Nature-based solutions for climate change adaptation and water pollution in agricultural regions

Lot 5: LDP in a continental environment

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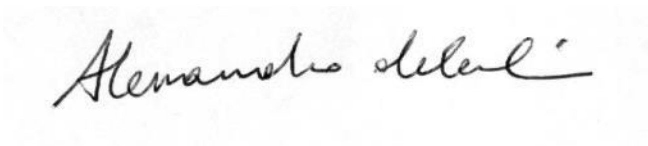

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EXECUTIVE SUMMARY

The present study analyses how Nature-based solutions (NBS) may contribute to reduce water pollution by retaining and processing diffuse pollutants generated by farming practices (Nitrogen, Phosphorus, sediments and pesticides) while delivering, at the same time, other benefits beyond water pollution control, such as shelters for biodiversity, amenity and recreational opportunities.

The study area

The study area is located in north-eastern Italy, a flat plain near the Venice Lagoon comprising two sub-basins (Marzenego and Dese-Zero), for a total surface of 37.785 hectares. The entire area is managed by the *Consorzio di Bonifica Acque Risorgive*: a public body in charge of managing the water and preventing floods (part of the area has been reclaimed through the centuries from original wetlands and swamps, and kept dry by mechanical drainage).

To protect the Venice Lagoon from eutrophication, since 1973 several national and regional laws have established a special regulatory framework in the area, sharing tasks and entrusting rules among the different administrative bodies (State, Region, Province, Municipalities). The most recent Regional Strategic Master Plan, approved in the year 2000, sets quantitative objectives for the removal of pollutants that includes nitrogen (the limiting factor controlling eutrophication in the Venice lagoon) from point and diffuse sources. The removal target set by the Strategic Master Plan is: 3000 tons per year for nitrogen for the whole region, including point and diffuse pollution sources.

Several actions are envisaged in the plan to reduce the nitrogen load in the lagoon. The removal target is expected to be obtained mainly through the upgrading of urban and industrial wastewater treatment plants, the treatment of animal manure and the reduction of nitrogen load at source by improving the farming practices. Out of a total of 3000 tons per year of nitrogen to be removed, 10% (**300 tons per year**) are expected to be removed through the implementation of NBS, such as riverbed and floodplain restoration, wetlands and buffer strips along the diffuse water body network draining into the lagoon catchment.

The Strategic Master Plan sets for the area managed by the *Consorzio di Bonifica Acque Risorgive* (the Drainage Authority managing 40% of the lagoon catchment) a removal target of **150 tons of total nitrogen per year** to be removed by increasing the self-purification capacity of the soil and water bodies.

Since the year 2000, 23 NBS have been implemented by the *Consorzio di Bonifica Acque Risorgive*, thanks to the financial resources provided by the government and allocated by the Regione Veneto – including on-stream and off-stream wetlands, buffer strips, and woody buffer areas – covering an area of approximately 252 hectares.

The 4 NBS analysed

Four of the NBS were selected (two wetlands, one buffer strip, one woody buffer area):

— **Scolo Rusteghin:** it is an in-line wetland that receives the water from the Rusteghin canal. This wetland covers an area of 3.5 ha and was designed to create a tortuous flux inside the wetland in order to increase the residence time and improve the effects of the natural processes on the nutrient removal. Due to its characteristics, the wetland can also be used to store rainwater thus contributing to the reduction of flooding risk.

— **Salzano:** the wetland (former clay quarry) covers an area of 21.6 ha out of the 65 ha of the total surface of the quarry. This wetland is located between two water bodies: the Marzenego river and the Rio Roviego. Part of the flow of the Marzengo river is withdrawn to feed the wetland and it takes 6 days to pass through the wetland and then flows into the Rio Roviego.

— **Scandolara:** is a buffer strip located in the Venetian Plain. The buffer strip has significant effects in removing the nitrogen carried to the river by the sub-surface flows that drain the adjacent cultivated areas. The buffer capacity of the system has been monitored in 2011 and 2012 (Gumiero & Boz, 2017)

— **NICOLAS site:** it is a 30 ha (0.86 ha as experimental site) sub-irrigated and afforested buffer area. It was designed to manage the hydrological fluxes that flow through a system of ditches carrying water pumped from the Zero River. Ridges and furrows facilitate subsurface water flow from the inlet point to the parallel drainage ditches located at lower elevations.

Each NBS is described in terms of its design (layout, illustrative design drawings such as cross sections or sketches), and their effectiveness in removing diffuse pollutants has been analysed in depth, relying as much as possible on real monitored data.

The removal capacity of the 4 NBS is quite variable and depends on the specific design and on the pollutant load. As an example, considering the most important pollutant for the Venice Lagoon (Total Nitrogen, TN), the Rusteghin wetland shows the worst performance in terms of removal % of the incoming load, but by far the best performance in terms of nitrogen removal capacity per space unit of NBS (see following table).

NBS	**TN removal [%]**	**TN removal [g m^{-2} y^{-1}]**
Rusteghin wetland	23	94.58
Salzano wetland	41.5	20.5
Scandolara buffer strip	39	22.5
Nicolas buffer strip	50	6

Based on the removal capacity of the 4 studied NBS, an estimate of the performances of all the 23 NBS existing on the two sub-basins was provided.

The investment, operation and maintenance costs of each of the 4 NBS were analysed and an analysis of cash flow was performed. The investment costs of the analysed NBS range between 3 and 22 €/m^2 while the maintenance & operation costs range between 0.02 and 0.26 €/m^2/year.

The social Analysis

A Social Analysis was conducted between October 2019 and January 2020, with the general objective of collecting and analysing the issues that affect the social sustainability of the application of an NBS to treat diffuse pollutants in the Venice Lagoon watershed.

Within the perspective of local development, based on the priorities and needs identified by local stakeholders and beneficiaries themselves, this part of the study focused in particular on the following specific objectives:

1. Understand the main relations among relevant stakeholders and local actors and their perceptions about NBS;

2. Explore the main issues that affect the social sustainability of the area where the NBS solution is in place;
3. Collectively identify and evaluate the functional capacity of the case as a successful model of local development.

At the social level, in order to explore the perception, among farmers, citizens, and other stakeholders, of the installation of the NBS solution in the target area, a **Need Analysis** was conducted. The Analysis adopted a participatory methodology based on the active involvement of the main stakeholders:

— *Consorzio di Bonifica Acque Risorgive* (Drainage authority in charge of managing most of the NBS)

— Farmer associations (Coldiretti Treviso, Confederazione Italiana Agricoltori Treviso, Confederazione Italiana Agricoltori Venezia, Confagricoltura Treviso)

— Local citizens NGOs (local WWF office)

Identification and quantification of costs and benefits

The ability to contribute to reducing the **flood risk** is one important feature of NBS, which increased their acceptability, especially among farmers, the stakeholder group most affected by the NBS. Obviously not all NBS provide the ecosystem service of flow regulation, and the performance depends on several aspects: the intensity of flood risk in the basin, the location of the NBS and its design.

For what concerns **recreation and health**, most of the NBS appear to provide a recreational service for the local population. The wetlands and the woods of the NBS are the only green "natural" spaces in the local intensively farmed landscape.

"**Education**", according to the results of the social analysis, is an important added value provided by NBS: "*the creation of natural areas has been highly appreciated by schools as they represent the only few examples of what the natural environment was like before the 1950s*".

Beside the **improved water quality,** NBS offer another important environmental benefit by providing a new habitat to support **biodiversity**: the positive effects of newly created NBS in intensive agriculture landscapes are well known. The biodiversity benefit of wetlands is greater than that of buffer strips, since they create habitats for important species (insects, amphibians, birds) strictly linked to aquatic ecosystems; habitats that have been heavily damaged and reduced in the past 150 years, by the land reclamation practice. Wooden buffer strips contribute to biodiversity thanks to the "ecotone" effect, while the positive effects of herbaceous buffer strips are nearly negligible. Of the four NBS object of the study, information on species and habitat of European interest was found only for two of them: the Salzano and the Nicolas sites.

The Salzano site is a large newly created wetland surrounded by a wood: an ideal condition to host interesting habitats and be colonized by plants and animals. That is why after a few years it has been identified as Special Conservation Zone according to the Habitats Directive (92/43/EEC).

The Nicolas site is now a large wood crossed by a dense network of water ditches. Even though it has not been included among the sites of community interest according to the Habitats Directive, some interesting species have been found in the site.

The costs and benefits identified were quantified using specific indicators and an estimate was made of the performance of the 23 NBS implemented in the study area. Then an assessment of non-monetary benefits was carried out through appropriate value transfer methods, to allow a general assessment of the benefits provided to the study area.

Objectives/ criteria	Indicators	Performance	Range of monetary values by value transfer €/year
Reduce flood risk	Retention volume available for peak flow reduction m^3	1,758,487 m^3	46,000 – 53,000
Use for recreation	Accessibility: number of people leaving in a range of 1 Km from the NBS (potential recreation users)	21,322 persons	960,000 – 1,070,000
Use for education	Number of pupils involved in educational activity	1760 pupils/y	30,000 – 70,000
Contribute to water quality	Nitrogen removal: t_N/year	48 t_N/year	450,000 – 1,450,000
	Phosphorus removal: t_P/year	3.4 t_P/year	
	Sediment removal: t_{TSS}/year	2073 t_{TSS}/year	
	Pesticide removal: $t_{glyphosate}$/year	0.5 $t_{glyphosate}$/year	
Support biodiversity	Extension of newly created natural habitat	2,523,260 m^2	80,000 – 90,000
Total			Sum of the above as range
Annualized CAPEX*	€/year	1,532,273	
OPEX	€/year	147,281	
Loss of farmland income	€/year	378,489	
Difference (costs-benefits)	€/year	492,043 – (-671,957)	

* The total amount of investment costs divided by 30 years. A life span of 30 years has been observed for wetland systems designed by IRIDRA, however the life span of wetlands could be higher than 30 years; thus the estimate must be considered very conservative.

