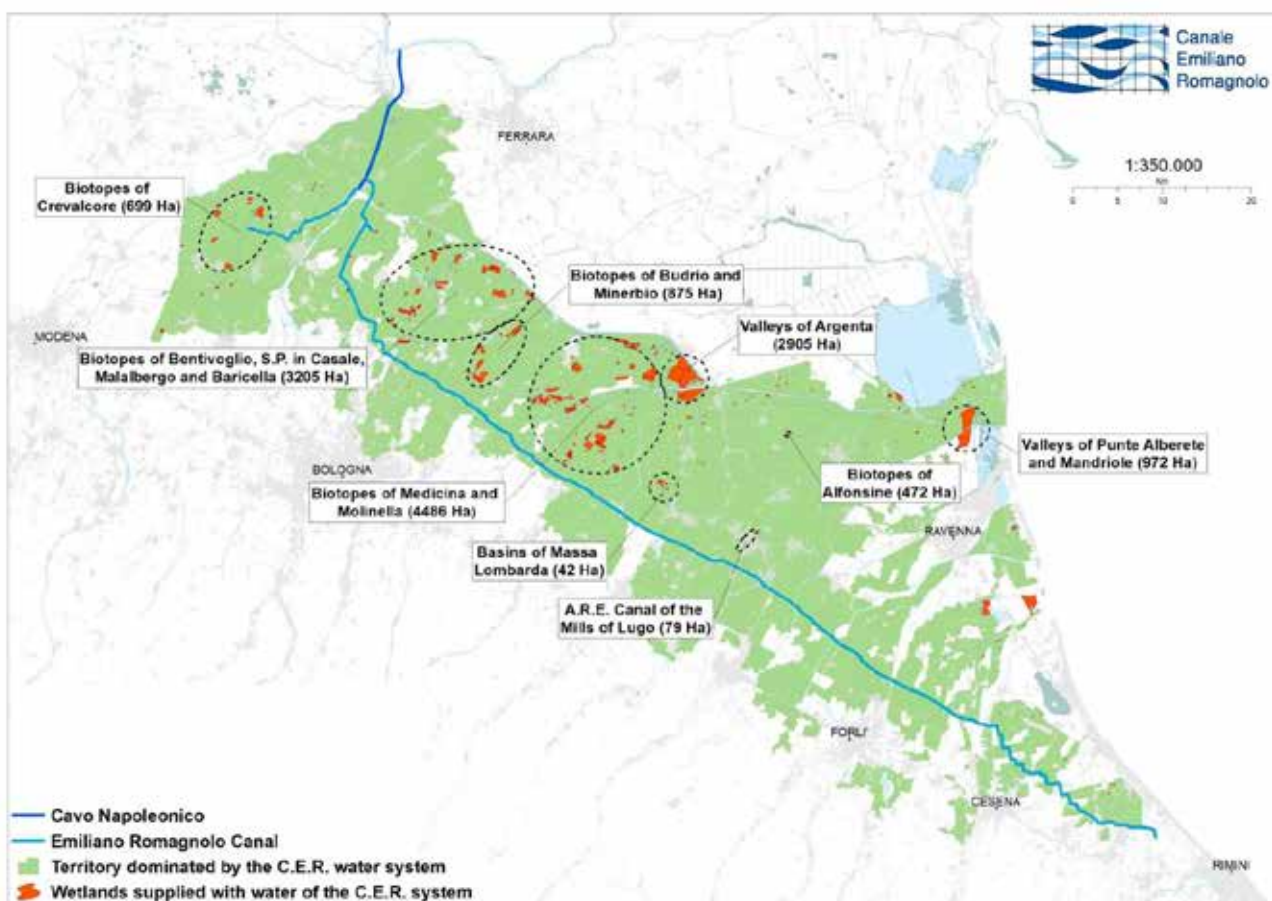
Unit values per hectare

In unit terms, meaning economic value per hectare per year, the wetlands have the greatest ecosystem value, with an average value of nearly 4,700 Euros per hectare, but at the same time by a great variety within the 17 studies examined, as it ranges from a minimum value of 455 Euros to a maximum of 11,584 Euros per hectare. They are followed by the forests, which as stated previously account for a residual share of the territory managed by the CER, with an average ecosystem value of nearly 4,000 Euros per hectare, in this case with a very low variety between the 17 studies, proof of a greater uniformity of judgement for this type of soil use. In third position in terms of environmental importance are the bodies of water and waterways, with an average value around 1,700 Euros per hectare, while the type of soil use most present in the area of the CER, meaning perennially irrigated land, shows an average value of 260 Euros per hectare, while the areas dedicated to permanent crops generate an ecosystem value of 596 Euros per hectare. For each of the 10 types of soil use present in the territory of the CER, the minimum, average and maximum economic values

²⁰ For further details on the ecosystem services mapped by each of the 17 selected scientific studies and the economic values obtained from studies divided based on type of soil use, see annex B at the end of the document.

within the 17 selected studies were obtained, to then obtain a complete range by applying these values to the surface of each type of soil use.

Figure 5.2 – Map of the wetlands present in the territory of the CER

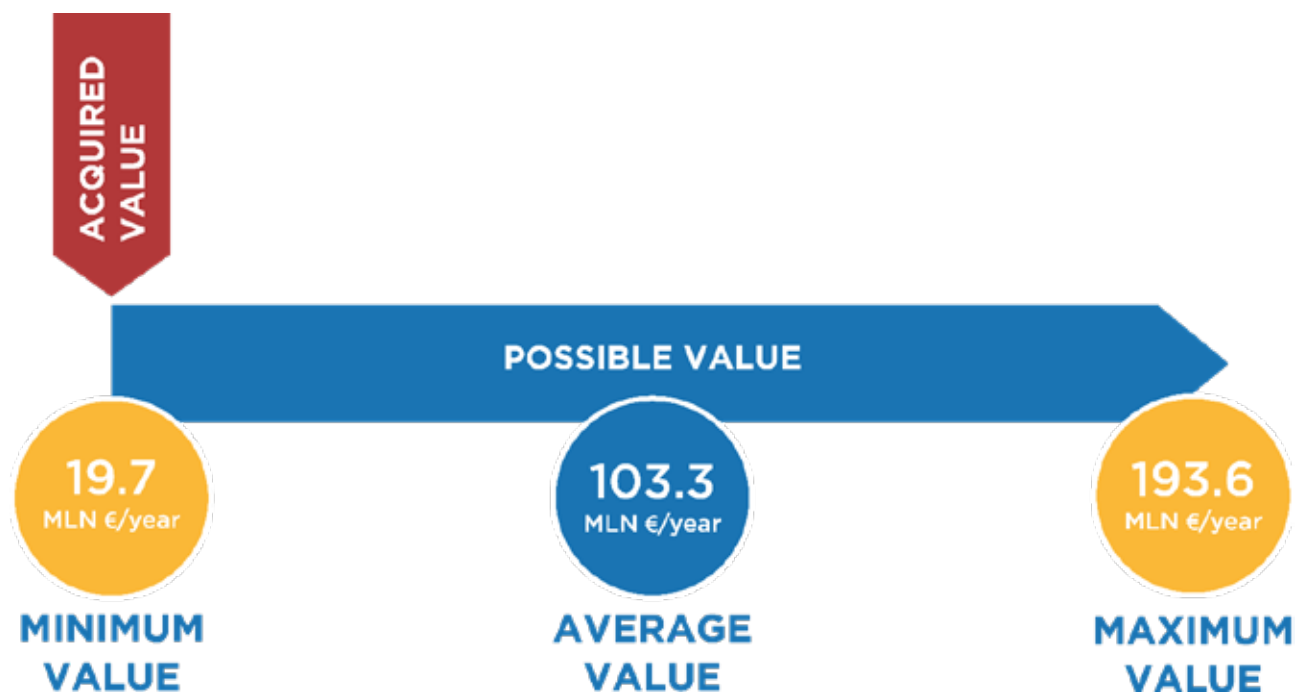


Source: The second-degree reclamation consortium for the Emilia Romagna Canal

The total values

By applying these parameter values to the extension of the single types of soil use and adding up all values one can determine that the Ecosystem Services provided by the CER have a total economic value ranging **between 19.7 and 193.6 Million €/year**, with an average value of **103.4 Million €/year**. As they are by far the largest type of soil use, permanently irrigated land makes up the largest total value, equal to 44.2 Million €/year, followed by permanent crops with 21.7 Million €/year. The wetlands, though occupying a limited surface in the area of competence of the CER, generate nearly 20% of the total ecosystem value, shown by an average value of 20.2 Million €/year. On this type of soil use there is less uniformity of judgement among the 17 studies considered but, also considering the minimum values rather than the average ones, one can note that, though occupying a surface equal to 1.7% of the total surface, the wetlands can generate 10% of the total ecosystem value (1.9 Million €/year out of a total of 19.7 Million €/year).

Figure 5.3 – Results of the economic assessments of the Ecosystem Services provided by the CER based on the Benefit Transfer methodology



Source: Nomisma

The total values considered with the precautionary principle

By observing the conversion process carried out with the Benefit Transfer method one obtains a very large value interval, between 19.7 and 193.6 Million €/year, as is often the case when one applies this type of methodology. By following a logic based on the precautionary principle, meaning a precautionary approach that avoids asserting estimates for which a full consensus is lacking, one intends to take into consideration the minimum values that emerge from the analysis of the 17 analogical studies.

With this approach, one can state that there is no scientific evidence of the economic value of the Ecosystem Services provided by the CER being less than 19.7 Million €/year: in other words, one can consider this value as acquired, given that the selected studies lead to an economic assessment that is at least equal to this figure. The economic-environmental value is probably higher than the lower limit, but **by applying a precautionary principle one intends to consider the 19.7 Million €/year the economic value of reference for the Ecosystem Services provided by the CER.**

Final aspects on the assessment approach

As was stated multiple times, the Benefit Transfer method takes into consideration a range of studies and methodologies, therefore obtaining an assessment of the uncertainty of the estimates, shown by the wide range of values that offer a general idea of the variety this type of assessments entails. There may be doubts on the fact of transferring estimates developed by far richer or far poorer countries than Emilia-

Romagna, in that the purchasing power and willingness to pay for an ecosystem benefit is heavily influenced by the level of wealth of the population. However, the literature shows that the estimate of the willingness to pay is often not related to the socio-economic conditions of the inhabitants: the WTP (Willingness To Pay) estimate is much higher in countries such as Guatemala, Ecuador and Thailand than among populations living in far wealthier areas (USA, Canada etc.).

Moreover, one may object that the different extension of the geographical areas considered in the selected studies can have distortive effects on the final estimates: however, in the literature it has been proven that there is no significant correlation between the size of the area and the willingness to pay for ecosystem services.

One must specify that the Benefit Transfer method should be the first step of a wider and deeper analysis of the environmental benefits provided by the availability of irrigated water, which is only roughly outlined in this work. As specified above, this method is useful for obtaining a first economic assessment, thanks to a series of estimates and, ultimately, a range of possible values.

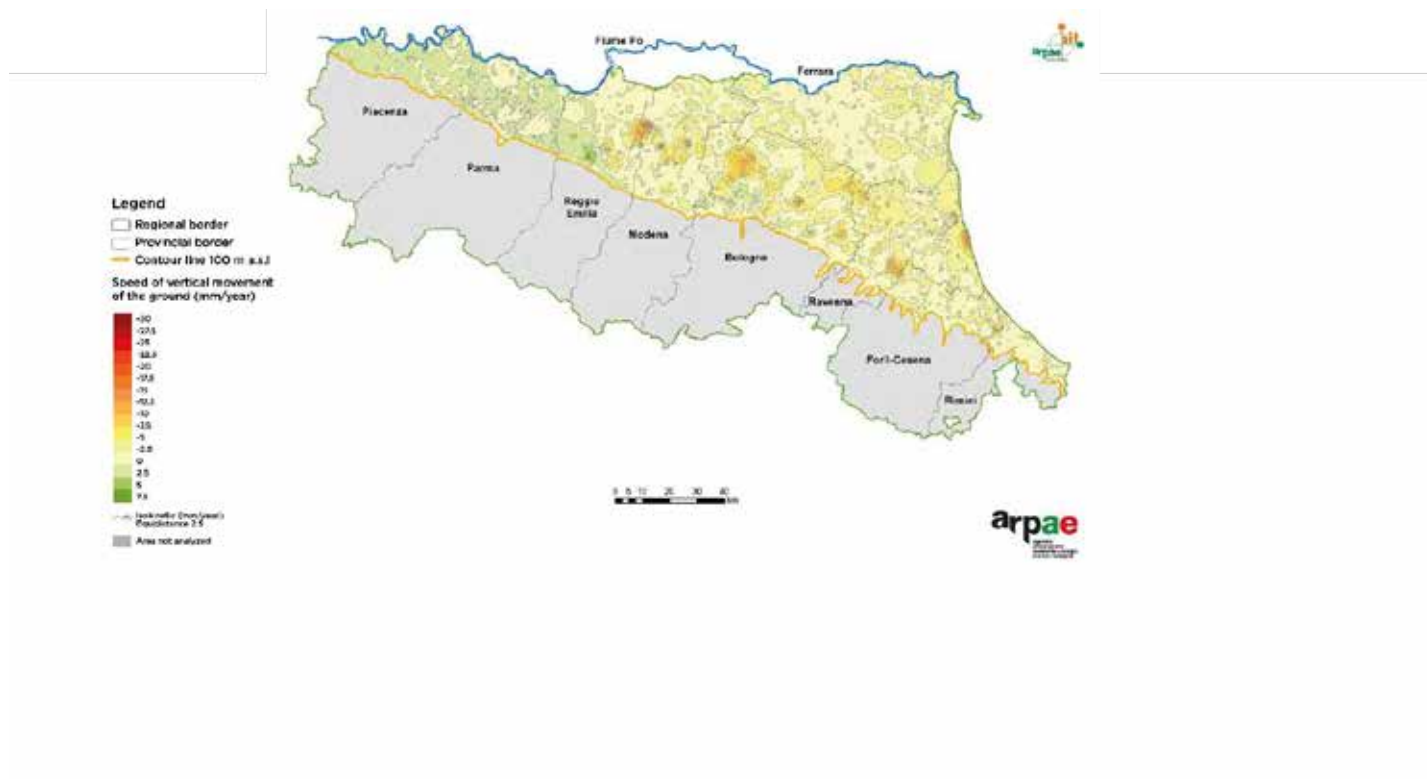
The analysis of the ecosystem services requires an *ad hoc* assessment carried out in the territory studied, through the use of suitable economic resources and research groups dedicated to examining all the various aspects that contribute to determining the environmental value. Ideally it would be desirable for the preliminary analysis through the Benefit Transfer method to be followed by an *ad hoc* study capable of obtaining an estimate realised “on the ground”, and that would ideally be contained in the specific range indicated by the result of the Benefit Transfer, which can ultimately validate the results of the original study. All these aspects of the assessment can be examined in future studies.