The "business model"

The main conditions that allow the business model of the Venice Lagoon watershed to be effective in the construction and maintenance of NBS for diffuse water pollution control are:

- The availability of funds (public (state or local taxes), provided by private companies for marketing reason, raised among sensitive population, etc.) to cover most part of the construction costs, including land acquisition;
- The role played by the Drainage Authority *Consorzio di Bonifica delle Acque Risorgive*, highly qualified and innovative in its technical approach.

The funds provided by the "special law" guaranteed the availability of financial resources for a long period of time: in fact, at the beginning, some of the NBS required quite a long time (up to 20 years) from the feasibility analysis to the final construction. Only the possibility to rely on a continuous and certain source of financial resources allows the progressive construction of new green infrastructures, starting from the easier and better accepted projects up to the most time requiring ones.

To figure out the possible replication of the "business model" to areas where the funds coming from the "Venice special law" are not available, an alternative hipothesis of financial source has been considered, by recurring to a "purpose local tax". According to the preliminary estimations, the purpose local tax seems to be bearable by the local community: considering a lifespan of the NBS of 30 years, the cost per inhabitant (living in the interested basin) of all the "green infrastructure" needed to fulfil the Nitrogen removal target of 150 tonnes/year would be 23€/year. Another solution, which would require a reform of the national law ruling the Consorzi di Bonifica, would be to transfer to them the task of guaranteeing, beside the land reclamation and irrigation, the multifunctionality of rural areas, including environmental quality and ecosystem services. Such a reform should design a different system of economic contribution of the landowners that also takes into account environmental issues and ecosystem services.

The presence of a skilled and innovative technical direction in the "Consorzio Acque Risorgive" has been an important added value for the NBS constructed over the last 20 years. In fact, even though the financial resources of the "special law" were available for other Drainage Authorities of the Venice Lagoon, the experience of the Acque Risorgive is by far the most important in terms of number of NBS done and of quality and effectiveness of the results.

Another key aspect for the acceptability of the NBS by the local farmer community is the high attention given to the flood risk prevention in the design of NBS. All the NBS are designed to provide, in addition to the other ecological services, also an extra volume for stormwater storage (e.g. all the buffer strips envisage earth movements to enlarge the stream section, to guarantee the hydraulic functionality even with a higher roughness due to the presence of vegetation). Such solution increases the construction costs of the NBS but contributes to strengthen the multi-functionality of NBS and specifically their effectiveness in flood risk prevention, an issue perceived as very important, particularly in reclaimed landscapes.

The involvement of the "urban population" (residents in the area that are not farmers) – even though their "power" as stakeholders in the decision process concerning NBS in the agriculture landscape is weaker compared to farmers – can contribute to gain support for the implementation of NBS. Their interest mainly concerns recreation and educational opportunities: the most important condition to satisfy such a demand is that NBS are accessible. To increase the interest of the local community towards NBS a specific attention should be paid in the design phase, taking care of possible tourist itineraries linking different NBS locations together. Even when NBS are accessible only by crossing private land, an agreement with farmers could be found, particularly if the farmer itself can take advantage by the presence of tourists (e.g. through direct sale of farm products, agritourism).

Conclusions

The performance of the 4 NBS in reducing pollution in terms of mass per m^2 of NBS appears to be in line with the existing scientific literature. Wetlands show better removal rates per m^2 than buffer strips for all parameters with the exception of sediments (SS), for which the best removal rate has been detected at the Scandolara buffer strip. It has to be underlined that the examined wetlands, differently from buffer strips, have not been designed following strict scientific criteria to maximize their pollutant removal capacity: therefore the pollutant removal capacity could have been significantly higher – with a minimum loss of side benefits – had a more "target oriented" design been adopted.

The construction parametric cost of NBS ranges between 10 and 40 €/m^2 for the two wetlands and the Scandolara buffer strip, while it decreases by an order of magnitude (around 3 €/m^2) for the Nicolas buffer strip, a value that is in line with the costs of "conventional" buffer strips according to literature data (1.5-2 €/m^2). The reason why the cost of Scandolara buffer strip is much higher than a "conventional" one is because it is a conceptually different system that could be considered a sort of "integrated buffer strip". This system includes a wet ecosystem downstream the wooded part of the system and requires a significant excavation work to also provide a flood prevention effect. However, this solution also proved to be valuable in terms of effectiveness, at least for nitrogen removal capacity: in fact, this kind of buffer strip shows rates 2 to 3 times higher than those of conventional buffer strips.

For what concerns "side benefits", the analysed NBS appear to provide several ecosystem services considered valuable by the local community.

Considering the whole surface of the interested basin (37,750 hectares) the construction of 23 NBS for a total surface of 252 hectares (0.67% of the drainage basin area) allows the removal of about 50 tons/year of nitrogen, 1/3 of the total target expected. The capital cost for the construction of all the NBS amounts to 45 million € (around 1 million per ton/year of total N removed and 1,200 € per hectare of the whole basin), spent in a period of 20 years (2.25 million € per year). O&M cost amounts to less than 150,000 €/year, fully acceptable for an administration with a turnover of tens of millions €.

Quantifying the value of ecosystem services provided by a value transfer method, the estimation results in an yearly value ranging between 1.5 and 2.7 million euros, values comparable to the yearly expenditures for the sum of capital and O&M costs in the last 20 years (2,275,000 €/year).

In conclusion, the experience of the Consorzio Acque Risorgive appears to be successful. A significant extension of NBS have been constructed showing a pollutant removal capacity in line with the scientific data, reasonable construction, and O&M costs, while providing several other benefits. The high value provided by the NBS every year to the community is shown if these benefits are monetized through a "value transfer" exercise.

It must be considered that the "business model" applied in this case study (that could be called "centralized governance") differs from the most common model. The model that could be called "diffuse governance" involves the construction and maintenance of NBS, specifically buffer strips or very small wetlands, on private land by directly subsidizing farmers who use public grants such as payments under the Common Agricultural Policy (CAP).

A "diffused governance" system would probably allow a reduction in the parametric costs of NBS (both capital and O&M), thanks to the use of farmers' work-time. Consequently, it could obtain, with the same amount of money, a wider diffusion of NBS in terms of total NBS area. However, the effectiveness in terms of pollutant removal and most likely also in terms of several other benefits, would be highly uncertain. For example, to be effective, buffer strips need to be carefully located and designed to obtain significant removal capacity. According to the experience of the technical staff of the Consorzio Acque Risorgive, farmers who access subsidies for buffer strips place them in order to minimize their negative effects on agricultural production, rather than to maximize environmental benefits.

A system of "centralized governance" can guarantee the effectiveness of environmental benefits much more than a "diffuse governance" system. Moreover, an approach used by Consorzio Acque Risorgive, acquiring the land where the NBS are constructed to the public property, guarantees that in the long term, the involved areas do not change their destination.

The total nitrogen removal of the 23 NBSs is estimated to be equal to 48 t_N/yr, while the removal target is 150 t_N/yr. Therefore, it is necessary to triple the area destined to NBSs. On the basis of this hypothesis, the impact of a total investment of 135 million euros – of which a third has already been made – has been estimated: the total annual cost per inhabitant would be between 23 and 33 euros/yr/inhabitant (52 – 76 euro/yr/ family).

These are orders of magnitude of cost that are generally bearable, also assuming redistributive mechanisms that allow low-income families to be exempted by slightly increasing the burden on wealthier families or by providing a share of the contributions to be borne by businesses. The business model analysis shows that – given the current legislation – the Consorzi di Bonifica would find it difficult to replicate the experience of this case study in other areas of Italy and that the involvement of the Municipalities and recourse to specific instruments such as the *Imposta Comunale di Scopo* (Municipal Purpose Tax) would be necessary to raise the financial resources for the NBS. This suggests the opportunity of a legislation reform on the Consorzi di Bonifica, rethinking the role of these organisations, born for the management of land reclamation, but which over time have assumed an increasingly important role in the management of water and territory. However, the situation differs from Region to Region and also from *consortium* to *consortium*: if some *consortia* (in particular in the North) actually exercise important environmental skills, others are strictly limited to guaranteeing the drainage of reclaimed areas and supplying water for irrigation.

Yet the Consorzi di Bonifica are, in Italy, the organizations most similar to those which, in other European countries, are responsible for the correct management of the minor hydrographic network in rural areas (e.g. the "district water boards" in the Netherlands). A reform that reviews its competences and financing mechanisms, and adequate training on modern approaches to water management and hydraulic risk aimed at recovering the ecosystem services of the agricultural territory (NWRM, NBS, multifunctional "win win" solutions), would be the main way to allow the diffusion on a national scale of experiences similar to the one described in the present case study.

1 INTRODUCTION

1.1 Objectives of the feasibility study

The present study analyses how Nature-based solutions (NBS) may contribute to reduce water pollution by retaining and processing diffuse pollutants generated by farming practices (Nitrogen, Phosphorus, sediments and pesticides) while delivering, at the same time, other benefits beyond water pollution control, such as shelters for biodiversity, amenity and recreational opportunities.

More specifically the present study, along with other similar ones being developed in different areas, will provide evidence to address the following questions:

— How can NBS contribute to mitigate agricultural water pollution (nutrients, pesticides, sediments, and other contaminants)?

— What are the costs and cost drivers of NBS?

— What are the benefits they deploy?

— What are the technical, capacity, governance, management and financial constraints hampering their take-up?

To answer these questions, a few existing real scale NBS were selected in North Western Italy (Veneto Region) in an area – the basins draining to the Venice Lagoon – interested by a long term program of water pollution control (see next paragraph).

Each NBS is described in terms of its design (layout, illustrative design drawings such as cross sections or sketches) in chapter 2 and their effectiveness to remove diffuse pollutants due to farming practices is analysed in depth, relying as much as possible on real data monitored (chapter 3).

Investment, operation and maintenance costs of the examined NBS are provided in chapter 4, together with a cash flow analysis.

To explore the main issues affecting the possible support or opposition to the NBS by the local community, a comprehensive social analysis was conducted, adopting a robust participatory methodology based on the active involvement of all key stakeholders (chapter 5).

A quantification of the direct and indirect benefits (recreation, flood protection, biodiversity, etc.) was carried out together with the possible negative effects (Loss of farmland income, nuisance to farming practice) and their valuation through appropriate value transfer methods. Benefits and Drawbacks were estimated for the 4 studied NBS and scaled up to the whole basin, considering the other NBS existing in the area (chapter 5.1).

Finally (chapter 7), the governance and financial scheme that allows the construction of tens of NBS by the local Drainage Authority "*Consorzio di Bonifica Acque Risorgive*" was analysed and discussed, to delineate a possible "business model" that could be proposed for a broader implementation of diffuse pollution NBS in agricultural landscapes.

1.2 Overview of the project area

The Venice Lagoon is an important water body that, due to the huge economic growth occurred in the area, since 1960 has undergone a dramatic deterioration of its ecological conditions.

The first "special law" for the protection of the lagoon dates back to 1973. That law imposed the treatment of municipal wastewater that discharged into the lagoon, when wastewater was normally disposed of untreated in Italy, with the exception of the most polluting industries, to which they required to treat wastewater according to local public hygiene regulations; the first national water protection law would only be approved in 1976.

Figure 1. Map showing the study region as a red dot in Europe

Since then, several national and regional laws update the regulatory framework in the area, sharing tasks and entrusting rules among the different administrative bodies (State, Region, Province, Municipalities): the most recent is the Regional Strategic Master Plan[1] (SMP) approved in the year 2000. That plan sets quantitative objectives of pollutant removal that includes nutrients from point and diffuse sources. According to the results of the ecological studies done on the Venice lagoon, the admissible Nitrogen load in the lagoon is 3000 tons per year; the admissible phosphorus load has not been estimated being nitrogen the limiting factor for algal growth in the lagoon. The total nitrogen load estimated by the SMP is around 6000 tons per year. The nitrogen removal target set by the SMP is therefore 3000 tons per year.

Several actions are envisaged by the plan to reduce the nitrogen load in the lagoon. The removal target is expected to be obtained mainly through the upgrading of the urban and industrial wastewater treatment plants, the treatment of animal manure and the reduction of nitrogen load at source by improving the farming practices.

Among the different actions put in place by the SMP, the implementation of NBS is envisaged, such as riverbed and floodplain restoration, wetlands and buffer strips along the diffuse water body network draining into the lagoon catchment. The contribution of the NBS to be implemented on the whole cathment area draining into the lagoon to the nitrogen removal target (3000 tons/year) amounts to **300 tons per year**.

[1] "Piano per la prevenzione dell'inquinamento e il risanamento delle acque del Bacino idrografico immediatamente sversante nella Laguna di Venezia - Piano Direttore 2000" . Deliberazione del 1° marzo 2000, n. 24 del Consiglio Regionale del Veneto. http://sistemavenezia.regione.veneto.it/content/piano-direttore-2000

The drainage basin of the Venice lagoon is composed of several basins, each of them managed by a different "Drainage Authority" (*Consorzio di Bonifica*): most of the catchment draining into the Venice lagoon is managed by 4 Consorzi di Bonifica (Veneto orientale, Piave, Acque Risorgive, Bacchiglione) (see **Figure 2** representing the basins managed by the different Drainage Authorities of the Veneto Region): among them the *Consorzio di Bonifica Acque Risorgive* operating on several basins located in the Northeastern part of the region and managing an area of around 100.000 hectares (around 40% of the whole area draining into the lagoon). The Strategic Master Plan sets for the basins manged by the *Consorzio di Bonifica Acque Risorgive* a target of diffuse pollution removal of **150 tons per year of total nitrogen** to be removed through the increasing of the self purification capacity of the soil and of the water bodies.

Consorzi di Bonifica, according to the Italian legislation, are a quite peculiar kind of Authority. They are Public Economic Entities, but they are an association of private citizens – mainly the farmer owners of the land managed by the authority – who play a key role in the governance of the body. Their main task is flood prevention and irrigation.

Figure 2. The Consorzio di Bonifica "Acque Risorgive" and the other Drainage Authorities of the Veneto Region.

To organise its management activities the *Consorzio di Bonifica Acque Risorgive* identified six sub-basins with similar characteristics (UTO – Unità Territoriali Omogenee).

Table 1. UTO managed by the Consorzio di Bonifica Acque Risorgive

Management units (UTO)	Area (Hectares)	Drainage network (Km)
1 – Muson	21.780	477
2 . Lusore Pionca	28.327	549
3 – Novissimo	7.678	148
4 – Marzenego	14.377	245
5 – Dese-Zero	23.408	412
6 – Sile	6.022	67

The present study is focused on two units, UTO 4 and UTO 5, where most of the NBS to reduce pollution have been implemented in the last 25 years.

The plan does not set a deadline to reach the target, however the Regione Veneto financially supports the *Consorzio di Bonifica* depending on the availability of financial resources since the year 2000. More in details: the *Consorzio di Bonifica* identifies possible solutions (wetlands, buffer strips or other NBS) based on their estimated nitrogen removal capacity and their technical and economic feasibility; the Region approves the preliminary design and then provides the financial resources for the detailed design and construction of the NBS (including the acquisition of the area, if needed).

After implementation, the ordinary management costs are covered by the *Consorzio di Bonifica* with its own resources, while other costs (such as monitoring of the removal effectiveness) are guaranteed by other financial sources (such as scientific research funds, Environmental Protection Agency, etc.).

Since the year 2000 several NBS have been developed in the two sub-basins (see **Figure 3**): more detailed information on them will be provided in section 5.1 of the present report.

Among the NBS implemented in the two sub-basins, 2 wetlands and 2 buffer strips have been identified, for which a considerable amount of monitoring data were available, to be analysed, in order to provide detailed parametric data to estimate NBS direct and indirect benefits and develop the business model for the UTO 4 and UTO 5.