5.3.4 An in-depth analysis of the actions to counter subsidence carried out by the CER

The control service and subsidence	The control service is one of the most important benefits, especially when it comes to subsidence, in that this phenomenon determines a series of correlated damage. Therefore what follows is a specific in-depth analysis.
Definition of subsidence	According to the definition provided by the Emilia-Romagna Region (2011): “Subsidence is a natural process that determines the compaction of sediments, and therefore the downward vertical movement of the soil, owing to the isostatic load of the sediments themselves, which results in the removal of fluids naturally included in the pores of the sediments and thus a crushing of the pores themselves. <i>Natural subsidence is often accompanied by “anthropic” subsidence, meaning generated by human activities that can speed the naturally ongoing process. These include the withdrawal of hydrocarbons or water from underground.</i>
The CER’s function in limiting subsidence	In particular, the realisation of great hydraulic infrastructure such as the Romagna Aqueduct , which uses the water of the Ridracoli reservoir, and the Emilia Romagna Canal (CER) , which brings the water of the Po River to the Emiliano-Romagnola plain, has favoured the use of surface water, limiting the collection of groundwater , which is one of the main causes of subsidence.
The evolution of the phenomenon	<p>This phenomenon is heavily monitored in the territory of the CER, in that in the past 50 years a major downward vertical movement of the plain area of Emilia-Romagna was observed²¹.</p> <p>Figure 5.4 shows the situation observed in the last five years of measurement (2011-2016). The province of Ferrara is the least hit by this phenomenon and there is no evidence of a change in this state of stability. The provinces of Ravenna, Forlì-Cesena and Rimini confirm the tendency to stabilisation with minor average regional decreases (about 2 mm/year), although areas remain where there is quite high subsidence: the mouth of Fiumi Uniti, East Faenza, Reda, San Mauro Pascoli (15 mm/year each) and Rimini (5-7 mm/year).</p>
The situation in the province of Bologna	The province of Bologna remains the most affected by this phenomenon , although there is a general slowdown of subsidence owing to the lower exploitation of the groundwater. In this province there was a shift from an average subsidence of 32 mm/year (recorded in the 1982/1992 decade) to 4 mm/year in the last five years of measurement (2011-2016); some areas remain, however, (Sala Bolognese, Castello d’Argine, Venezzano and Budrio) where subsidence remains rather high (about 15 mm/year), without an acceleration being recorded.

²¹ See, for example, https://www.arpae.it/cms3/documenti/subsidenza/Subsidenza2017_fase2.pdf

Figure 5.4 – Average subsidence of the plain area of the Emilia-Romagna region in the 2011-2016 period



Source: ArpaE, 2018

The data in the province of Bologna

The situation observed in the last five years of measurement (2011-2016) shows that the province of Bologna remains the most affected by this phenomenon, although there is a **general slowdown of subsidence owing to the lower exploitation of the groundwater**.

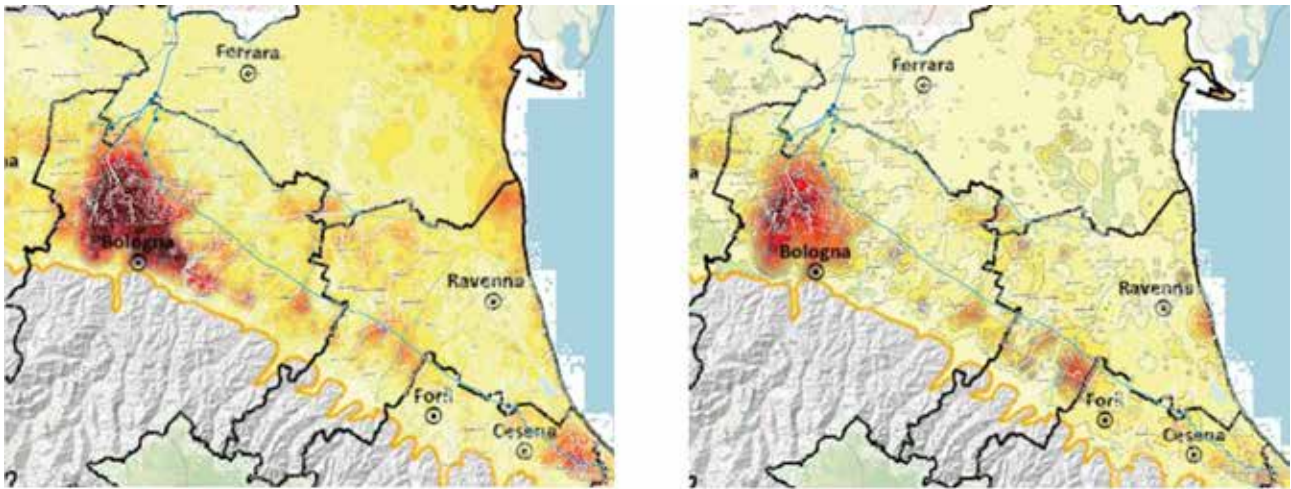
There was a shift from an average subsidence of **32 mm/year** (recorded in the 1982/1992 decade) to **4 mm/year** in the last five years of measurement (2011-2016);

The mitigation effects of the distribution of surface water

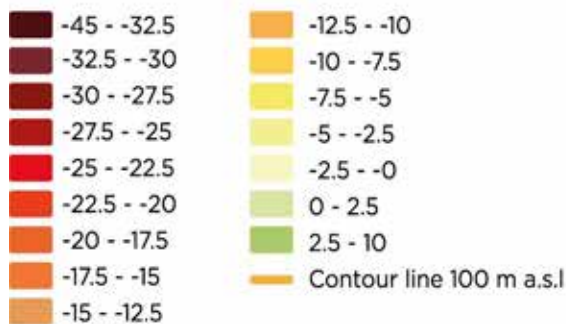
Some areas remain (Sala Bolognese, Castello d’Argine, Venezzano and Budrio) where subsidence remains rather high (about 15 mm/year), without an acceleration being recorded.

The control and distribution activity of surface water and the recharging activity of the aquifers carried out by the CER and the associated Consortia allow for a controlled exploitation of underground water, which in the past decades led to a general slowdown of anthropic subsidence, without undermining the water availability of the agricultural area (fig. 5.6).

Figure 5.5 – Comparison between the average values of subsidence of the plain area of the Emilia-Romagna region in the following periods: 1992-2000, 2002-2006 and 2006-2011



Vertical movements of the soil in the Emiliano-Romagnola Plain



Source: Arpae, 2018

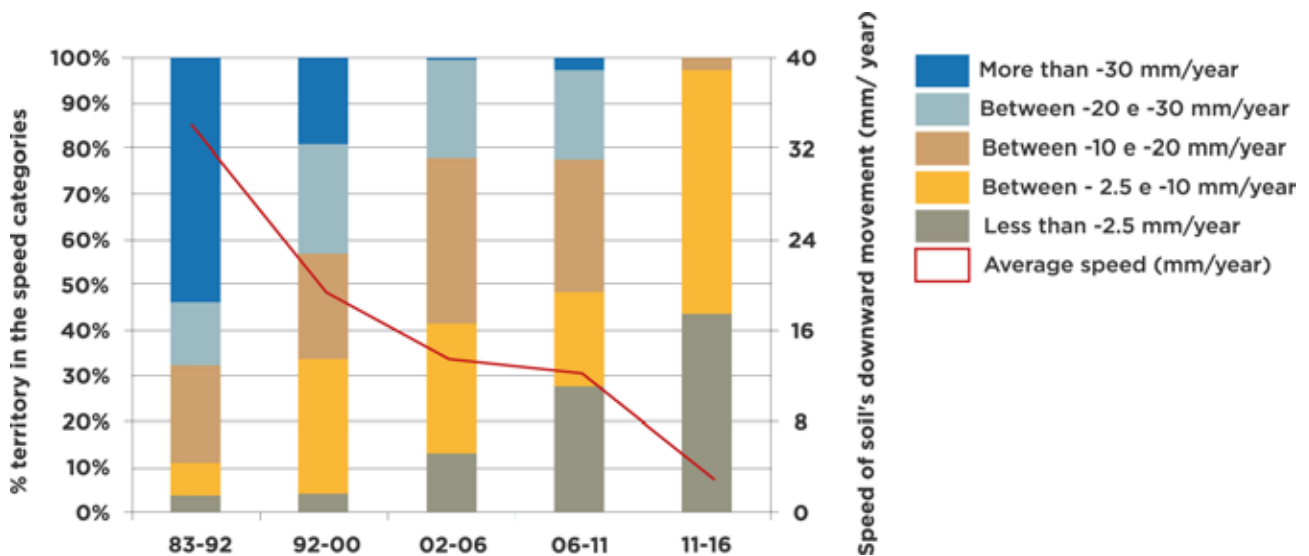
Evidence of the cause-effect relationship between pumping water and subsidence

The studies conducted have shown that over time pumping water from the aquifers of the Bologna territory has greatly decreased: from over 90 Mm³/year in the 1970s, to slightly over 60 Mm³/year from the early 2000s to the late 2000s, and down to less than 50 Mm³/year in the most recent years.

At the same time, out of the 17 municipalities forming the territory of competence of the CER the speed of the ground's downward vertical movement has fallen sharply: from over 33 mm/year on average in the 1980s (with large areas with a speed of over 50 mm/year) to about 13 mm/year on average since the early 2000s, ultimately reaching an average of 3 mm/year in the most recent period.

There is a clear cause-effect relationship between the decrease in pumping water from the aquifers and the decrease in the speed of the ground's downward movement, in fact most recently the decrease in pumping potable water from the wells-fields in the Reno area, connected to the activation of the Reno-Setta diversion channel, also led to a strong decrease in the subsidence values.

Figure 5.6 – Percentage distribution of the territory in relation to the subsidence speed and average speed of the ground’s downward movement



Source: Arpae, 2018

The CER’s contribution

The CER’s contribution over the years has been instrumental in reducing the pumping of water and therefore of subsidence. Today the contribution in water provided for surface irrigation is equal to **300 million cubic metres pumped every year by the CER.**

Without the provision of surface water (CER) and recharge service of the groundwater the speed of downward movement today would be the same as the critical decades of the past century (1970s and 1980s), with severe consequences on the entire territory concerned.

Counter effects against the water advancing

The complexity, extension of the phenomenon beyond the interdependence of the factors leading to it (climate change, methane extraction from deep deposits etc.) do not allow for this study to quantify the loss in ecosystem services, which would instead require in-depth analyses of the issue.

One of the effects that is already apparent concerns a possible “re-occupation” of the water in the territory of the Po Valley, which can only be countered through major investments. The phenomenon, with these levels of downward movement of the ground, would nevertheless have major effects on all 4 categories considered to assess the Ecosystem Services.

Phenomena related to subsidence

More specifically, one can nevertheless identify the main types of damage related to subsidence:

- salt wedge intrusion;
- erosion of coastal salty shores;
- damage to road infrastructure;
- damage to reclamation infrastructure;
- damage to property;
- increase in hydro-geological risk;

The following are the first assessments on the economic benefit of containing subsidence, regarding the following issues:

a) Containing the salt wedge intrusion

b) Recharging the groundwater

The benefit of containing the salt wedge intrusion

Description: in the past 20 years the sea's salt water managed to move up by nearly 30 km in the delta mouths, in particular in the secondary branches, which when it comes to the Ferrara area are the Po of Goro and the Po of Volano. By entering the hinterland it puts at risk thousands of hectares and the farms that operate on the Ferrara province area towards the coast, owing to the presence of greater levels of salinity both in the water necessary for irrigation, and groundwater, which is equally important. The rise of salt water, known as salt wedge, in the branches of the Po River's delta is a serious problem that is exacerbated by droughts and irregular drainage. It contaminates the groundwater and, in the worst situations, it makes water impossible to use as potable water or for land irrigation. The European project called "Reservoir" was initiated for a sustainable management of groundwater, the CER is part of this programme, with the aim of monitoring the phenomenon in the Comacchio area.