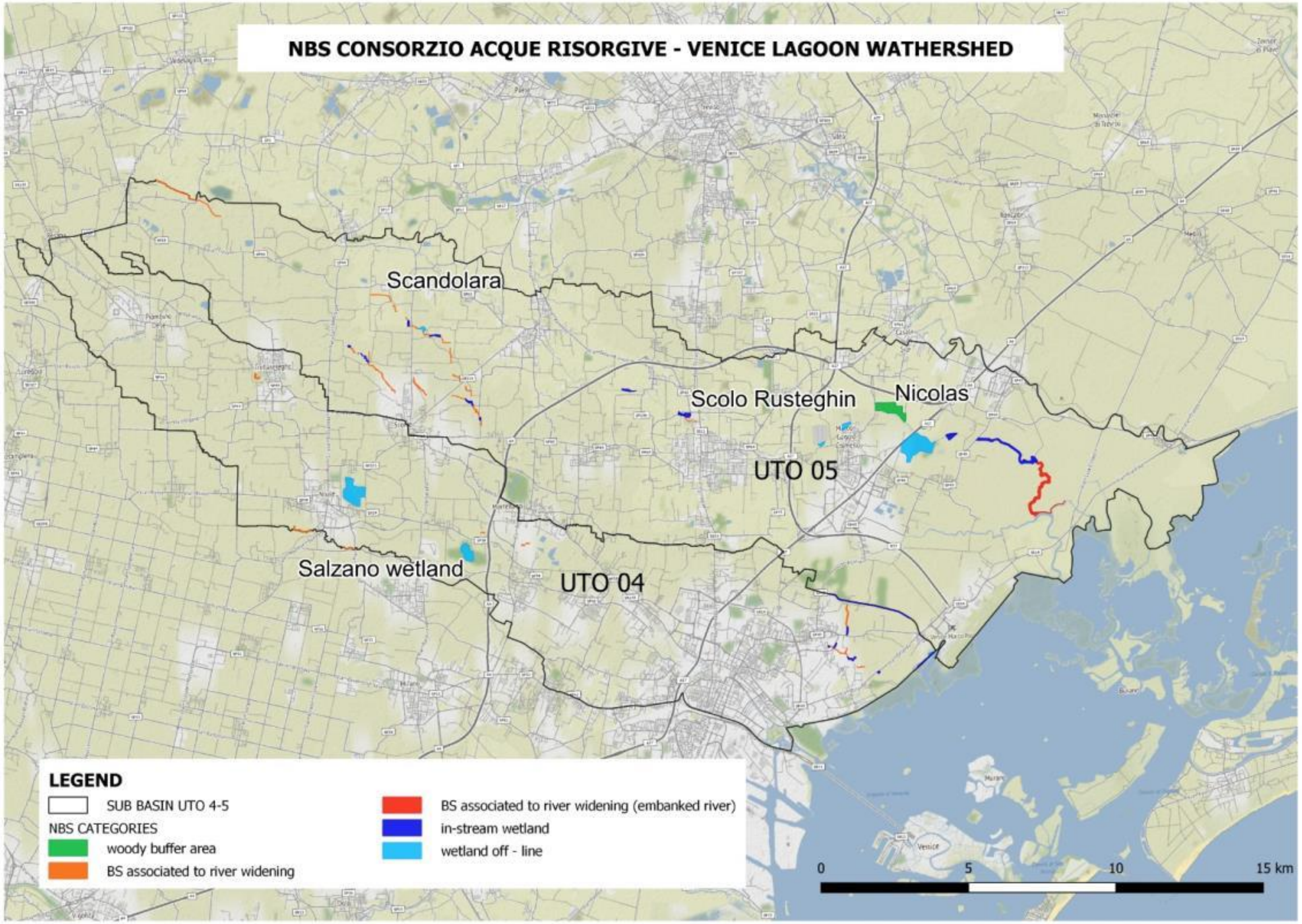


Figure 3. The 2 sub-basins (UTO) of the Consorzio di Bonifica "Acque Risorgive" where most of the NBS have been implemented since the year 2000 and the 4 NBS selected for the present study (BS: Buffer Strips)

2 CHARACTERIZATION of the NBS

2.1 NBS design

2.1.1 Wetlands

The wetlands that have been taken into consideration are:

— **Scolo Rusteghin** (located near the town of Mogliano Veneto). It is an in-line wetland that receives water from the Rusteghin canal and releases it into the Buratti stream.

— **Salzano** (former clay quarry in the area of Villetta di Salzano). The wetland covers an area of 21.6 ha of the 65 ha of the total area of the quarry. This wetland is off-line and limited between two water bodies: the Marzenego river and the Rio Roviego. Part of the flow of the Marzenego river is withdrawn to feed the wetland and it takes 6 days to pass through the wetland and then flows into the Rio Roviego.

These two areas are both located near urban contexts, nevertheless they host some important elements in term of biodiversity. For example, a study carried out by the Acque Risorgive Consorzio di Bonifica on the Scolo Rusteghin wetland has shown that in only 4 years the wetland has become the habitat for 137 different species of plants and at least of 23 species of aquatic birds. The Salzano wetland is part of the Special Areas of Conservations (SAC) IT3250008 "Ex Cave di Villetta di Salzano", including 8 species listed in Annex II of Directive 92/43/EEC and 2 habitat types of community interest.

In terms of constructed wetland (CW) classification, Scolo Rusteghin and Salzano are free water surface (FWS) wetlands

2.1.1.1 Scolo Rusteghin

This wetland covers an area of 3.5 ha and was designed to create a tortuous flux inside the wetland in order to increase the residence time and improve the effects of the natural processes on the nutrient removal. Because of its characteristics the wetland can also be used to store rainwater and reduce the effects of floods.

The wetland is included in the set of small streams and channels reported in **Figure 5**, with the following functioning:

— the wetland receives two types of influent loads

  - loads from the Rusteghin stream, a small channel conveying the water collected from a drainage basin equal to about 165 ha; the Consorzio di Bonifica estimates an average flow of 50 l/s to be diverted from the Rusteghin stream towards the wetland all over the year;
  - loads from the Zero river, a river conveying the water collected from a drainage basin equal to about 500 ha; the Consorzio di Bonifica diverts from the Zero river towards the wetland, to improve the water quality for irrigation purposes, an average flow of 25 l/s during summer months;

— the wetland outflow is discharged in the Buratti stream, a downstream tributary of the Zero River; since the Buratti stream has a culvert with not sufficient hydraulic functioning for heavy rain events, the Rusteghin wetland was also designed to be a detention basin to reduce the flood risk of the road and downstream houses, targeting heavy rain events with return period up to 10 years

As previously mentioned, this area was subject of a study lasted 2 years (2016/2017) on the flora and fauna living in the wetland. In addition, a specific study to measure the residence time and the mass balance has been carried out.

Figure 4. Pictures of the Rusteghin wetland from the site visit held the 17th September 2019.

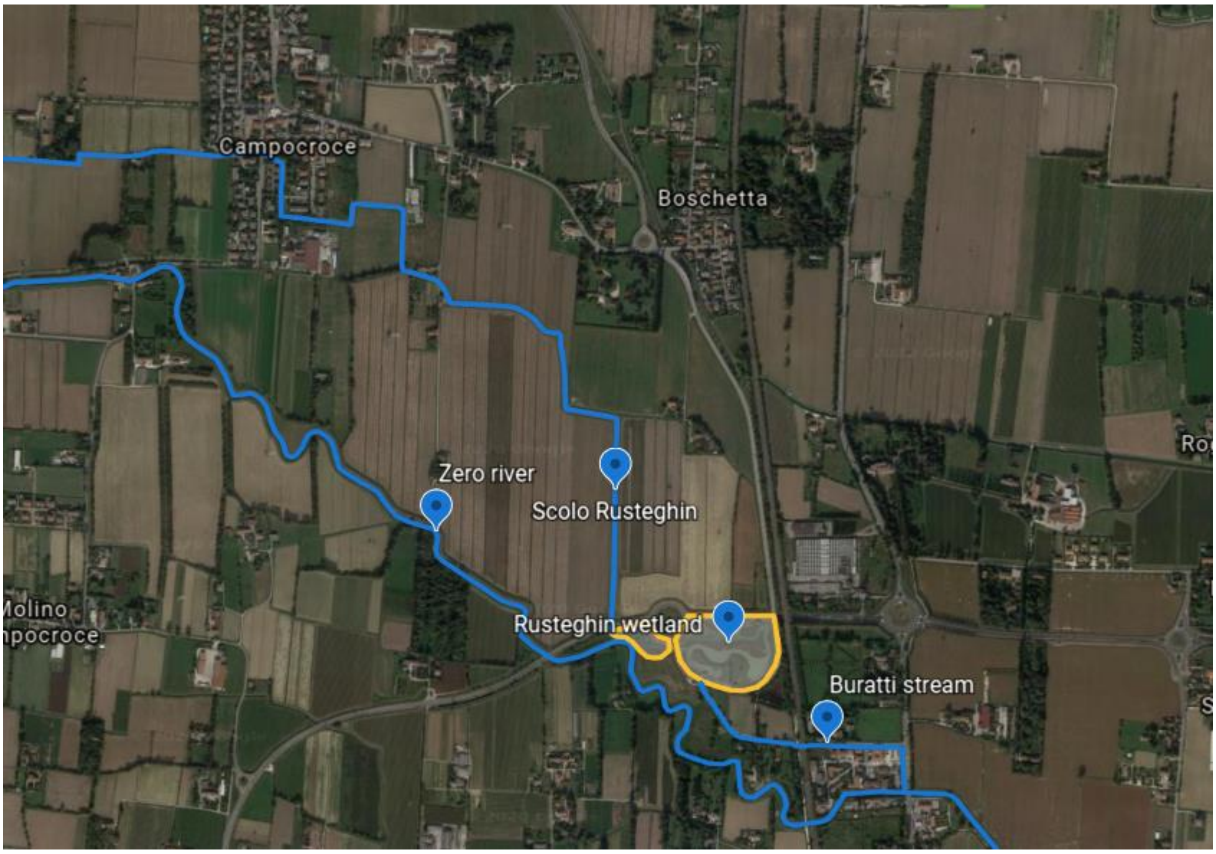
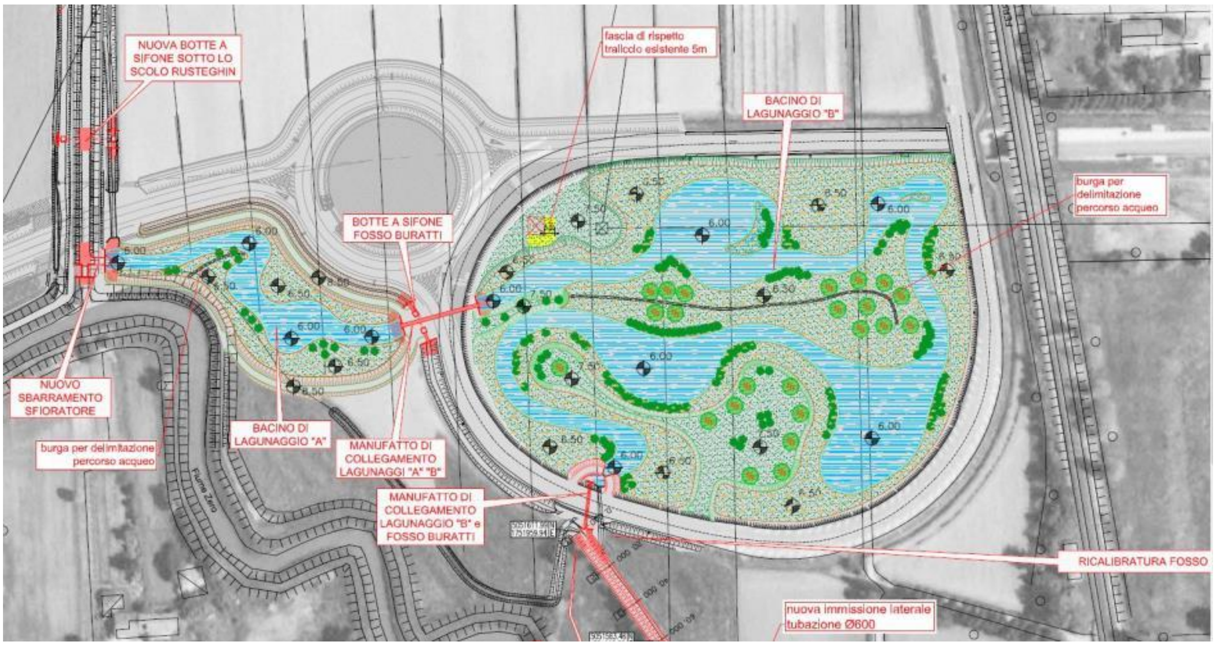