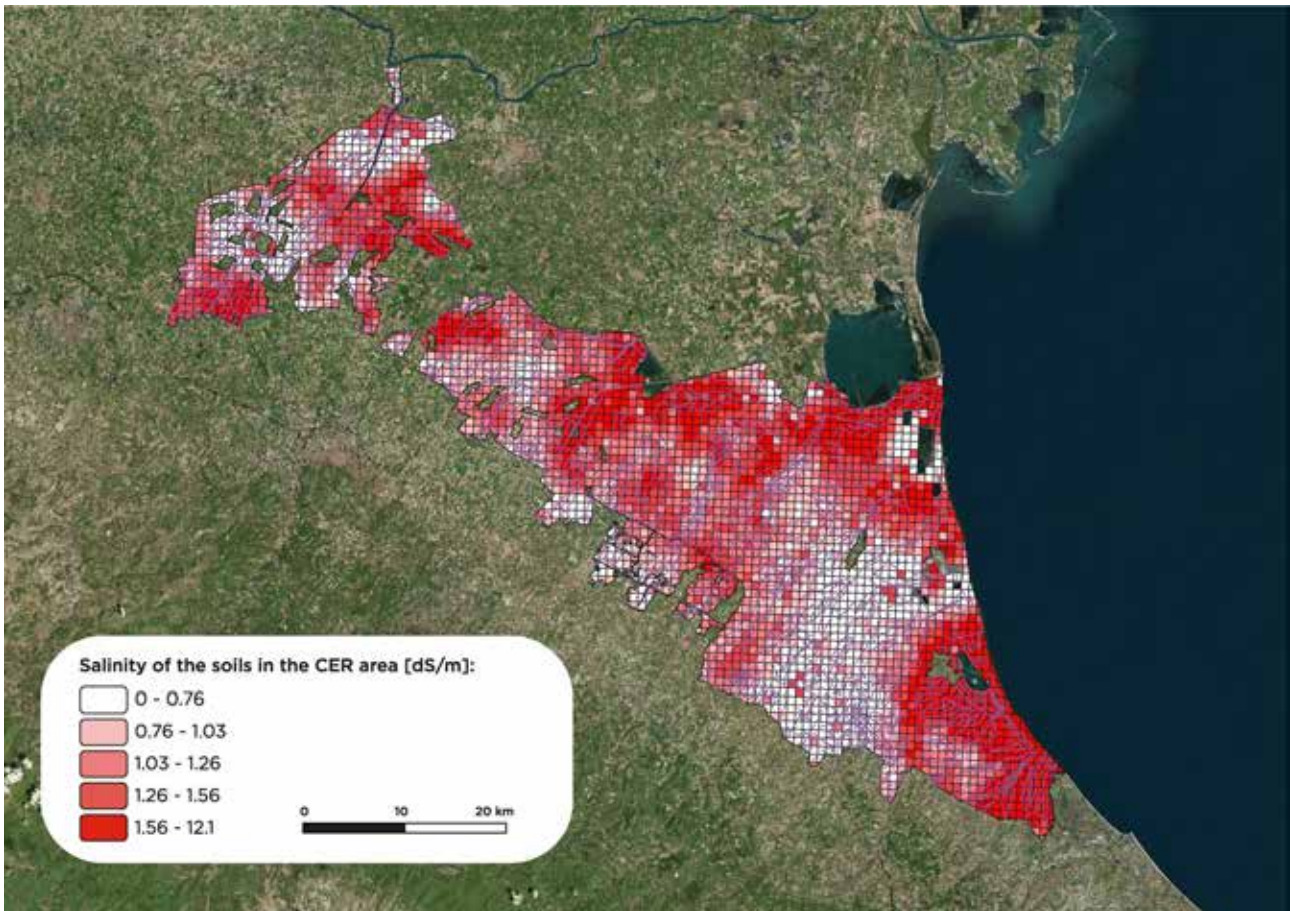
Estimate: as part of the management work of the CER, the countering effect is caused by the percolation of irrigation water, which counters the capillary rise of the saline aquifer, guaranteeing greater agricultural productions compared to similar land located farther away from the canals.

The method to estimate the benefit followed these steps:

- ✓ identifying land with salinity problems at 50-100 cm (map of the soils of Emilia-Romagna);
- ✓ selecting surface irrigation canals in the CER's territory (map of the land reclamation network);
- ✓ assignment of the average GSP to the territory;
- ✓ indicating for each area the damage due to salinity based on the productivity-salinity relationship of the soils indicated in FAO Paper No. 61 (FAO Irrigation and Drainage Paper No. 61);
- ✓ identifying a buffer area around the selected canals where the percolation of irrigation water counters the capillary rise of the saline aquifer, guaranteeing greater agricultural productions compared to similar land located farther away from the canals;
- ✓ The salinity-related damage that was avoided in the buffer areas is then calculated.

Results: based on the illustrated procedure, the benefit guaranteed by the activity of the CER in terms of reducing the salt wedge intrusion is of 592,000 €/year.

Figure 5.7 – Value of the ES “Reduction in salinity of the groundwater and soils”: 592,000 €/year



Source: CER calculations on the Emilia-Romagna Region's data (<https://ambiente.regione.emilia-romagna.it/it/geologia/suoli/proprietà-e-qualità-dei-suoli/salinità>)

The benefit of recharging groundwater and surface water discharge

Description: the level of groundwater is the sum of anthropic and natural effects on the underground water system, meaning the withdrawal activities of groundwater on the one hand and recharging the aquifers on the other.

Estimate: the value of the ecosystem service of water production associated with groundwater recharge can be approximated to the realisation costs of the reservoir works necessary for the recharge²². In other words, the costs necessary to build hydraulic works capable of recharging the groundwater can be an estimate of the economic value of the benefits deriving from recharging the aquifers which, as said previously, prevent all the damage caused by subsidence.

Results: Therefore a series of studies were conducted to obtain a unit cost of the aquifers' recharge, which was 0.49 €/m³ of water. Given that the volume of water pumped by the CER's plants is equal to 300 million m³ per year and that the loss due

²² Santoloni & Morri, 2017

to infiltration in the soil is equal to 10%, the volume of water allocated to recharging the aquifers is about 30 million m³. By multiplying the average recharge cost (used as the value of the benefit) for the volume of water that is absorbed by the ground, an **economic benefit guaranteed by the recharge of the groundwater equal to 14.6 million €/year is obtained.**

Need for in-depth analyses

The assessments illustrated above are a first attempt to provide an economic quantification of the benefits deriving from the containment of subsidence. As was already mentioned, this phenomenon is very complex and has many implications that would require an *ad hoc* study to reach a more complete and comprehensive assessment.

Average cost of recharging the aquifers		
Source	Value (€/m ³)	Region
Morri et al., 2014	0.98	ER
Tavoloni, 2019	0.23	Marche
Santoloni & Morri, 2017	0.36	ER
Assennato et al, 2018 (ISPRA)	0.37	Italy
Average	0.49	

Estimate of the benefit of recharging the aquifers	
	Value
Average volume pumped at the PALANTONE plant (m ³)	300,974,395
Total average infiltrated volume (m ³)	30,266,943
Share of losses due to infiltration (%)	10%
Average annual benefit of the ES of recharging the groundwater (€)	14,684,764

5.3.5 Further assessments on the CER's environmental value

Estimated environmental aspects

This paragraph shows some in-depth assessments of specific environmental aspects. Specifically, a further assessment of the environmental value of the wetlands was carried out, which is complemented by the one indicated in paragraph 5.3.3, which further confirms the importance of this field.

Afterwards, a specific analysis was carried out to assess the economic benefit generated by water phytodepuration.

The benefit of maintaining the wetlands

Description: the wetlands generate an environmental value tied to nature and the habitats, as was described at length in the previous chapters. To calculate this specific value, in paragraph 5.3.3 the Benefit Transfer method was used.

To apply a verification assessment, albeit precautionary, in this section we quantified the value of the realisation of a wetland as a proxy of the generated benefit. This method obviously underestimates the real value of the benefit in that, with reference to the planting phase, one can obviously not calculate the benefits tied to the nature and biodiversity generated by the wetland itself, which refer to mature habitats.

Estimate: the applied method is based on the hypothesis that the benefit generated by the creation and maintenance of wetlands is at least equal to the direct costs sustained to realise the ecosystem and maintain it, in the case of agri-environmental measures carried out in agricultural land and financed by the RDPs.

Below, the 2 boxes include the investment costs and the direct maintenance costs of the wetlands.

Investment costs	Direct maintenance costs
<ul style="list-style-type: none"> • Excavations (creating the reservoir, banks and islands) • Hydraulic works (transport and discharge system, water gates etc.) • Planting <p>Total 12,000 €/Ha → 390 €/Ha/year</p>	<ul style="list-style-type: none"> • Maintenance of the green areas and hydraulic works • Water management and input <p>Total 600€/Ha/year (excluding land benefit)</p>

Results: the value calculated in the table below, 13.6 million €/year, refers to the natural area as the annualised realisation value.

This approach contributed to validating the benefit of the wetlands calculated with the Benefit Transfer method (paragraph 5.3.3) and equal to an average value of 20 million €/year, which also takes into account the multiple ecosystem benefits generated by the wetlands themselves (habitats, cultural benefits etc.).

Estimate of the benefit of maintaining the wetlands

	Surface (Ha)	Investment (€/year)	Maintenance (€/year)	Total benefit (€/year)
Reservoir area	3,044	1,187,000	1,827,000	3,014,000
Natural area	13,737	5,358,000	8,242,000	13,600,000

The benefit of water phytodepuration

Description: phytodepuration is a natural purification system of domestic waste water, as well as agricultural and sometimes industrial, which reproduces the typical self-purification principle of water environments and wetlands. In short, ecosystems like wetlands filter both human and animal waste and are a natural buffer for the surrounding environment. Through the biological activity of microorganisms in the soil, most of the waste is removed. This thus eliminates pathogens (microbes that cause diseases) and the level of pollution is reduced. The CER with its water control and water supply activities allows for this filtration and “finishing” function.

The phytodepuration system powered by the CER is very large and tied to the capillary irrigation network managed by the Reclamation Consortia to which the CER as second-degree body provides water, but above all it is tied to the wetlands supplied directly by the Consortium. A further example is the Cavo Napoleonico, where for years the CER has been conducting experimentation work aimed at the phytodepuration action of the system (Anconelli et al. 2018).

Estimate: to proceed with a first estimate reference was made to the Cavo Napoleonico. The low speed of the watercourse regime, together with the large exchange surface with the atmosphere and the action of the sun rays, allows for the partial degradation of many polluting elements. In addition to this, there is also the phytodepuration action carried out by the aquatic vegetation. The hydraulic isolation of the canal protects from the discharge of blackwater or their input into the Apennine streams that are underpassed. The constant contact with the atmosphere and the action of the sun rays along the entire path ensures that the water improves its quality as it moves towards the valley.

Results: for the estimate the purification cost of 1 kg of nitrogen was taken into consideration, as is indicated in an ISPRA (Higher Institute of Environmental Protection and Research) report (2009), has values ranging from 4 to 11 €, obtaining it from the operating costs of a purification plant for the treatment of blackwater, while the cost for the denitrification process alone is equal to 0.7 €/kg of removed nitrogen²³.

Therefore, **the economic benefit guaranteed by the removal of the nitrogen pollutants of the water is, in the case of the Cavo Napoleonico, about 60,000 €/year.**

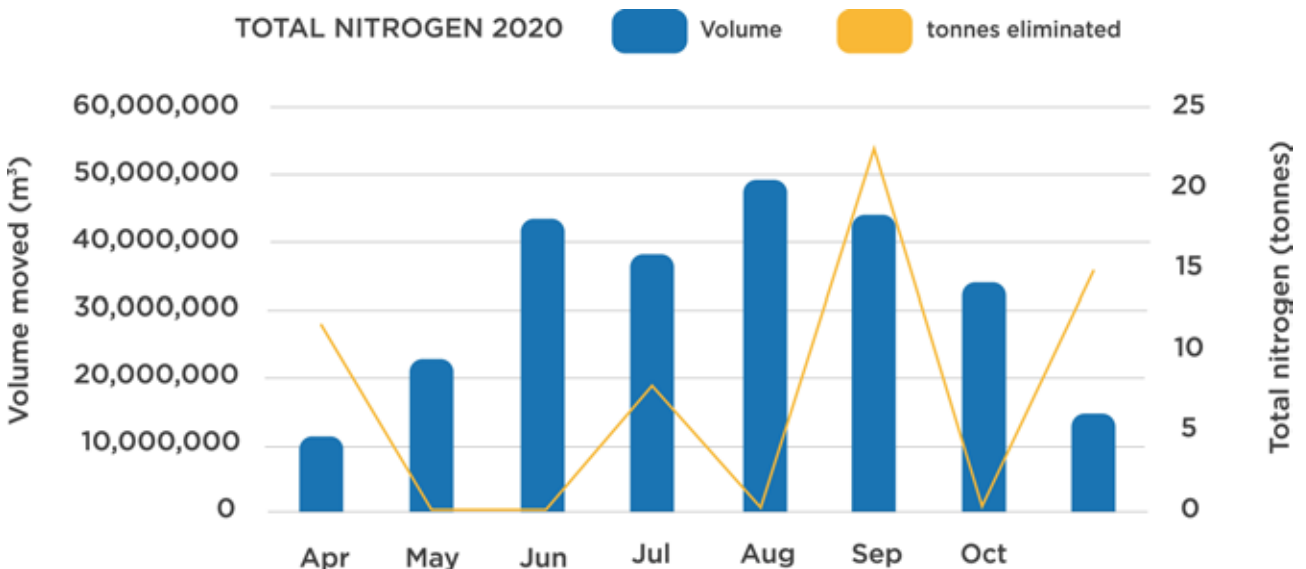
²³ Morri & Santolini 2013; Soana et al., 2013

To this benefit one must add, albeit not estimated in the previous analysis, the further removal of other polluting substances (including heavy metals, phosphate, coliform) that make a major contribution to the quality improvement of water and consequently to the generation of ecosystem services.

Estimate of the benefit of phytodepuration of water

	Value	Source
Denitrification cost (€/kg of nitrogen)	0.7	Soana et al., 2013; Morri & Santolini 2017
Nutrients abated (kg/year)	87,251	Analysis average 2014/2020
Value of the phytodepuration ES (€/year)	61,076	

Figure 5.8 – Total nitrogen abated during transport along the Cavo Napoleonico



Source: analysis and calculations of the CER based on 2020 data

The scenarios of climate change and the approach to determine the effects on the ecosystem services

Thus far, the economic assessment of the Ecosystem Services was based on the “picture” of the current situation, in conditions of future stability of climate conditions. This section highlights the variability elements to which the Ecosystem Services considered in the study may be subject, because of the ongoing phenomenon of climate change.

Apart from highlighting the bond between Ecosystem Services and climate change, there was also a first estimate of the evolution effects of the climate on agricultural production.

6.1 CLIMATE CHANGE AND THE EFFECTS ON THE ECOSYSTEM SERVICES

The indicators of climate change and the RCP (Representative Concentration Pathways)

The European Environment Agency, EEA, has developed and regularly updates a list of 46 climate indicators (EEA, 2014), of which 9 are summed up in table 6.1, connected to the issue of climate change and its impact on the water resource sector.

Most of them are based on the regional projections based on the RCP scenarios (Representative Concentration Pathways), while some indicators still refer to the SRES scenarios (Special Report on Emission Scenarios).

The EEA assessments mainly consider the medium-long period and report as examples the most extreme scenarios (RCP8.5). Most of the projections can be viewed through the ClimateAdapt portal²⁴. Moreover, the EEA has recently created an overview of the extreme weather-climate events in Europe (Van der Linden et al., 2015).

These reports are complemented by other analyses regarding the efficient use of water (EEA, 2015a, 2015b, 2015c, 2012a, 2012b).

²⁴climate-adapt.eea.europa.eu/knowledge/tools/map-viewer

Table 6.1 – Climate indicators and impacts of climate change on water resources

Climate indicator	Data	National trends
Average rainfall ²⁵	08/07/2014	<ul style="list-style-type: none"> Decrease in the weather contribution to the order of magnitude between 0 and 17.5 mm per year, with great inhomogeneity. Expected reduction (up to -30%) of the annual rainfall above all in the South of Italy and Sicily and Sardinia; over 40% decrease in the summer season across all of Italy (RCP8.5; 2070-2010).
Extreme rainfall ²⁶	11/08/2014	<ul style="list-style-type: none"> Downward trend of the consecutive days with rain and increase during dry periods. Increase in rain intensity in winter and decrease in summer, except along the Adriatic coast; major increase in the consecutive days with no rain across Italy except in the North (RCP8.5; 2070-2010).
Snow cover ²⁷	26/08/2014	<ul style="list-style-type: none"> Decrease in the altitudes in which the temperatures have gone over the freezing point.
Volume of the rivers ²⁸	02/04/2014	<ul style="list-style-type: none"> Up to a 40% decrease except in winter in Northern and Central Italy, and in spring in the Alps; decrease in the average annual volumes across the entire Italian territory except in the Alps.
Low volumes ²⁹	04/09/2015	<ul style="list-style-type: none"> Assessment also based on the SRES scenarios; decrease in the low volumes up to -20% for the return period 1:20 years.
Water temperature ³⁰	04/09/2015	<ul style="list-style-type: none"> 1-3 degree increase in Europe throughout the past century, great Lombard lakes about 0.1–0.3 °C per decade.
Soil humidity ³¹	15/03/2015	<ul style="list-style-type: none"> It decreased in the 1951-2012 timeframe above all in Northern and Central Italy (from -5 to over -8 l/m³/10 years). Substantial reduction already in the mid to long term (2012-2050).
Water requirement ³²	29/07/2014	<ul style="list-style-type: none"> Progressive increase in water requirement Minor increase for RCP2.6 and RCP4.5. For RCP8.5 possible increase by over 20% by the end of the century.
Economic damage owing to extreme events ³³	28/06/2016	<ul style="list-style-type: none"> The damage caused by droughts and water shortage is underestimated in the available databases.

²⁵ CLIM002, www.eea.europa.eu/data-and-maps/indicators/european-precipitation-1/assessment-1

²⁶ CLIM004, www.eea.europa.eu/data-and-maps/indicators/precipitation-extremes-in-europe-2/assessment

²⁷ CLIM008, www.eea.europa.eu/data-and-maps/indicators/snow-cover-2/assessment-1

²⁸ CLIM016, www.eea.europa.eu/data-and-maps/indicators/river-flow-2/assessment

²⁹ CLIM018, www.eea.europa.eu/data-and-maps/indicators/river-flow-drought-1/assessment

³⁰ CLIM019 www.eea.europa.eu/data-and-maps/indicators/water-temperature-1/assessment

³¹ CLIM029, www.eea.europa.eu/data-and-maps/indicators/water-retention-3/assessment

³² CLIM033, www.eea.europa.eu/data-and-maps/indicators/water-requirement-1/assessment-1

³³ CLIM039, www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters/direct-losses-from-weather-disasters

Among the most important studies regarding the entire European continent various ought to be highlighted (J.-C. Ciscar et al., 2014; Forzieri et al., 2014; Jacob et al., 2014; Prudhomme et al., 2014; Roudier et al., 2016).

The analyses of the PESETA II project (J. C. Ciscar et al., 2014) are based on medium-to-small scale projections (~25 km), regarding 3 different climate scenarios, and a single, large-scale hydrological model (LISFLOOD). Despite the major differences between the various climate models on a European scale, the situation in Italy is quite homogeneous. The results show a strong decrease in summer rainfall across the entire national territory except in the Alps, while winter rainfall seems to be increasing in Northern Italy and decreasing in Southern Italy and Sicily and Sardinia. In some scenarios the same situation could be witnessed along the Adriatic coast all the way to the mouth of the Po River.

The set used by Forzieri et al. (2014) is even larger and consists of 12 projections coming from 4 GCMs (Global Circulation Models) and 7 RCMs (Regional Circulation Models) for a single scenario (SRES A1B), used as inputs for the LISFLOOD hydrological model. The analysis also considers the anthropic diversions of water coming from the WaterGAP3 model where there is the hypothesis of an increase in the water withdrawn between 5% and 25% in Northern and Central Italy and a decrease in the rest of Italy. According to the analysis, the impact of climate forcing on the low volumes becomes large starting from 2050 (2041-2070) and subsequently decreases to over 40% for the volumes corresponding to the return time of 20 years, because of a reduction in rainfall and the increase in evapotranspiration following the higher temperatures. A further decrease of the volumes (10-15%) is caused by the increase in anthropic diversions.

The analysis by Roudier et al. (2016) is based on 11 regional climate projections related to scenarios RCP2.6, RCP4.5 and RCP8.5, and three large-scale hydrological models. Unlike the previous studies, the authors compared the various projections for the three-year period in which the GCM forcing reached a 2° increase in the average global temperature compared to pre-industrial levels. The analysis shows a decrease up to over 15% of low volumes, corresponding to the return time (RT) of 10 years. There was, however, a strong difference between the models also concerning the sign of change determined on the first and third quartile of the distribution of the possible changes that concern the entire Italian territory.

A growing number of studies has thoroughly investigated the impacts of climate change on water resources at a national and sub-national level. The most relevant for the Consortium area of the Emilia Romagna Canal are listed in table 6.2 below.

Table 6.2 – Studies on the impacts of climate change on water resources

Region/ Basin	Main results	Source
Northern Italy	By using the data on daily rainfall on five weather stations of Genoa (1833-1998), Milan (1858-1998), Mantua (1868-1997), Bologna (1879-1998) and Ferrara (1879-1996), the authors test the hypothesis of growing intensity in Northern Italy. The number of rainy days has a stronger and more significant negative trend compared to total rainfall, suggesting that the intensity of rainfall has a positive trend in Northern Italy. This is particularly apparent in the last 60-80 years of the time series. This translates into an increase of total rainfall brought by strong rainfall (for example daily rainfall > 25 mm and daily rainfall > 50 mm).	Brunetti et al., 2000
Italy	The authors use 12 experiments on the climate deriving from a combination of 4 models of global circulation and 7 regional climate models to force the GIS LISFLOOD hydrological model. The series of data used for validation only correspond to Northern Italy along the Po Valley. Also water withdrawals and consumption in various sectors are assessed using the WaterGAP3, a platform based on a set of sub-models. The large water withdrawals (> 100 mm) will increase by 25% in Northern Italy because of the intensification of agricultural production and will slightly decrease in Southern Italy. The forecast is that the minimum outflows in Italy will be reduced up to 40% by 2080. In Northern Italy the reductions in minimum run-offs are relatively more severe for small return periods. The drought events with return period of 20 years will increase by 50% by 2020 and up to 80% in 2080. In the Alpine regions, periods with deficit run-off are expected to increase between 20 and 50% from 2050 onward.	Forzieri et al., 2014
Italy	Salt water intrusions and a loss of wetlands in the coast reservoirs are expected. In the Alps a growing intensity and frequency in winter rainfall, as well as a reduction in the summer period are expected; retreat of the glaciers and reduction in permafrost, and potential formation of great Alpine lakes as a consequence, which may cause the flooding of glacial lakes. Compared to the 1971-1990 average, the small glaciers will disappear by 2050; the larger glaciers will diminish by 30 to 70% in volume by 2050; and the ice cover will diminish by 80% by 2050. In Northern Italy stronger rainfall and floods are expected. In Southern Italy rainfall will diminish and summer droughts are expected.	Ministry of the Environment and Protection of the Territory and the Sea, 2013
Italy	In Italy the average annual rainfall and waterflow are expected to diminish, thus worsening the water stress conditions (+25%) already present in some Italian reservoirs such as Rio Mulargia, Sardinia and the Alento River in Campania. A series of processes will contribute to the rise of the phenomenon, including the reduction in the availability and quantity of water, the increase in frequency and intensity of summer droughts, greater frequency and intensity of the reductions of run-off during the summer periods (-45%) and the reduction in annual run-off of the river and the limited recharge of groundwater. Other impacts include the gradual melting of the glaciers and the reduction of the seasonal snowpack of the Alps, the increase in the intrusion of salt water because of the rising sea levels, the increase in winter run-off (+90%) and the risk of inland flooding and landslides because of extreme rainfall, in particular in the Po River basin and other Alpine and Apennine areas.	Medri et al., 2013
Italy	The main concerns have to do with the lower availability of water, extreme weather events (droughts in southern regions, risk of floods in the Alpine area) and the consequent loss of biodiversity. Water stress can increase by 25% during the current century because of the growing demand for irrigation. Guaranteeing water supply will be particularly difficult in the southern regions and the islands (Apulia, Basilicata, Sardinia and Sicily). The decrease in water availability will also be felt in Northern and Central Italy, in particular along the Po River basin. The intrusion of salt water will undermine the quality of water and the reserves both in the aquifers and in the coastal wetlands. The Alpine water regime will be affected by the changes in rainfall, the lower snow cover, the retreat of glaciers and the decrease in glacier deposits. This will lead to an increase of the winter run-off (+90%), a lower summer run-off (-45%), more summer droughts and floods and landslides in winter, including the floods due to the breakup of glacial lakes. Floods will also increase in Southern Italy.	OECD, 2013
Centoanara River, Apennines	By using weather data on the 1986-2015 period, the authors identify a trend with the Mann-Kendall test. 338 rain run-off events recorded in the 1994-2009 period are analysed. The results show an increase in the minimum (+0.08° C), average (+0.09° C) and maximum (+0.13° C) temperature, an increase in the number of humid days and a decrease in annual rainfall. In winter there is an increase both of rainy days and total rainfall. The events of extreme rainfall (rainfall>20.2 mm and duration 18.3 hours) increase significantly, especially in spring and autumn. The response of the run-off to rain indicates that the run-off mainly depends on the rain, suggesting that an increase in the run-off level may occur during spring and autumn.	Pieri et al., 2016

Region/ Basin	Main results	Source
Upper Basin of the Po River	Two climate models (REMO and RegCM) are used to force a set of 8 hydrological simulations within the framework of the A1B emission scenario. This research compares the 2020-2050 and 1960-1990 periods. The results show the spring peak in discharge run-offs moving from May to April, which is completely justified by the time needed for the snow to melt. The run-off decreases throughout the entire year except in winter. The increase in the winter run-off is concentrated in the northern area (+20% in the areas at low altitude and +40% in the areas at high altitude). The volume drops by 20% everywhere and up to 40% in some areas in the northernmost and southernmost parts of the basin. In spring, the volume drops down by up to 20%.	Coppola et al., 2014
Basin of the Po River	Rainfall and temperature estimates for the RCP4.5 and RCP8.5 scenarios are used to obtain climate projections through the combination of the regional climate model COSMO-CLM and the global climate model CMCC-CM. The estimates are used to force the hydrological model and compare the impacts on the hydrological processes for the 2041-2070 and 2071-2100 periods compared to the 1982-2011 period. The average volumes decrease in both RCP scenarios. In the 2041-2070 period the discharges drop from May to November and remain steady for the rest of the year. In the 2071-2100 projections, the reduction of the volumes from May to November remain and is more severe compared to the previous period, increasing by up to 60% the rest of the year.	Vezzoli et al., 2015
Basin of the Po River	By using graphic and analytical instruments, the authors assess the variability of the river volumes to distinguish the disruptions caused by humans on the volumes with a natural regime. The analysis shows the fluctuations in the river regime and in the floods and droughts that seem to derive from disruptions “whose memory is maintained long term”. The impacts of man-induced climate change on the volumes do not emerge clearly from the temporary trends assessed.	Montanari, 2012
Basin of the Po River	The authors extend the series of volumes available by 110 years collecting data from the historical archives of the Hydrological Office of the river Po-Parma. This data is integrated with the data regarding evapotranspiration and rainfall of the 1831-2003 period. The authors observe a movement in the regime starting from 1920 (gradual depletion of the reserves in the dams) which coincides with a decrease in rainfall and an increase in evapotranspiration. The increase in the maximum run-off observed is apparently the result of impoundment works	Zanchettin et al., 2008
Basin of the Po River	The authors use a chain of modelling that includes hydrological/hydraulic models (a model distributed on a physical basis, TOPKAPI and a water budget model, RIBASIM) to reproduce the volumes observed during the 1971-2000 period. The authors quantify the uncertainties associated with the assumptions in each simulation phase using a curve of the duration of the flood and determine that a simple correction in the probability of the duration curve can remove most of the differences between observations and simulations. In Pontelagoscuro, the correction of the probability completely modifies the impact of climate change on the curve of the duration of the flood for the 2012-2040 period under RCP4.5. This highlights the importance of the uncertainties that influence the modelling chain and its impact on the results.	Castellarin et al., 2014

The RCP 4.5 scenario adopted by the Emilia-Romagna Region

The graph in figure 6.1 regarding the scenarios shows that the shifts expected in 2030 in terms of equivalent emissions between RCP2.6 and RCP8.5 are at a few tens of equivalent PPMs.