Figure 5. Drained watershed and intervention area of the Rusteghin wetland. (https://www.google.it/intl/it/earth/)



Open water FWS areas

Vegetated FWS surface

Emergent area (no FWS)

Embankments

Populus nigra var. Italica

Salix cinerea

Figure 6. Planimetry of the Rusteghin wetland

2.1.1.2 Salzano

The Salzano wetland represents a particularly interesting case of environmental action on a former clay quarry in which the creation of a wetland developed a diversified aquatic environment able to host a wide biodiversity. The biodiversity increased since the flooding of the area that progressively in time restored a unique aquatic environment which attracted many species of aquatic flora and fauna. After the completion of the wetland the area was declared SIC (Site of Community Importance). The wetland extends its area for 21.6 ha, about 1/3 of the total quarry area (64.4 ha). The mean hydraulic retention time of the Salzano wetland is estimated to be 6 days. No pumps are used to allow the water to flow through the wetland: the water's movement is just based on gravity since the wetland was designed with different heights of the water level. Electro-mechanical regulation and control structure are installed, in order to regulate the influent flow rate.

The wetland is located on an Italian State property (Demanio) but is currently managed by a group of environmental associations named NAPEA (Associazioni per il Presidio e l'Educazione Ambientale).

Figure 7. Planimetry of the Salzano wetland, built within the Salzano quarry: wood area (dark green dots); vegetated FWS area (light green dots); open water FWS area in blue.

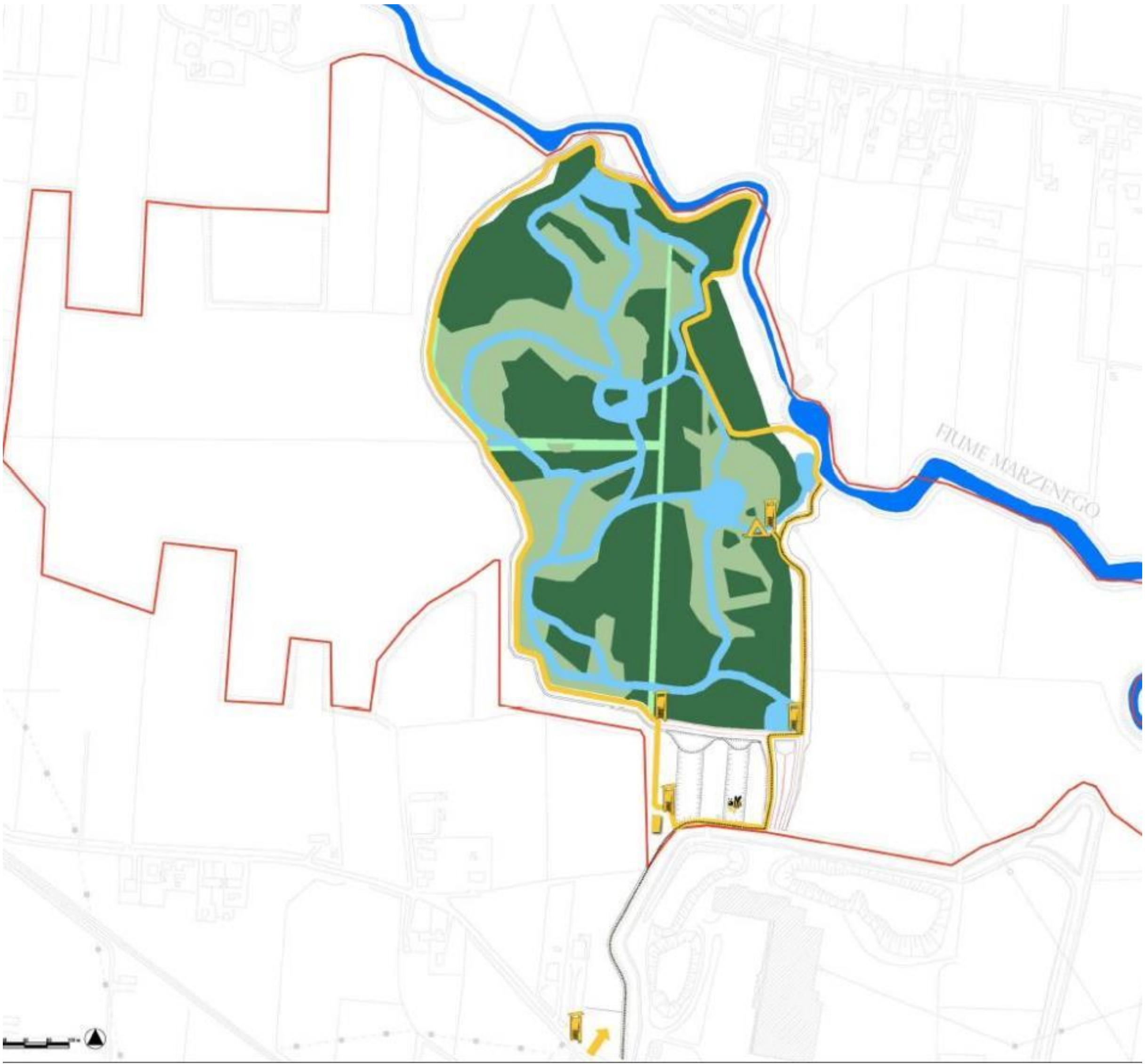


Figure 8. Planimetry of ecological (in green) and recreational infrastructure (in yellow)

Figure 9. Pictures of the Salzano wetland from the site visit held the 17th September 2019.

Resume of design characteristics of wetland systems

Table 2. Design parameter for the 2 studied wetlands

Design parameter	Unit	Salzano	Rusteghin
Wetland type	categorical	FWS (Free Water Surface)	FWS
Topographic adjustment[2]	categorical	yes	yes
Total area	ha	21.6	3.5
Pond area	ha	2.5	
FWS area	ha	4.2	
Hydraulic retention time	d	6	1.5
Type of vegetation	plant list	*Allium angolosum* *Carez elata* *Carex pseudacyperus* *Cirsium canum* *Cladium mariscus* *Senecio paludosus* *Typha laxmannii* *Iris pseudocorus*	

[2] Here intended as some design recommendations that have been done to insert variability in the NBS design; for wetland systems, this is intended if some extra excavations have been done to differentiate water depths inside the wetland

Design parameter	Unit	Salzano	Rusteghin
Periodical removal of the biomass	binary	no	no
Entertainment infrastructure	categorical	yes	no

2.1.2 Buffer strips

In the case of Buffer Strips 2 sites were selected:

- **Scandolara:** is a buffer strip located in the Venetian Plain (lower Po flood-plain in the North-East of Italy). The buffer strip has a significant effect in removing the nitrogen transported to the river by the sub-surface flows draining the adjacent cultivated areas. The buffer capacity of the system has been monitored in 2011 and 2012 (Gumiero & Boz, 2017)
- **NICOLAS site:** it is a 30 ha (of which 0.86 ha as experimental site) sub-irrigated and afforested riparian buffer. It was designed to manage the hydrological fluxes that flow through a system of ditches carrying water pumped from the Zero River. Ridges and furrows facilitate subsurface water flow throughout the field from the inlet point to the parallel drainage ditches located at lower elevation. The site has been selected because it was subject to a long-term monitoring activity in the period 1999 to 2009 (Gumiero *et al.,* 2011; Gumiero & Boz, 2016; Boz *et al*., 2013; Mastrocicco *et al*., 2014).

2.1.2.1 Scandolara

This 11 m wide buffer strip (Figure 10 and Figure 11) was constructed in 2007 along the left bank of the Piovega di Scandolara stream (45°36′51″N; 12°05′5″E). This project was part of a wider river restoration project (including the implementation of some km of buffer strips) aiming to reduce nutrient loading into the Venice Lagoon and to control flood risk. The trapezoidal section of this lowland stream was reshaped in order to create a 6 m wide riparian strip that would become flooded during moderate water level rise.

As final result, a 4 m wide herbaceous strip, between farmland and the restored river section, was created at the same level of the adjacent cultivated field (upslope). This buffer strip is representative of the pre-restoration conditions and is coherent with the obligations of the Common Agricultural Policy (CAP)'s cross compliance standards[3].

Proceding along the river section (downslope), two rows of trees were planted within the higher portion of the bank (see Figure 10), while the inner part of the buffer strip, interposed between the river and the tree rows, was covered by spontaneous and unmanaged helophytic vegetation (Figure 11).