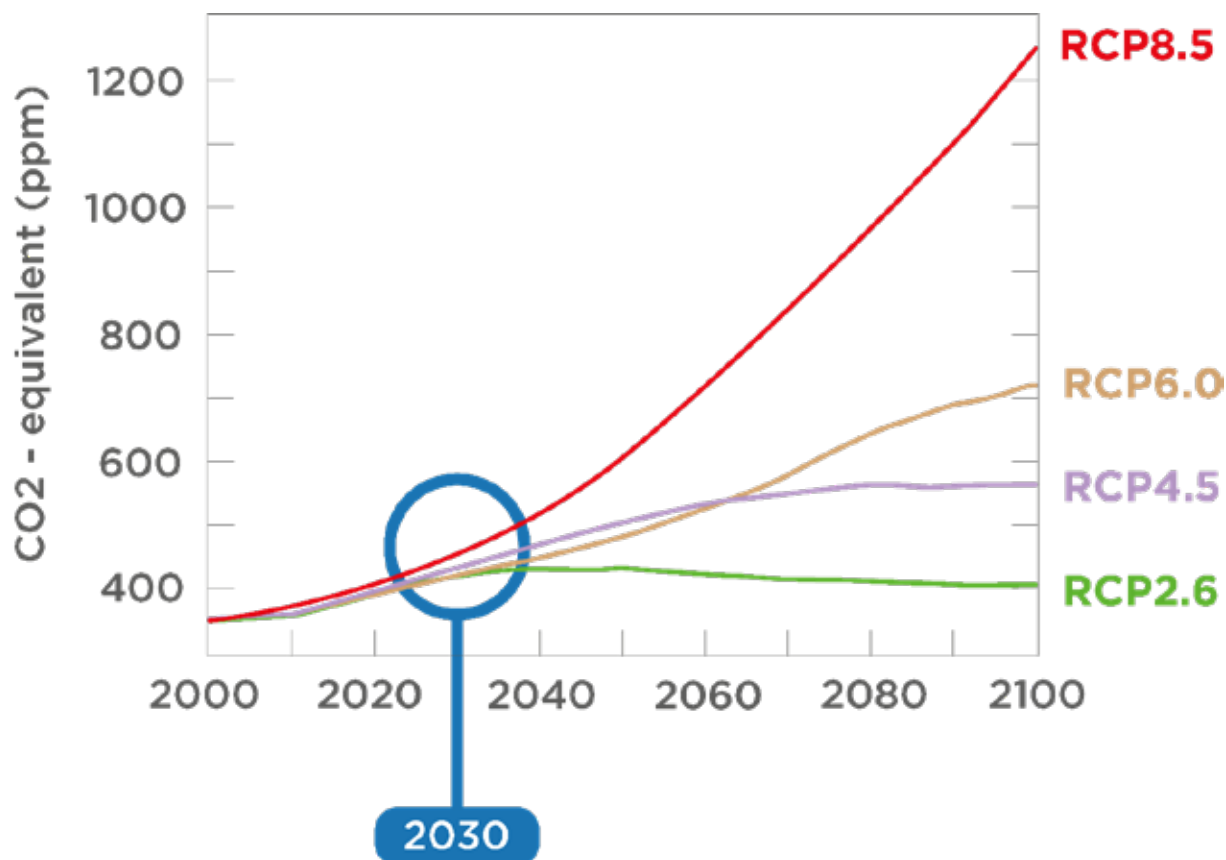
The previous graph shows the temperature differential between the ensemble means of the two scenarios by 2030 at 0.7°C. The RCP4.5 scenario, deemed more reliable in relation to the actions undertaken by the Governments, in 2030 is in an intermediate situation, as it presents for several decades an approximately linear trend and then decreases between 2050 and 2060, which represents stabilisation.

Table 6.3 sums up what was previously said to determine the possible future scenario assumed, showing different levels of probability/criticalities depending on the cited scientific studies.

The analysis carried out clearly shows that climate change will have major impacts on the structure of the agro-systems and ecosystem services provided by them.

Based on the studies indicated above, table 6.4 then highlighted the importance of climate change regarding the ecosystem services considered.

Figure 6.1 – Representative Concentration Pathways of greenhouse gas provided by the Intergovernmental Panel on Climate Change (IPCC)



Source: Intergovernmental Panel on Climate Change (IPCC)

Table 6.3 - Climate change scenarios

Scenario 2 (RCP 8.5)	Scenario 3 (RCP 8.5, upper threshold)
<p>1) The spring peak in discharge run-offs moves from May to April, which is completely justified by the time needed for the snow to melt. The run-off decreases throughout the entire year except in winter. In the 2041-2070 period the discharges drop from May to November and remain steady for the rest of the year. In the 2071-2100 projections, the reduction of the run-off from May to November is more severe compared to the previous period and increases by up to 60% for the rest of the year. The forecast is that the minimum run-offs in Italy will be reduced by up to 40-45% by 2080. The reductions in minimum flows are relatively more severe owing to drought elements with smaller return periods (Coppola et al., 2014; Vezzoli et al., 2015; Zanchettin et al., 2008).</p>	<p>1) The spring peak in discharge run-offs moves from May to April; which is completely justified by the time needed for the snow to melt. The run-off decreases throughout the entire year except in winter. In the 2041-2070 period the discharges drop from May to November and remain steady for the rest of the year. For the 2071-2100 projections, the run-off reduction from May to November is more severe than in the previous period and increases by 60% the rest of the year. The forecast is that the minimum run-off in Italy will be reduced by 45% by 2080. The reductions in minimum flows are relatively more severe owing to drought events with smaller return periods (Coppola et al., 2014; Vezzoli et al., 2015; Zanchettin et al., 2008).</p>
<p>2) The water withdrawals will increase by 25% in Northern Italy because of the intensification of agricultural production (2040).</p>	<p>2) The water withdrawals will increase by 25% in Northern Italy because of the intensification of agricultural production (2040).</p>
<p>3) Limited recharge of underground water (Medri et al., 2013).</p>	<p>3) Limited recharge of underground water (Medri et al., 2013).</p>
<p>4) In the coastal areas intrusions of salt water and wetland losses are expected. The intrusion of salt water will reduce the quality of water and the reserves both in the aquifers and in the coastal wetlands (Castellarin et al., 2014).</p>	<p>4) In the coastal areas intrusions of salt water and wetland losses are expected. The intrusion of salt water will reduce the quality of water and the reserves both in the aquifers and in the coastal wetlands (Castellarin et al. 2014).</p>
<p>5) The deficits owing to extreme drought events with return period of 20 years will increase by 50% by 2020 and up to 80% by 2080 (Forzieri et al., 2014).</p>	<p>5) The deficits owing to extreme drought events with return period equal to 20 years will increase by 50% by 2020 and up to 80% by 2080 (Forzieri et al., 2014).</p>
<p>6) Water stress can increase by 25% during the current century owing to the growing demand for irrigation (Medri et al., 2013).</p>	<p>6) Water stress can increase by 25% during the current century owing to the growing demand for irrigation (Medri et al., 2013).</p>
<p>7) Increase in total rainfall owing to intense rainfall (for example daily rainfall 25 mm and 50 mm) (Brunetti et al., 2000; Forzieri et al., 2014; Pieri et al., 2016). Increase in winter run-off (up to +90%) and risk of inland flooding, flash floods and landslides owing to extreme rainfall. The increase in flood risk seems to be connected to the impoundment of the rivers (OECD, 2013).</p>	<p>7) Increase in total rainfall owing to intense rainfall (for example daily rainfall 25 mm and 50 mm) (Brunetti et al., 2000; Forzieri et al., 2014; Pieri et al., 2016). Increase in winter run-off (+90%) and risk of inland flooding, flash floods and landslides owing to extreme rainfall. The increase in flood risk seems to be connected to the impoundment of the rivers (OECD, 2013).</p>
<p>8) In the Alps, a growing intensity and frequency of rainfall in winter and a reduction in summer are expected; retreat of the glaciers and reduction in permafrost; potential formation of large Alpine lakes, which may cause/intensify flooding (Italian Ministry of the Environment and Protection of the Territory and the Sea, 2013).</p>	<p>8) In the Alps, a growing intensity and frequency of rainfall in winter and a reduction in summer are expected; retreat of the glaciers and reduction in permafrost; potential formation of large Alpine lakes, which may cause/intensify flooding (Italian Ministry of the Environment and Protection of the Territory and the Sea, 2013).</p>

Table 6.4 – Impact of climate change on the ecosystem services provided by the Emilia Romagna Canal – (Impact intensity: ↓ Moderate; ↓↓ High; ↓↓↓ Very high)

Category of Ecosystem Service	Ecosystem Service	Scenario 1	Scenario 2	Scenario 3
SUPPLY	Food availability	↓↓	↓↓↓	↓↓↓
	Raw material availability	↓↓	↓↓↓	↓↓↓
	Freshwater availability	↓↓↓	↓↓↓	↓↓↓
CULTURAL	Aesthetic value	↓↓	↓↓↓	↓↓↓
	Physical and mental well-being	↓	↓↓	↓↓
	Tourism	↓↓	↓↓↓	↓↓↓
	Habitat preservation for animal and plant species	↓↓	↓↓↓	↓↓↓
SUPPORT FOR THE HABITATS	Maintaining genetic diversity	↓	↓↓	↓↓
	Mitigation of extreme events (natural disasters)	↓	↓	↓↓
	Local climate and air quality	↓	↓	↓
REGULATION	Carbon dioxide absorption (greenhouse gases) from the atmosphere	↓	↓	↓
	Biological control	↓	↓	↓↓
	Maintaining soil fertility	↓	↓	↓
	Pollination	↓	↓↓	↓↓

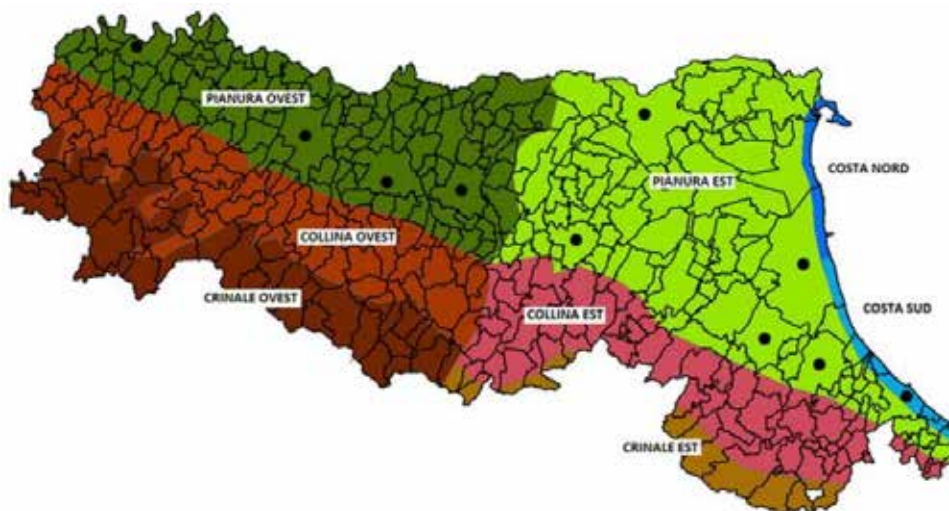
Source: Nomisma

6.2 ABILITY TO ADAPT TO CLIMATE CHANGE

The climate variations and the influence on the agricultural sector

The climate variations expected for the upcoming decades will therefore heavily influence the development of the agricultural sector and its production dynamics, above all in vulnerable areas such as the Mediterranean.

Figure 6.2 – Homogeneous territorial areas of the Emilia-Romagna Region



Source: Emilia-Romagna Region

The climate variations and the influence on the agricultural sector

In the general context of the territory in which the Consortium is active and that is part of zone C-Mediterranean, therefore stretching over three homogeneous areas (Southern Coast, Eastern Plain, and Eastern Hill) the risks are briefly listed in the specialised literature as follows:

- Resilience risk of water replenishment
- Risk of soil salinisation
- Biodiversity loss/reduction
- Reduction in pollination (phenological shift between flowering and presence of pollinators)
- Competition with toxic, alien and invasive plants.
- Internationalisation of pathogens
- Susceptibility growth and direct risks from pathogens (increase in need for chemical defence)
- Quality of the productions (at a nutritional, organoleptic and safety level)
- Susceptibility to heatwaves
- Vulnerability to late frost

- Greater risk of fires

Potential risks and synergies between climate factors

The agro-systems will be subject to variations in terms of the duration of the phenological cycle, productivity and movement of the typical crop areas (towards the north and higher altitudes), with different responses in terms of intensity and signal based on the species and geographical areas of reference.

The climate's effects on the development of agricultural plants

In short, the risk of droughts results in the possibility of a decrease in photosynthesis and biomass, a greater presence of dry matter per weight unit and therefore less water content in the tissues.

The lower hydration of the buds and leaves can, consequently, cause a greater predisposition to fires, which are at the same time facilitated by the higher temperatures. The fire risks are in turn connected to the gradual increases in the erosion phenomena tied to hydrophobicity and a lower regeneration of the woods³⁴. In drought conditions, there may also be short-term, reversible effects of temporary stress tied to the closing of the stomata (and therefore the reduction in the absorption and fixation of CO₂) and more in the long term if the conditions of water shortage remain, a reduction in the growth and re-allocation of sugar towards flowers and seeds to mature earlier and ensure that the plant can reproduce before the water stress becomes too severe. Together with this, there can be changes in size and/or morphology, increases in catabolism and losses in organic Carbon, desertification trends.

The Plan to Adapt to Climate Change (NPACC) and the significant actions

The Plan to Adapt to Climate Change (NPACC) can help contain these scenarios through adaptation actions, as it provides a database with over 350 actions classified in macro-categories and categories, with the main measurement methods.

This database is a useful support tool that works as a starting point to select the specific actions at a territorial local level. However, it is the local planner who must develop these actions for them to be concretely applied/implemented in their specific context of reference. In particular, the selection of the preferred adaptation options ought to take place in close interaction with all the players involved in the adaptation process (Cavazza et al., 2018).

³⁴ This risk is highlighted in the AGRIADAPT report, in which the processing of the raw data of the Landsat 8 sensor showed that in this same territory the increase in temperature has a negative effect on the vegetation conditions highlighting, in wooded and agricultural areas, a greater propensity to fires.

The assessment of rainfall in the future scenario

The selection of suitable policies can nevertheless be further examined through the predictive assessment of the rainfall parameter, meaning through the estimate of the evolution of water availability in the 2030-2050 period.

This can be done through a model assessment (<https://cds.climate.copernicus.eu/cdsapp#!/dataset/projections-cmip6?tab=form>) along with a downscaling analysis in the specific territory examined.

The results of the models must be correct based on the evolution of the historical data of the territory in question. In general one can determine the vulnerability of a given territory and the potential benefits that can be obtained from the presence of infrastructural works that mitigate its vulnerability. One can currently determine the variation in the key parameters such as the number of rainy and dry days, so as to obtain a representation through maps of the trends in the present situation and as forecasts of future scenarios, obtained through a proper downscaling for the relevant climate period (<https://dati.arpae.it/dataset/erg5-eraclito>).

Agriculture and the role of the CER's irrigation

To conclude, the in-depth analysis carried out in this section, as well as the results deriving from the PMP simulation model illustrated in paragraph 4.3, have shown that irrigation is a vital activity for the territory of competence of the CER, given that over half of the GSP comes from the water supply guaranteed by the Emilia Romagna Canal.

The final scenarios of climate change in the absence of adjustment actions

In particular, considering the two scenarios of climate change for the area of the Po basin present in the National Plan for the Adaptation to Climate Change – NPACC (MITE, 2018) and derived from the simulations by the IPCC (Intergovernmental Panel on Climate Change) one can proceed with a first assessment of the adjustment of farmers to climate change, in the absence of structural measures.

These scenarios hypothesise a reduction in the volume of the Po River ranging between 30% (RCP4.5 scenario) and 45% (RCP8.5 scenario) in 2080, with a 25% increase in water demand owing to the rise in temperatures.

The estimates in terms of loss in value of agricultural production

Specifically, according to the studies conducted by the University of Salamanca, in the irrigated areas of the CER a water deficit ranging from 20% (RCP4.5) to 40% (RCP8.5) is expected. By applying the PMP simulation model described in paragraph 4.3.4, this water deficit would determine an impact in terms of loss in value of agricultural production equal to -24 million €/year (RCP4.5) and -54 million €/year (RCP8.5) respectively.

The benefits of the CER and the approach to the assessment

This study illustrated an analysis process that led to the identification of the economic value of the Emilia Romagna Canal's infrastructure and of the management by the Second-Degree Reclamation Consortium.

The starting point was the awareness that the CER's activity tied to water distribution generates multiple benefits, which must therefore be studied with multiple approaches. Given the impossibility of translating into an economic value all the externalities guaranteed by the Consortium, it was decided to focus the attention on some specific positive effects generated by the water availability guaranteed by the CER to its territory of competence. These effects were analysed with techniques and methodologies that were also very different from one another, which required a certain level of estimation and approximation, highlighted by preliminary assumptions and hypotheses.

The rationale adopted throughout the entire analysis process was counter-factual, meaning that an attempt was made to answer the following question: "What would happen if there was no CER? What would be the economic loss for the territory and, consequently, the economic value attributable to the CER for the very fact of existing?"

By following this logic, the first thing that was done was calculate the economic value of the infrastructure managed by the Consortium (infrastructural value), with the goal of quantifying the financial burden that the public subject would have to sustain to build such works and products. The goal was to carry out a sort of cost-benefit analysis, to reach a sort of estimate of the construction cost of the CER's hydraulic infrastructure, to compare with the benefits and economic values generated by this infrastructure, listed and analysed in the present work. This analysis used the estimation values of single plants calculated for insurance purposes in terms of reconstruction costs, to reach a total estimate of the economic value of the infrastructure managed by the Consortium.

Once the economic value necessary to build a great work such as the CER was determined, the analysis focused on two macro-fields of benefits generated by the water availability guaranteed by the Consortium, namely the agricultural value and environmental value.

The first field (agricultural value) is, from a methodological point of view, easier to examine as the assessment is based on the economic quantification of tradeable goods on the market as agricultural products, which by definition have a market value, or land assessments with the aim to establish the differences in value between irrigated and rainfed lands, done also in this case by using as a reference the values of the different types of land used when it comes to expropriation procedures.

The second field (environmental value), on the other hand, features greater analysis difficulties because it aims to give an economic value to goods that lack a reference market where it can appear, or they are intangible goods such as the beauty of a

landscape or the prevention of natural disasters. One should therefore use alternative methods, such as sample surveys conducted on the population residing to gather the impressions of those who live in the territory, alternatively, another example would be to estimate the environmental damage avoided thanks to the presence of infrastructure capable of preventing hydro-geological instability phenomena. Such methods, however, require major economic resources and *ad hoc* studies that involve large research groups. As an alternative, and this is the path chosen for this study, one can use as a reference a selection of scientific studies conducted in contexts similar to the one analysed, so as to use the results reached by these studies and transfer them to the territory in question by turning them into the parameters with respect to the sizes and characteristics of said territory. While on the one hand this methodology presents a higher degree of approximation compared to the *ad hoc* study as it is based on an analogical approach that does not use as reference the actual area being studied but rather other similar territories, on the other hand it has the advantage of generating a range of possible results rather than a single assessment, with the possibility of having at one's disposal information on the variability and uncertainty of the assessment methods. However, such an assessment is the starting point of the analysis of the environmental benefits, which would later be enhanced by specific research projects, by involving various experts and using multiple resources.

Apart from the two macro-fields there are other sectors in which the CER generates benefits and positive externalities, such as the industrial and civil uses of water, or the research activity on irrigation for the benefit of the farmers, technicians and Reclamation Consortia. Given the complexity of these issues and the difficulty in reaching plausible estimates of their economic value, these fields merely received a qualitative assessment of their importance.

Finally, a further remarkable element stems from the fact that, while the CER is the subject that brings the water to the territory, subsequently the associated Reclamation Consortia are the ones tasked with distributing it to the end users (farmers, companies, citizens). This highlights the fact that the associated Consortia make a key contribution to the economic values obtained in this study. Their contribution must be acknowledged, which is inseparable from that of the CER.

The assessments

In summary, the research work aimed at focusing on **3 separate assessments**: the first sought to measure **the “infrastructural” value**, meaning the estimate of the economic value of the hydraulic infrastructure managed by the Consortium and owned by the state. The second assessment concerns **the benefits that water distribution** guaranteed by the CER **brings to the agricultural sector**, both in terms of agricultural production and appreciation of the value of the irrigated land compared to rainfed lands. The third assessment, in the end, concerns **the environmental and ecosystem benefits** that the presence of the water brought by the CER onto the territory can generate in terms of natural habitats, countering hydro-geological instability, welfare guaranteed to human beings thanks to the natural resources and

the aesthetic value of a landscape that becomes unique thanks to the presence of water.

Table 7.1 – Synthesis of the economic values generated by the Second-Degree Reclamation Consortium for the Emilia Romagna Canal

		Value	Unit of measurement
INFRASTRUCTURAL VALUE (replacement value of the products managed by the CER)		1,100	Mln €
AGRICULTURAL VALUE	• Land value (increase in the value of the land thanks to irrigation)	1,730	Mln €
	• Value of the agricultural production (guaranteed by irrigation)	304	Mln €/year
ENVIRONMENTAL VALUE (economic value of the Ecosystem Services provided)		20	Mln €/year

The infrastructural value

When it comes to the first of the 3 assessments, meaning the **INFRASTRUCTURAL VALUE**, the results of the study showed a sort of “asset” value of the CER equal to **674 million Euros** in terms of Current Value, which turned into **1.1 billion Euros** when considering the Replacement Value, meaning the cost to rebuild the plants managed by the Consortium, after the cost of the expropriated land and the planning costs. This is the economic value of the infrastructure thanks to which the water of the Po River can be brought to the southern areas of Romagna, and this is the economic investment that constitutes the prerequisite, together with management and maintenance activities, of all those benefits discussed in this study.

The agricultural value: increase in land value

When it comes to the second assessment regarding the effects of water supply to the agricultural sector (**AGRICULTURAL VALUE**), the analysis first provided an overview and listed the main irrigated crops that benefit from the CER’s water distribution; subsequently two different estimation methods were applied with the shared goal of highlighting the economic value generated by the water provided by the CER to the agricultural sector. One must stress the fact that the two assessments are not complementary but rather provide two measurements of the same object analysed, based on two different points of view.

When it comes to the first of these two estimation methods, it entails a comparison between the land value of the land intended for hydro-demanding crops and land with no water availability. The results showed that **the land intended for irrigated crops shows a higher value compared to that of rainfed land**, namely **75% for arable land, 45% for vineyards and 18% for orchards**. Moreover, when it comes to the equipped surface guaranteed by the CER, equal to 174 thousand hectares, it was shown that **the total increase in land value generated by irrigation** is equal to **1.7 billion Euros (LAND VALUE)**.

The agricultural value: assessment of the agricultural production tied to the CER's water supply

The second assessment method, on the other hand, determined the value of agricultural production related to the water supply that the CER guarantees to the associated Reclamation Consortia through its “second-degree” function, answering the question of what would be the loss in agricultural productivity if the Consortium no longer provided water to the territory. To this end the decision was to apply a statistical simulation model with which to hypothesise an alternative crop scenario caused by the lack of water provided by the CER, and the consequent loss in agricultural production was calculated as the difference between this scenario and the current scenario. The results of the simulations highlight a gradual reduction in the agricultural production during the first steps of water deficit, while the intensity of the decrease intensifies with the ever lower water availability hypothesised each time, until it reaches **a hypothetical loss of 304 million Euros per year of gross saleable product** in the event of a complete absence of water provided by the CER (**VALUE OF THE AGRICULTURAL PRODUCTION**), equal to 56% of total production of the area studied, and nearly **13% of the crop productions of the entire Emilia-Romagna Region**. If this value is estimated by admitting that the farmers may adjust, at least partially, their crop choices in relation to the quantity of water available, **in the extreme scenario of there being no water owing to a sudden breakdown of the CER's plants, the production loss would be of 349 million Euros per year**, equal to 65% of the total production of the area managed by the CER. Water shortage would also have social and employment-related effects, as it would result in **the loss of over 100 thousand contract working days per year, equal to 8.8 million Euros per year of pay for seasonal workers**.

The ecosystem value

When it comes to the third and last assessment of this report, the issues examined were the environmental benefits generated by the presence of water on the territory guaranteed by the Consortium's infrastructure. Based on the categories recognised internationally by the scientific literature of the sector, the assessment method **identified the ecosystem services provided by the CER**, attributable to the **availability benefits** (supply of consumer goods such as water and agricultural resources), **regulation** (controlling natural phenomena and hydrological instability prevention), **habitat support** (guarantee of maintaining and developing living organisms), related to **well-being and culture** benefits (beneficial effects that the ecosystems tied to water ensure to humans).

For this type of assessment, the Benefit Transfer method was selected, a benchmark analysis of international studies realised in territories similar to the one of the CER with which to reach, thanks to the transfer of the parameter estimates obtained from this comparison, a quantification of the monetary value of the ecosystem services attributable to the presence of the CER. By applying a precautionary principle, **the economic value of the environmental benefits guaranteed by the CER (ENVIRONMENTAL VALUE)** was calculated at **20 million Euros per year**, of which about 10% (1.9 million) ensured by the wetlands, while most of the environmental benefit comes from the largest areas in the CER's territory, namely irrigated land and permanent crops. One must stress that this estimate does not include the CER's

contribution to countering subsidence, whose economic value is hard to quantify given the many variables it entails, but that would most likely be higher than the estimated number, considering the damage to property and infrastructure that would take place in the absence of the CER's water because of this phenomenon.

**The stakeholders'
opinion**

Finally, this study also analysed the opinions of the stakeholders from the territory (Institutions, Universities, Bodies tied to water management) on the role and functions performed by the Consortium: this provided an image of the CER as a **subject mostly recognised as a water provider** on the territory, in particular used by the agricultural sector, and secondly for the benefit of the industrial and civil sectors. Likewise, they acknowledge the CER's commitment to research and innovation in terms of water saving, with all the projects started at the service of farms. Vice versa, the Consortium is given less importance when it comes to environmental activities, with a minor role concerning containing hydrological instability phenomena. According to expert witnesses, in the CER's near future, apart from maintaining its role of water distributor for the territory, it will have to pay more **attention to environmental issues and those related to the provision of ecosystem services**, also in relation to the impact that climate change will have in terms of water rationalisation. In this respect they hope for an ever-greater commitment towards technological investments and an ever more intense dialogue with the institutions to promote virtuous actions to this end.

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FERRARA PLAIN RECLAMATION AND IRRIGATION CONSORTIUM



Irrigated surface	110,000 ha
Volume of water distributed by the Consortium	520 Mm ³
Volume of water withdrawn from the CER	40 Mm ³
Surface of the wetlands within the area	>12,000 ha
Length of the land reclamation and irrigation network	4,200 km

Chairperson: Stefano Calderoni; **Director General:** Mauro Monti

The role of the Consortium for agriculture

The irrigable territory is equal to 200,000 hectares (21,000 hectares are served by the CER system). The mechanical discharge of nearly the entire territory is the top priority to guarantee the land's cultivation. The availability of irrigation water (also attributable to the entire Area) has enabled the irrigation of over 50% of the surface. Of particular note are the spread of pome fruit such as the Pear tree (8,000 Ha), Apple tree (2,200 Ha), horticultural crops (Tomato, Carrot, etc.) 11,000 Ha, Rice 5,000 Ha, Soya (25,000 Ha), Maize (26,000 Ha), the nursery industry, which is not particularly widespread but of considerable economic importance. When it comes to the Gross Saleable Product of the agricultural sector, there is no updated data, but it should amount to about 700,000,000 €/year, of which about 100/150,000,000 related to typically non-irrigated crops. Regarding the irrigated area of the CER system, the main irrigated crops are orchards (pear tree and apple tree).