[3] Standard 5.2 "Establishment of buffer strips along water courses" (M.D. 27417, December 22, 2011)

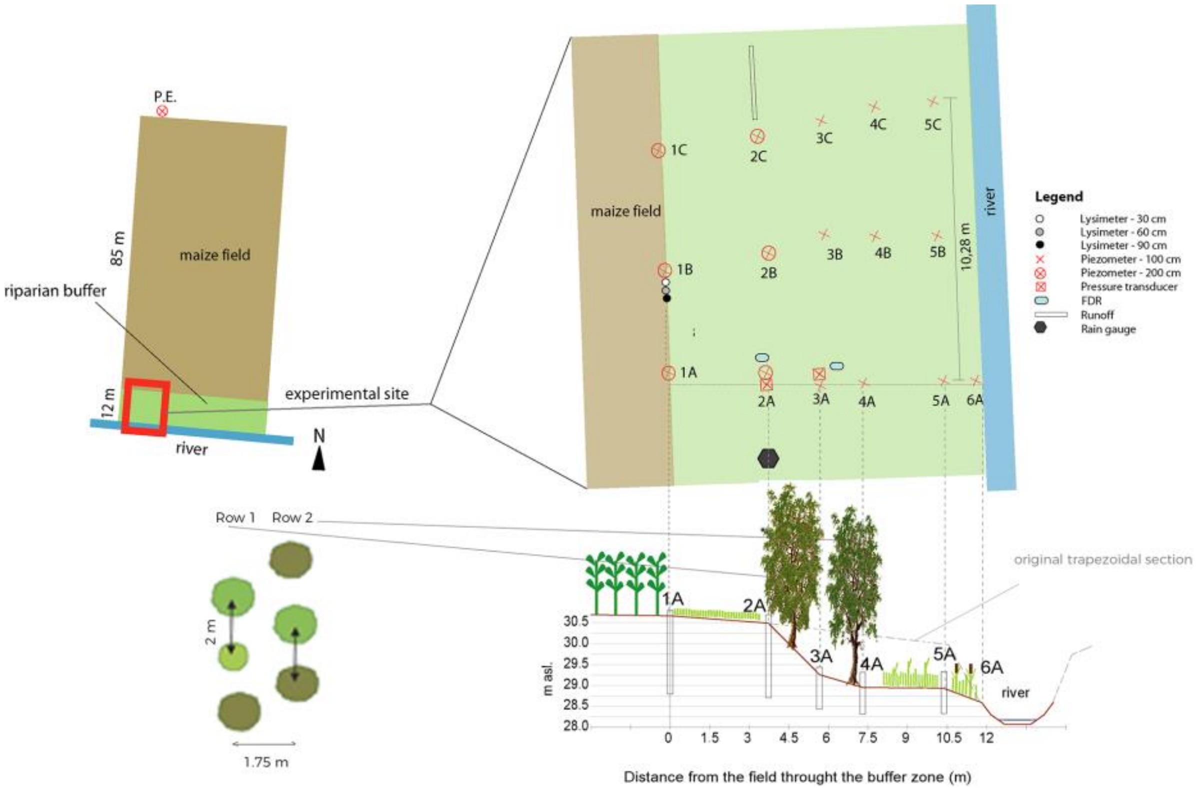


Figure 10. Illustrative design of the Scandolara buffer strip, including indications on the experimental scheme (modified by Gumiero & Boz, 2017)

Figure 11. General and detailed views of the Scandolara buffer strip 3 years after the restoration project (ph. Bruno Boz).

Figure 12. Pictures of the buffer strip from the site visit held the 17th September 2019.

2.1.2.2 NICOLAS site

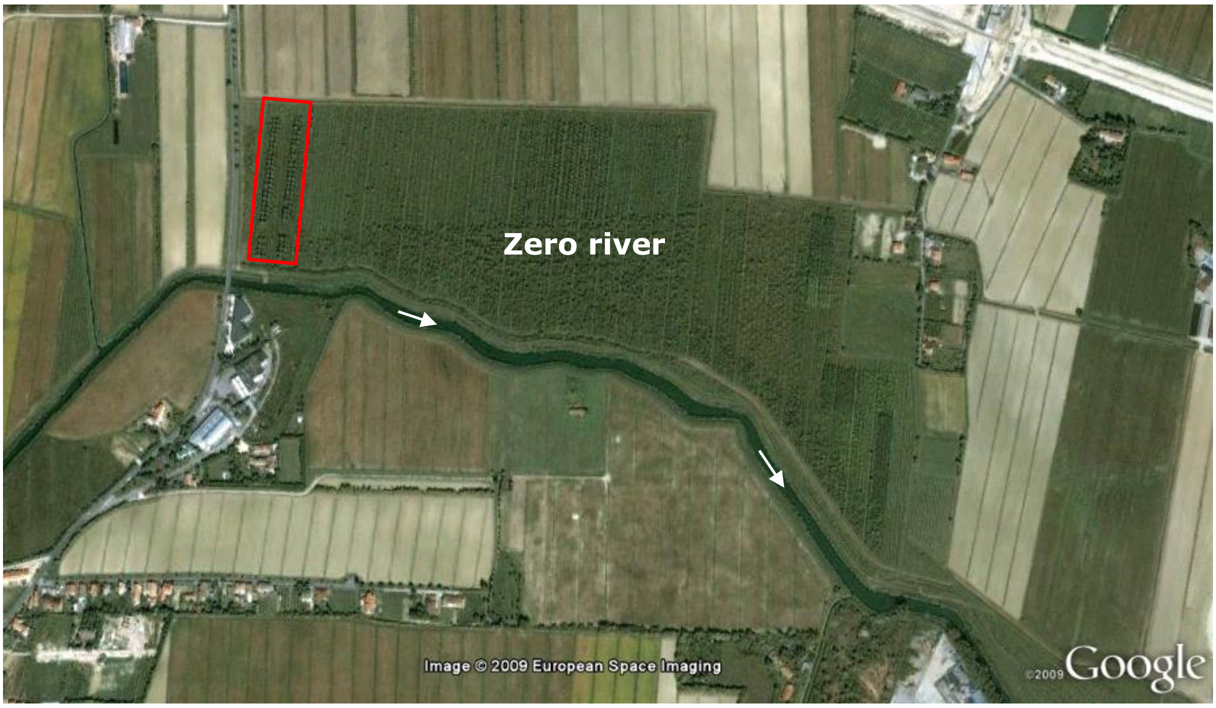


Figure 13. Aerial view of the whole (30 ha) afforested riparian buffer area, located in the left bank of the Zero river. The red area includes the NICOLAS experimental site (0.85 ha).

The site is located in the area of the village of Mogliano Veneto and named NICOLAS (Nitrogen Control by Landscape Structures in Agricultural Environment) after the European Research Project NICOLAS (1997-2000), aimed at design and monitor buffer strips throughout Europe. The buffer strip includes a wooded area of 30 ha on the side of the Zero river. Five pumps distribute the water from the Zero river to 30 drainage channels, where water is accumulated and then allowed to flow through the soil. Finally, water reaches the main drainage channel and then it is discharged back to the Zero river.

The site has been selected because it was subject to a long-term monitoring activity in the period 1999 to 2009. Even if the data collected during the monitoring activity refer to a particular type of buffer strips, treating the water abstracted by a polluted river instead of the runoff or the sub-surface flows draining from cultivated areas, they could be considered also as representative for buffer strips with an irrigation ditch.