The role of the Consortium for the environment

The activity of the Consortium is carried out for six/seven months per year (summer period) to guarantee the water run-off in the dense network of canals across the territory. The presence of water in smaller waterways, which ought not to be taken for granted, guarantees the water supply for farms but also the fundamental support for maintaining the plants and animals of the territory they flow through which, without water, would risk desertification. The proximity to the sea, moreover, makes this territory vulnerable to the salinisation of the surface groundwater near the mouths. The transit of freshwater is an indispensable element to counter the rise and natural recharge of the groundwater for underground infiltration.

The role of the Consortium for industrial and civil uses, and for the development of the territory

The maintenance of the habitat in depressed territories also constitutes a supply guarantee for extra-agricultural farmers, for sporting facilities, industrial users and feeding of wetlands suitable for nature tourism (Comacchio and Boscone della Mesola valleys).

BURANA RECLAMATION AND IRRIGATION CONSORTIUM



Irrigated surface	37,000 Ha
Volume of water distributed by the Consortium	200 Mm ³
Volume of water withdrawn by the CER	4 Mm ³
Surface of the wetlands within the area	670 Ha
Length of the land reclamation and irrigation network	>2,200 km

Chairperson: Francesco Vincenzi; **Director General:** Cinalberto Bertozzi

The role of the Consortium for agriculture

The water supply for irrigation use of the Consortium is of vital importance for the agricultural crops of the area, with particular importance when it comes to those present in the main fruit and vegetable districts (e.g.: vineyards in the Lambrusco area of Sorbara in Bomporto (MO), watermelons and melons of the low plain areas around Modena, Mantua and Ferrara, pear orchards of the Modena low plain area, cherry trees of the Vignola area, alfalfa in the Parmigiano Reggiano area etc.); the presence of this resource in the territory allows for the production of valuable crops that determine an increase in GSP in the farms that are consortium members. Water as a production factor also enabled the consortium members to choose the most suitable agricultural crops for their company structure, with the possibility of diversifying their productions based on the market dynamics. Water is therefore an indispensable element for PDO, CDO and DOCG (Controlled and Guaranteed Designation of Origin) excellence products present in our area such as Lambrusco wine, Parmigiano Reggiano, fruit and vegetable products in forced and semi-forced crops etc.

The role of the Consortium for the environment

The Consortium provides water every year to fill 670 hectares of wetlands, of which about 75 hectares are located in the irrigated area served by the water diverted by the CER. Most of these wetlands are in SCI-SPA Areas of the Modena province (Valli mirandolesi, Le Meleghine). During the irrigation season the Detention Basin of Manzolino, with its over 30 hectare-surface, also receives water coming from the CER (SCI-SPA Area Manzolino) located on the border between the provinces of Modena and Bologna. Over the past more or less twenty years the Consortium has planted, with straight lines of local trees and shrubs, over 100 hectares of land located near the Consortia's waterways, with the aim on the one hand to contain the widespread pollution of the water, especially nitrate, and on the other to increase the biodiversity in its fields. The water transported on the waterways of the Consortia is also vital for maintaining the agricultural landscape of the plain present in our area, which features a dense hydraulic infrastructure serving the territory. The Consortium actively participates in a whole range of projects and activities aimed at maintaining and consolidating the nature present in the area and, where possible, to incentivise the initiatives aimed at restoring the elements of nature that are suffering. The environmental importance of the irrigation activity can be attributed to the presence of water within the water carriers, distributed in a capillary way across the entire area of the Consortia, which contributes to determining the following positive effects apart from strictly irrigation-related ones: countering subsidence, groundwater restoration, qualitative improvement of the water present in the canals managed by the Consortium and safeguard of the local avifauna and fish fauna.

The role of the Consortium for industrial and civil uses, and for the development of the territory

The Consortium's water supply in the area in many cases also performs a hygienic function: in the inhabited areas and in small business-industrial areas it can have a fire-extinguishing function, as well as of cooling within some production and food processes for a fish farming function (fish farms). In correspondence of some hydraulic carriers of our area there have been now for decades various cycle pedestrian paths of regional and interregional significance (e.g.: cycle pedestrian path FE101 Burana, Mirandola-Finale Emilia cycle path, Ciclovía del Sole cycle path etc.): this road infrastructure is a prodromal element of the birth and development of tourist activities in our rural territories.

RENANA RECLAMATION AND IRRIGATION CONSORTIUM



Irrigated surface	19,000 Ha
Volume of water distributed by the Consortium	90 Mm ³
Volume of water withdrawn from the CER	60 Mm ³
Surface of the wetlands within the area	2,700 Ha
Length of the land reclamation and irrigation network	2,000 km

Chairperson: Valentina Borghi; **Director General:** Paolo Pini

The role of the Consortium for agriculture

The Renana Reclamation and Irrigation Consortium plays a key role in the distribution of water for irrigation purposes. The possibility of benefiting from water supply heavily affects the company average profit of every single farmer. Production would diminish in a linear manner following the reduction in water, which would generate a sharp drop in profits. The greatest drop in profit would be reflected in the replacement of the most profitable crops, such as vegetable and fruit crops, with far less profitable crops. Water availability also allows for the possibility of diversifying the crop plans, which improves production but most importantly creates a remarkable diversity both in terms of landscapes and biology, with the consequent development of ecosystem benefits.

The role of the Consortium for the environment

The activities of the Renana Reclamation and Irrigation Consortium (discharge, hydraulic defence, water supply and control) contribute to maintaining the vitality of the habitats by providing an important ecosystem service. In the plain district biodiversity is concentrated in the wetlands, because the rest of the territory is very anthropised (human settlements and agricultural crops). The Consortium directly manages surfaces with specific hydraulic functions which obtain naturalistic importance; moreover, there are other remarkable protected naturalistic areas that are supplied indirectly (e.g.: Siti Natura 2000 with priority habitats for the European Union). These ecosystems can filter both human and animal waste and are a natural buffer for the surrounding environment. Through the biological activity of microorganisms in the soil, most of the waste is removed. This thus eliminates pathogens (microbes that cause diseases) and the level of nutrients and pollution is reduced. A similar service is provided by maintaining the water in the canals, which specifically guarantees the safeguard of the physical characteristics of the waterway, the chemical-physical characteristics of the water as well as the maintenance of the biocenoses typical of the local natural conditions. An interest in the quality and protection of the water connected to resilience and the close bond with the conformation of the landscape was also observed.

The role of the Consortium for industrial and civil uses, and for the development of the territory

The activities carried out by the Consortium, specifically the management of the natural ecosystems, provide a vital “consultation function” and contribute to the maintenance of human health by providing opportunities to reflect, of spiritual enrichment, cognitive development, recreational and aesthetic experiences. Through the aesthetic qualities and boundless diversity of the landscapes, the natural environments provide many opportunities for recreational, tourism, leisure and sporting activities: walks, hiking, camping, fishing, swimming and studying nature. Ecotourism can also spread awareness among people on the importance of biodiversity and thus contribute to strengthening other ecosystem services. Language, culture and nature are closely tied to human history. Biodiversity, ecosystems and natural landscapes are sources of inspiration for art, culture and recently science. Moreover, in many parts of the world, natural elements such as forests, caves and mountains are deemed sacred or have a religious meaning.

WESTERN ROMAGNA RECLAMATION AND IRRIGATION CONSORTIUM



Irrigated surface	37,005 Ha
Volume of water distributed by the Consortium	92 Mm ³
Volume of water withdrawn from the CER	88 Mm ³
Surface of the wetlands within the area	349 Ha
Length of the land reclamation and irrigation network	1,532 km

Chairperson: Antonio Vincenzi; **Director General:** Giovanni Costa

The role of the Consortium for agriculture

The role of the Consortium becomes apparent through the institutional activities tied to the maintenance and functioning of the hydraulic land reclamation works, the planning of new works, managing water for irrigation use and hydro-geological defence in mountainous areas. These activities directly or indirectly result in positive effects on agriculture:

water availability, apart from increasing the value of the agricultural land, guarantees an increase in production yields and the introduction of crop systems of great value such as fruit growing, wine growing, industrial crops and seed crops that would otherwise not be possible;

the support and development of the agricultural activity in mountainous areas takes place through the realisation of accumulation reservoirs (hill lakes) and the related primary distribution networks, by harnessing the resources made available by the Emilia-Romagna Region and the MIPAAF through the regional and national Rural Development Plans.

The role of the Consortium for the environment

The institutional activities of the Consortium result in positive externalities for the environment:

the maintenance of water pulling in the canals for mixed use guarantees the replenishing of the hypodermic aquifer for the entire duration of the irrigation season, with the consequent restoration of the aquifers and countering the intrusion of the salt wedge in the coastal territory;

the planning and realisation of new consortium works of water pressure distribution (RDP, NRDP, NRRP) allows, in the territories reached, to replace the withdrawals from the groundwater with surface water (CER), to counter the depletion of underground resources and subsidence.

The role of the Consortium for industrial and civil uses and for the development of the territory

The institutional activities of the Consortium result in positive externalities for the territory in general:

the water distribution activity for the benefit of valuable crops allows for the settlement and maintenance of production facilities of the agri-food supply chain, generating added value for the local economic fabric and employment in the related industries;

the realisation and management of rural aqueduct networks in mountainous areas serving utilities in various locations such as buildings, agricultural and livestock companies that cannot be reached by other public water networks, guarantee civil and economic activities in territories that would otherwise be bound to depopulation and abandonment, thus maintaining a constant defence against hydro-geological instability.

WESTERN ROMAGNA RECLAMATION AND IRRIGATION CONSORTIUM



Irrigated surface	380,000 Ha
Volume of water distributed by the CER	35 Mm ³
Volume of water withdrawn from the CER	88 Mm ³
Surface of the wetlands within the area	40,000 Ha
Length of the land reclamation and irrigation network	2,197 km

Chairperson: Stefano Francia; **Director General:** Lucia Capodagli

The role of the Consortium for agriculture

The Reclamation Consortium favours the growth of the agricultural and agri-food sector by distributing water. The management of the water asset for agricultural uses has improved thanks to an ever-greater rationalisation of consumption and system improvement. The Consortium pursues common interests by guaranteeing the improvement of the productions and countering climate change with ever longer periods of droughts that in the absence of water distribution would not allow for the maintenance of the income and diversification of the crop plans. In 2022 the Consortium started experimenting the reuse of purified waste water in agriculture with Hera and the Emilia-Romagna Region. It works with the Second-Degree Irrigation Consortium for the Emilia Romagna Canal on building new infrastructure (smart water gates, feasibility studies for extending the Canal, distribution for multiple uses) and national and European study projects to reduce water waste and the reuse of purified water.

The role of the Consortium for the environment

The Consortium also works on the safeguard of the network and public land reclamation works and the related buffer zones, also to pursue the safeguard of hydro-geological and environmental balance. The environmental function is vital to increase the resilience of our territories. The Romagna Reclamation and Irrigation Consortium, apart from internally developing environmental engineering projects, is working with private, public bodies and universities on renaturalisation projects, reuse of purified waste water and fertigation with the same and for the implementation of the sensor network for the integration of information coming from the consortium weather stations, both public and private. The Romagna Reclamation and Irrigation Consortium participates in the development of the territorial and urban plans and the soil and environment defence plans also with agreements with local bodies; with the execution and maintenance of the reclamation works it guarantees the preservation and defence of the soil, with major effects such as the maintenance of the landscape. With the mixed use of the consortium canals, by maintaining the reservoir thereof with the CER's water, as well as allowing for water distribution the Consortium performs a vital environmental function both in terms of recharge of the aquifer volumes in the dominated area and in terms of countering the intrusion of the salt wedge in the closest territories of the coastline. With the planning and realisation of new reservoirs the Romagna Reclamation and Irrigation Consortium plans to reduce the hydraulic risk and reduce the water withdrawal from the aquifers, thereby effectively countering subsidence in the plain areas. In the mountainous areas the Romagna Reclamation and Irrigation Consortium takes care of about 500 km of private roads for public use and historical paths, it implements hydro-geological defence and consolidation projects with RDP funds. Public-private interventions contribute to limiting the depopulation of the inland areas.

The role of the Consortium for industrial and civil uses and for the development of the territory

By guaranteeing the hydro-geological stability of the secondary network, irrigation and the correct run-off of the water, the Consortium makes the territories of the area safe and productive. Through the supply of the Emilia Romagna Canal it acts as a technical body for raw water intended for purification plants, in particular in the area going from Ravenna to the province of Rimini. By maintaining the mountainous territories accessible and safe, defending important tourism and industrial hubs from flooding, the Romagna Reclamation and Irrigation Consortium is a body that safeguards the tourism options and services, economic prosperity and the safety of those who live or simply come to visit our area.

ANNEX A

A.1 THE SIMULATION MODEL TO CALCULATE THE AGRICULTURAL VALUE

The model used to calculate the agricultural production tied to the CER's water supply (par. 4.3) is the *Positive mathematical programming* model. Specifically the decision was to employ the model developed by Howitt, (1995b). The model was programmed with the GAMS (General Algebraic Modelling System) software and includes two different phases: calibration and simulation. GAMS is a software that enables you to perform maximisations of utility functions, both linear and non-linear, with different methodologies and is currently among the most used to conduct studies in the agri-economic field (Graveline, 2016). Specifically this model has been developed to carry out simulations of the reduction in water availability for irrigation, so as to identify the different adaptation scenarios that would arise with the gradual shortage of water.

A.2 MATHEMATICAL FORMULATION OF THE MODEL AND CALIBRATION

The calibration procedure is performed to ensure that the model portrays the reality observed in the most realistic way possible. This goal is pursued through the reformulation of the original linear model. To carry out this procedure it was necessary to create a database that had the information regarding:

- Surface cultivated of every crop in the year of reference;
- Gross margin for every crop, average value of the available data;
- Production for every crop, average value of the available data;
- Prices for every crop, average value of the available data;
- Costs for every crop, average value of the available data;
- Quantity of water necessary for the irrigation of every crop;
- Family labour force necessary for every crop;
- Paid work necessary for every crop.

With this database the GAMS software was set up to carry out simulations of choosing a portfolio of the crops that would maximise the expected profit. The model is formulated as follows:

$$\max_x U = U(\mathbf{X}) = \sum_i y_i p_i x_i + s_i x_i - c_i x_i \quad (\text{A.1.1})$$

s.t.

$$\sum_{i=1}^n x_i = 1 \quad 0 \leq x_i \leq 1 \quad (\text{A.1.2})$$

$$\sum_{i=1}^n w_i x_i = \text{WA} \quad 0 \leq w_i \leq \text{WA} \quad (\text{A.1.3})$$

$$\mathbf{X} \in F \in R^n \quad (\text{A.1.4})$$

$$\mathbf{Z}(\mathbf{X}) \in R^3 \quad (\text{A.1.5})$$

\mathbf{X} indicates the portfolio of i crops, which contains the information regarding the allocation of the land for each crop x_i ; w_i indicates the specific water requirements of each crop, while WA indicates the supply of water in the area studied. y_i , p_i , s_i , c_i respectively represent the specific production, price, any subsidies and specific costs. The optimisation process is subject to some constraints (equations from A.1.2 to A.1.5).

The calibration of the PMP model takes place in three steps:

1. A second constraint is introduced regarding the crop area, to obtain an overconstrained linear model that perfectly recreates the reality observed; one can thus calculate the dual values associated with this constraint for each crop;
2. These dual values that have just been calculated are used to add a non-linear component to the original model; it is normally added in the cost, which is transformed into two components $\alpha_i e \beta_i$;
3. The original objective function (A.1.1) is replaced with a new non-linear function (A.1.6) that is maximised again with similar constraints to the original ones to perfectly recreate the reality observed.

$$y_i p_i x_i + s_i x_i - \alpha_i x_i + \frac{1}{2} \beta_i x_i^2 \quad (\text{A.1.6})$$

$\alpha_i e \beta_i$ indicate the linear and quadratic term of the new function of cost and are specific for each crop.

The dual values calculated in (1.) are interpreted by some scholars as a metric capable of capturing all the information that is not known to the analyst, but that make the choice of the rational agent the observed one; for this reason the PMP models can be interpreted as capable of detecting also all the other countless attributes that help the agent make a decision, though not making them explicit in the objective function like the multi-attribute models. On the other hand, the economic validity of these values is criticised, which one is often forced to justify with ad-hoc arguments that derive from a mathematical process rather than a socio-economic analysis (Graveline, 2016; Heckeley et al., 2012; Henry de Frahan et al., 2007).

The constraints used that define the model domain are described below and were used both in the calibration and in the simulation.

- *Available surface* (A.1.2). The available agricultural surface is deemed fixed and equal to the sum of the agricultural surface observed, therefore neither decreasing nor increasing the cultivated surface is permitted.
- *Water availability* (A.1.3). It is assumed that the water available for irrigation cannot increase during the simulation.
- *Climate and soil*. As each agricultural area has its own climate and physical characteristics, which make it more or less suitable for growing certain species, the agents in the model can only employ the crops observed on the database (Essenfelder et al., 2018).

$$\sum_{i=1}^n y_i x_i = 0 \vee y_i \in \{0,1\} \quad (\text{A.1.7})$$

where $y_i = 0$ indicates that the crop is observed and can therefore be used, while $y_i = 1$ means that the crop is not present in the area studied.

- *Specific constraints of some crops*. Some crop species have an upper (lower) limit to prevent them from increasing (decreasing) below a certain threshold. In the application proposed this limit is set for tree crops to prevent them from increasing (decreasing). This limit was set to assess the short-term effects without considering the possibility of major investments (disinvestments) in the event of expansion (contraction) of crops that were not accounted for by the model. Setting a limit to these crops is a very common practice in this type of models (Gutiérrez-Martín and Gómez, 2011; Parrado et al., 2019)

- *Crop rotations.* A common practice in agriculture is for certain crops to follow one another over the years for the soil to remain fertile over time. By following Pomato et al., (2007) e Tedeschini et al., (2017) the typical crop rotations used in the Po Valley for rainfed crops were considered. If one considers for example the wheat-sunflower rotation and considers an area with a sufficient number of farmers (for example a macro district) one can observe that the areas occupied by these crops are similar (Gómez-Limón et al., 2016). In accordance with the example rotation the wheat surface cannot exceed that of the sunflower or vice versa.

Calibration also allows for inserting some constraints to prevent the programme from considering in the same way permanent and seasonal crops and allows for setting up the different types of crop rotation that are implemented in reality. Rotations prevent the soil from exhausting the nutritional components that the crops consume in different ways. The constraints are the same for all macro-districts.

The following table indicates the water requirement of the main crops at a provincial level (the data of the province of Rimini is not available) in the event of full water availability, while the following table includes the list of irrigated and non-irrigated crops divided by type of seasonality considered in the analysis.

Table A.1 – Quantity of water available for the irrigated crops at a provincial level in a scenario of full water availability (values in millimetres/year)

	Ravenna	Forlì-Cesena	Modena	Ferrara	Bologna	Rimini
Grassed inter-row actinidia	457.5	433.6		425.6	476.7	Not available
Sugar beet	165.1	172.8	196.2	129.2	162.6	Not available
Onion	280.6	280.8	334.0		297.9	Not available
Alfalfa	165.1	137.4	225.6		145.0	Not available
Green bean	237.7	238.0		177.4	253.3	Not available
Average maize	271.1		291.7	177.9	262.2	Not available
Melon			325.3	232.9	290.3	Not available
Potato	259.1	256.5	303.5	218.5	262.1	Not available
Grassed inter-row pear tree	396.3		434.6	329.3	412.9	Not available
Grassed inter-row peach tree	254.0	246.4	268.7	176.5	216.6	Not available
Tomato for food processing	263.3	254.5		184.6	274.2	Not available
Soya	186.0	196.1	212.6	148.7	199.7	Not available
Tilled inter-row Vine	178.4	207.9	202.4		169.1	Not available

Table A.2 – Irrigated and non-irrigated crops divided by type of seasonality considered in the analysis

IRRIGATED	SEASONALITY
ACTINIDIA	Multi-annual
GARLIC	Summer
APRICOT TREE	Multi-annual
ASPARAGUS	Multi-annual
CHARD	Summer
SEED BEET	Summer
CHERRY TREE	Multi-annual
ONION	Summer
WATERMELON	Summer
ALFALFA	Multi-annual
SUMMER FIELD CROPS	Summer
GREEN BEANS	Summer
BROAD BEAN	Summer
FLOWERS	Multi-annual
IRRIGATED FODDER	Summer
STRAWBERRY	Multi-annual
MIXED ORCHARDS	Multi-annual
SUNFLOWER	Summer
IRRIGATED INDUSTRIAL CROPS	Summer
PERSIMMON TREE	Multi-annual
IRRIGATED LEGUMES	Summer
MAIZE	Summer
APPLE TREE	Multi-annual
MELON	Summer
WALNUT TREE	Multi-annual
VEGETABLE CROPS <60DAYS	Summer
VEGETABLE CROPS <60DAYS SUMMER CYCLE	Summer
VEGETABLE CROPS <60DAYS WINTER CYCLE	Winter
POTATO	Summer
PEAR TREE	Multi-annual
PEACH TREE	Multi-annual
SMALL FRUIT	Multi-annual
PEA FOR FOOD PROCESSING	Winter
TOMATO	Summer
POLYPHYTE LAWN	Multi-annual
RICE	Summer
SOYA	Summer
SORGHUM	Summer
PLUM TREE	Multi-annual
TOBACCO	Summer
VINE	Multi-annual
NURSERY CROPS	Multi-annual

NON-IRRIGATED	SEASONALITY
TREE CROPS	Multi-annual
WINTER GRAINS	Winter
SEED CROPS	Summer
RAPESEED	Winter
EXTRA CROPS	Multi-annual
FODDER	Winter
INDUSTRIAL	Winter
LEGUMES	Summer
OLIVE TREE	Multi-annual
HEDGES	Multi-annual

ANNEX B

B.1 THE ESTIMATE OF THE ECOSYSTEM SERVICES PROVIDED BY THE CER

Table A.3 includes the 17 scientific studies following the selection carried out with the Benefit Transfer method, to which a number from 1 to 17 was given to singularly identify them in the tables below for the sake of brevity.

Table A.4 illustrates the ecosystem services mapped by the 17 scientific studies, while table A.5 shows the total economic values divided based on type of soil use obtained from the 17 studies.

Table A.3 – List of the scientific studies selected with the Benefit Transfer method

No.	Authors	Title	Year	Country
1	Bielski, S., R. Marks-Bielska, A. Novikova, and B. Vaznonis	Assessing the Value of Agroecosystem Services in Warmia and Mazury Province Using Choice Experiments	2021	Poland
2	Aziz, T., and P. Van Cappellen	Comparative Valuation of Potential and Realized Ecosystem Services in Southern Ontario, Canada	2019	Canada
3	Polizzi, C., M. Simonetto, A. Barausse, N. Chaniotou, R. Kankanen, S. Keranen, A. Manzardo, K. Mustajarvi, L. Palmeri and A. Scipioni	Is Ecosystem Restoration Worth the Effort? The Rehabilitation of a Finnish River Affects Recreational Ecosystem Services	2015	Finland
4	Galioto, F., Marconi, V., Raggi, M., Viaggi, D.	An Assessment of Disproportionate Costs in WFD: The Experience of Emilia-Romagna	2013	Italy
5	Dachary-Bernard, J. and T. Rambonilaza	Choice experiment, multiple programmes contingent valuation and landscape preferences: How can we support the land use decision making process?	2012	France
6	Martin-Lopez, B., M. Garcia-Llorente, I. Palomo and C. Montes	The Conservation against Development Paradigm in Protected Areas: Valuation of Ecosystem Services in the Doñana Social-Ecological System (southwestern Spain)	2011	Spain
7	Jenkins, W. A., B. C. Murray, R. A. Kramer and S. P. Faulkner	Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley	2010	United States
8	Wilson, S. J.	Natural Capital in BC's Lower Mainland: Valuing the Benefits from Nature	2010	Canada
9	Southgate, D., T. Haab, J. Lundine and F. Rodriguez	Payments for Environmental Services and Rural Livelihood Strategies in Ecuador and Guatemala	2010	Guatemala, Ecuador
10	Thompson, J. and M. Anielski	Economic Activity and Ecosystem Services in the North Saskatchewan River Basin	2010	Canada
11	Troy, A. and K. Bagstad	Estimating Ecosystem Services in Southern Ontario	2009	Canada
12	Batker, D., I. De la Torre, M. Kocian and B. Lovell	The Natural Economy of the Nisqually Watershed	2009	United States
13	Wilson, S. J.	Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services	2008	Canada
14	Wilson, S. J.	Lake Simcoe Basin's Natural Capital: The Value of the Watershed's Ecosystem Services	2008	Canada
15	Alberini, A.; P. Rosato; A. Longo; and V. Zanatta	Information and Willingness to Pay in a Contingent Valuation study: The Value of S. Erasmo in the Lagoon of Venice	2004	Italy
16	Travisi, C.M., and P. Nijkamp	Willingness to Pay for Agricultural Environmental Safety: Evidence From a Survey of Milan, Italy, Residents	2004	Italy
17	Carlsson, F., P. Frykblomb and C. Liljenstolpec	Valuing Wetland Attributes: An Application of Choice Experiments	2003	Sweden

Table A.4 – The ecosystem services mapped by the 17 scientific studies

Number of the scientific study	SUPPLY SERVICES				CULTURAL SERVICES			HABITAT SUPPORTING SERVICES		CONTROL SERVICES								
	Food availability	Raw material availability	Availability of medical and pharmaceutical resources	Freshwater availability	Aesthetic value	Physical and mental well-being	Sense of belonging to a place	Tourism	Supporting habitats for animal and plant species	Maintaining genetic diversity	Mitigation of extreme weather events	Local climate and air quality	Carbon dioxide absorption (greenhouse gases) from the atmosphere	Waste water treatment	Biological control	Quality of the waters	Erosion prevention and soil fertility maintenance	Pollination
1					X	X		X					X			X		
2					X	X	X											
3				X	X	X	X	X		X								
4											X							
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8					X	X	X	X					X					
9				X							X	X						
10				X	X		X	X	X	X	X	X	X	X		X	X	
11					X	X	X	X	X	X								
12	X	X		X	X	X			X	X				X				
13					X	X	X	X						X		X		
14									X							X		
15	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
17	X			X	X	X	X	X	X	X	X	X	X			X	X	X

Table A.5 – The economic values divided by type of soil use obtained from the 17 scientific studies (€/Ha/year)

	CLC 5 - 212 ³⁵	CLC 7 - 220	CLC 1 - 112	CLC 2 - 11100	CLC 10 - 511	CLC 3 - 411	CLC 9 - 320	CLC 8 - 310	CLC 4 - 211	CLC 11 - 511
Number of the scientific study	Permanently irrigated land	Permanent crops	Discontinuous urban fabric	Continuous urban fabric	Bodies of water	Wetlands	Shrubby and/or herbaceous vegetation	Forests	Non-irrigated arable land	Waterways
1						1427.93				
2							1076.00			
3										2800.00
4	233.95					3071.18		4520.76		
5						456.41				
6	293.59						356.15			
7	58.80	58.80							58.80	
8	372.28					11045.87	1262.79	4225.42	372.28	261.45
9	222.48				3860.96	11583.64	270.65	3396.88	222.48	
10	412.86	1134.01			1114.50	8719.32	1154.30	3744.65	412.86	
11										2954.90
12										
13										
14	412.68									
15						455.02				
16	259.58									
17	74.54				193.74	795.04	242.72		74.54	193.74
MINIMUM (€/Ha/year)	58.80	58.80	0	0	193.74	455.02	242.72	3,396.88	58.80	193.74
AVERAGE (€/Ha/year)	260.09	596.40	0	0	1,723.06	4,694.30	727.10	3,971.93	228.19	1,552.52
MAXIMUM (€/Ha/year)	412.86	1,134.01	0	0	3,860.96	11,583.64	1,262.79	4,520.76	412.86	2,954.90
Surface (Ha)	170,151	36,495	18,722	8,144	5,558	4,308	1,568	1,160	1,147	985

³⁵ The column headings show the codes used by the Corine Land Cover programme to classify the types of soil use.



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