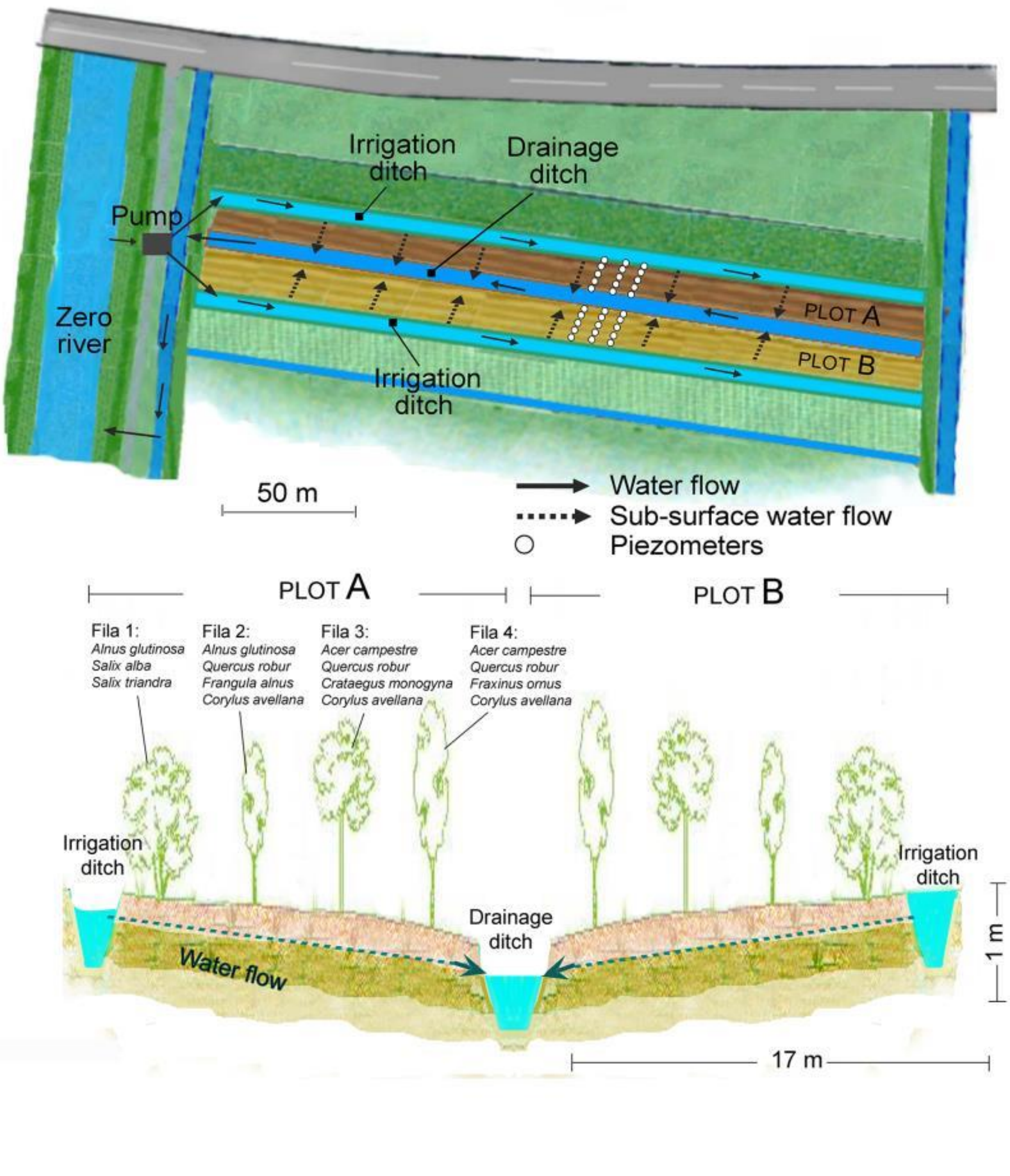


Figure 14. Plan (above) and section (below) of the 30 m wide experimental site: each plot is watered through an irrigation ditch carrying water from the Zero river. Soil setting allows a difference in elevation among the irrigation ditches (INPUT) and the drainage ditch (OUTPUT), resulting in a subsurface flow of water running through the wooded buffer strips (modified by Gumiero et al., 2011).

Figure 15. Sequence of images depicting the evolution of the riparian buffer site during the monitoring period.

Figure 16. Pictures of the sub-irrigated riparian buffer strip from the site visit held the 17th September 2019.

2.1.2.3 Summary of design characteristics of buffer strip systems

Table 3. Design parameter

Design parameter	**Unit**	**Scandolara (upslope)**	**Scandolara (downslope)**	**NICOLAS**
Buffer strip type	categorical	Riparian buffer strip	Riparian buffer strip	Sub irrigated, afforested buffer area
Topographic adjustment[4]	categorical		River widening (6m)	Excavation of irrigation ditches
Area	ha	0.38	0.57	0.85
Width	m	4	6	30 and 5
Slope of the buffer strip	%	7.5	25.0	4.0
Length	m	957	957	205
Type of soil	categorical	loamy sand	loamy sand	silty clay loam
Hydraulic retention time	d	*n.a.*	*n.a.*	1.1
Type of vegetation	categorical	herbaceous	trees, shrubs, herbaceous	trees
Periodical removal of the biomass	binary	twice per year	unmanaged	unmanaged

[4] Here intended as some design recommendations that have been done to insert variability in the NBS design; for wetland systems, this is intended if some extra excavations have been done to differentiate water depths inside the wetland

2.2 Investigation of the context

2.2.1 Landscape framework

Landscape has been investigated considering the following features and sources:

- Satellite view: Google Earth
- Land use and infrastructure: Corine Land Cover (https://land.copernicus.eu/)
- Topography: technical regional map (Carta Tecnica Regionale – CTR – https://www.regione.veneto.it/))
- Soil type: Regional soil type map (https://www.regione.veneto.it/)

Drawings for each feature and each NBS are given in Annexes.

2.2.2 Climatic framework

- **Climatic framework** has been developed consulting the data of the Regional Agency for Environmental Prevention and Protection of Veneto (ARPAV - www.arpa.veneto.it)

The data have been used to estimate mean monthly and yearly precipitation and evapotranspiration values for the mass balance analysis of chapter 3.

Hydrological analysis is done following the rainfall depth-duration frequency curves provided by Veneto Region in the guidelines for flood mitigation measures[5].

The detailed analysis of climatic and hydrological data is given in Annexes.

[5] https://www.regione.veneto.it/web/ambiente-e-territorio/compatibilita-idraulica. Access: June 2020

3 MATERIAL FLOW ANALYSIS

3.1 Source of data and assumptions

The material flow analysis has been based on **monitored data** for all the NBSs described at chapter 2.

For the 2 selected buffer strips the dataset (a summary of the data collected is described in **Table 4**) includes:

- one year of data collected for the Scandolara "natural" buffer strips, those include hydrological data, soil samples, and water quality for nitrogen pollutants;
- six years of data collected for the Nicolas site, aimed at estimating the effects of different removal processes (uptake, nitrogen fixation, biological processes); in this case the effectiveness of the NBS was also monitored with a tracer test.

For the 2 wetlands the dataset includes:

- detailed monitoring of wetland systems, including tracer tests, water quantity, nutrient balance (N and P), characterization of plant uptake

Table 4. Monitored parameters in the buffer strips

Parameters	BS sites	Sampling point	Frequency	Methods	Aims
Water table depth (continuously)	**SCANDOLARA**	One point input and one point output	Every 30 minutes	Pressure transducers	To understand the dynamics of the saturated zone and to calculate the water balance.
	NICOLAS site	One point input and one point output	Every 30 minutes	Pressure transducers	To understand the dynamics of the saturated zone and to calculate the water balance.
Saturated hydraulic conductivity (Ks)	**SCANDOLARA**	All piezometers	Once	Slug test	Water balance
	NICOLAS site				
Water table depth (instantaneous measurements)	**SCANDOLARA**	In each piezometer (5 x 3 grid)	During the water sampling (approximately every 15 days)	Handily freatimeter	To integrate the data recorded in continuous in a single section, with data relating to the whole piezometric net in order to define the groundwater direction.
	NICOLAS site			Handily freatimeter	
Chemical parameters of water (N_{tot}, N-NO_3, N-NH_4, N-NO_2)	**SCANDOLARA**			Standard laboratory methods	
	NICOLAS site				
Chemical parameters of soil (TOC, TN, NO_3, NH_4).	**SCANDOLARA**	Three points (replicates)	2-3 times for year	Standard laboratory methods	To estimate nitrogen storing or loss in the soil.
	NICOLAS site				
Rainfall	**SCANDOLARA**	One pluviometer in each experimental site	Continuously	Rain gauge connected to a datalogger	Water balance, climate trend.
	NICOLAS site				
Tracer	**SCANDOLARA**	*n.d*	*n.d*	*n.d*	*n.d*
	NICOLAS site				

3.2 Pollutant flow analysis

3.2.1 Mass load removal

3.2.1.1 Rusteghin wetland

Water inflow/outflow

The monitoring of the wetland has been done between February 14, 2018 and April 12,2019, by the Industrial Engineering Department of Padova University. The monitoring stations were located at the inlet and at the outlet of the wetland. The hydraulic and mass balances have been carried out for the year 2018, considering the total wetland area of Rusteghin equal to 3.5 ha.

The inlet and outlet stations presented some problems for the flow measurement[6]. The entrance section is characterized by a small jump not comparable to a weir in size; while downstream there is a rectangular weir on a sluice gate. Both presented problems of accumulation of sediments, branches and leaves, which alter the flow. From the experimental measurements, an ad hoc curve was fitted during the monitoring campaign to estimate the average flow rate entering the Rusteghin wetland (**Figure 17**). On the basis of the flow rate curve, University of Padova[6] has estimated an average influent flow rate in the range 50-75 l/s for the year 2018, in line with the value targeted by the Consorzio di Bonifica. These values were also confirmed by a tracer test, conducted from 8th to 14th March 2018 by University of Padova, i.e., during spring months in which there was no withdrawal from the Zero River. The hydraulic retention time resulted equal to 1.5 days, corresponding to an average influent flow rate of 50 l/s.

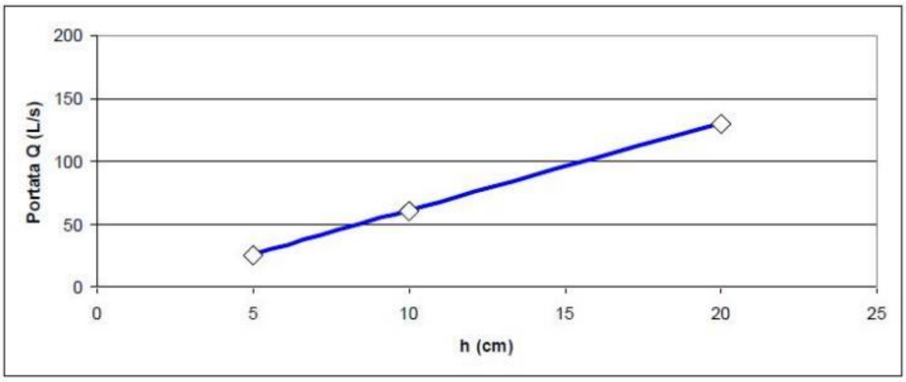


Figure 17. Flow rate curve – Outlet section[6]

Influent flow rate faced by the Rusteghin wetland in the year of monitoring, i.e. 2018, were reconstructed considering the following input and source of data:

— base flow of Rusteghin stream ($\mathbf{Q_{IN\_1}}$), reconstructed according to the average value given by the Consorzio di Bonifica experience and expected annual variability estimated during detailed design, with an average value equal to about 35 l/s

— runoff from the Rusteghin basin ($\mathbf{Q_{IN\_2}}$);

— withdrawn from the Zero river ($\mathbf{Q_{IN\_3}}$), which, according to information given by the Consorzio di Bonifica, was assumed equal to 25 l/s in summer months.

[6] Prof. Luca Palmieri, Dott. Giovanni Marco Carrer, Dott. Paola Cocurullo; Monitoraggio delle acque del Rio Rusteghin (Mogliano Veneto TV) Rapporto finale delle attività; Università degli Studi di Padova Dipartimento di Ingegneria Industriale Laboratorio Analisi dei Sistemi Ambientali

The runoff from the Rusteghin basin ($\mathbf{Q_{IN\_2}}$) was calculated considering the sub-basin of the Rusteghin watersheds (***Figure 18***), and separately considering two types of soil use, green area (runoff coefficient equal to 0.3) and urban area (runoff coefficient equal to 0.7). The runoff was calculated at monthly basis for 2018, applying the average-weighted runoff coefficient for each sub-basin and the mean monthly precipitation from the Mogliano Veneto station (ARPAV data).

Table 5. Sub-basins of the Rusteghin watershed

	Green Area [ha]	**Urban Area [ha]**	**Area [ha]**
Sub-basin 1	32.01	16.52	48.53
Sub-basin 2	22.3	2.2	24.5
Sub-basin 3	53.6	0	53.6
Sub-basin 4	35	4.02	39.02
TOT	**142.91**	**22.74**	**165.65**

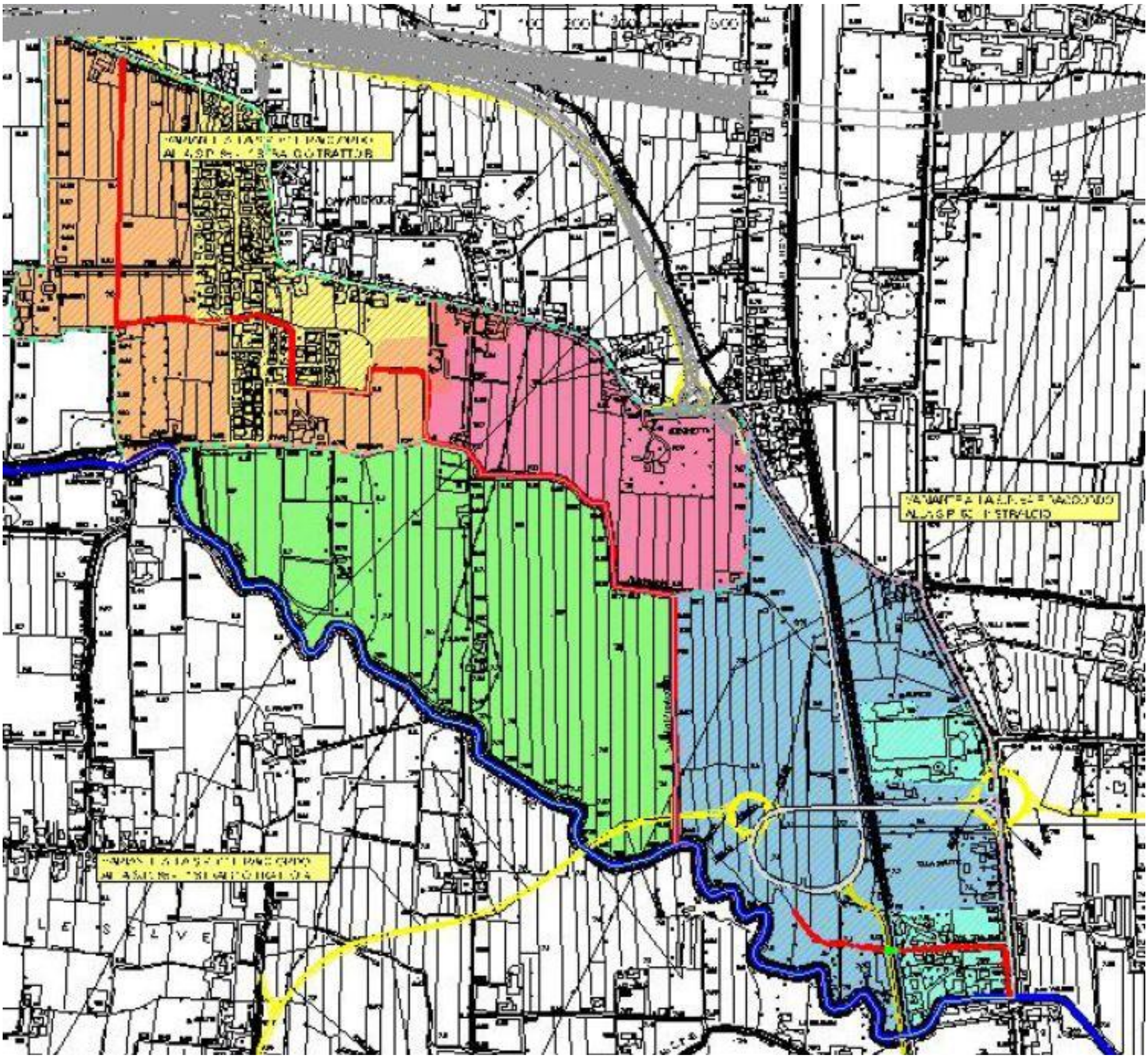


Figure 18. Four sub-basins (orange/yellow, pink, green, and blue) of the Rusteghin watershed according to the detailed design documentation

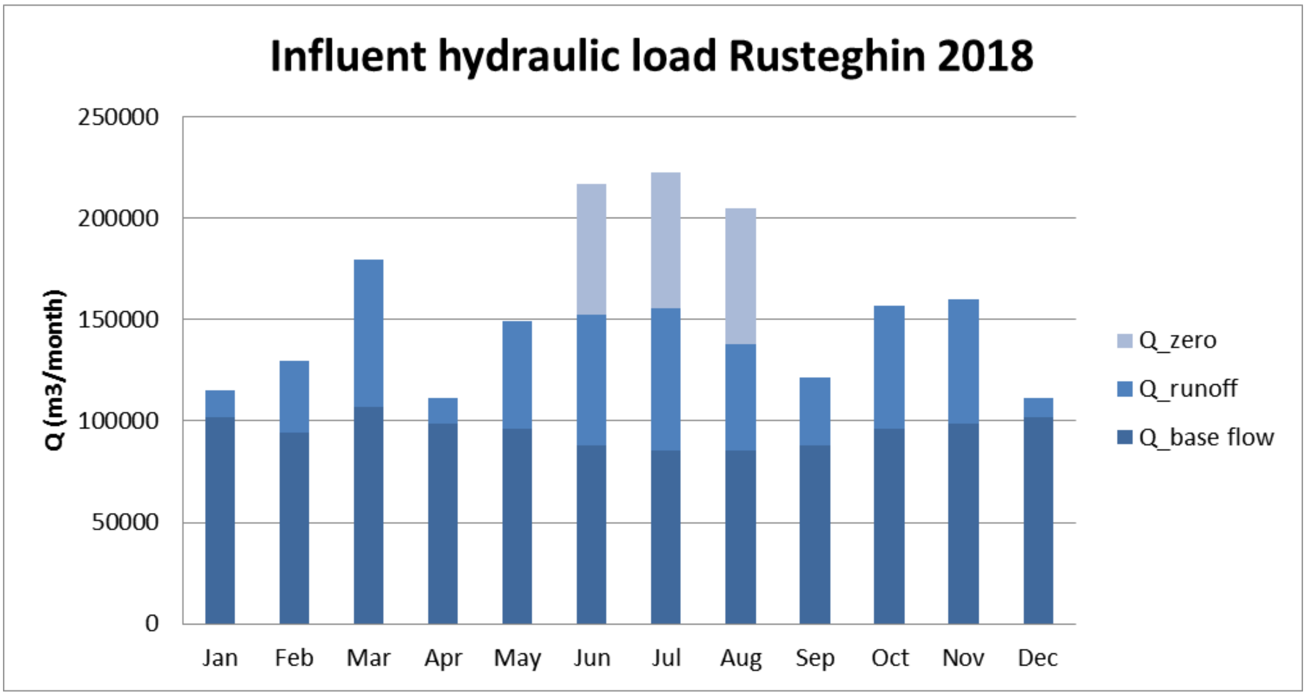


Figure 19. Influent hydraulic loads estimated for the Rusteghin wetland in 2018

The potential monthly evapotranspiration is obtained using the Thornthwaite method. The average value is multiplied by the average crop coefficient for constructed wetlands, assumed equal to 1.66 (Kadlec and Wallace, 2009). Not considering infiltration, the results of the hydraulic balance are shown in **Table 6**.

Table 6. Monthly hydraulic balance for the Rusteghin wetland for the year 2018

Month	**P**	**ET**	**Q_{IN_1} base flow Rusteghin**	**Q_{IN_2} runoff Rusteghin watershed**	**Q_{IN_3} Withdrawn from river Zero**	**Q_{IN_TOT} base flow Rusteghin**	**Q_{OUT}**
	l/s	**l/s**	**l/s**	**l/s**	**l/s**	**l/s**	**l/s**
Jan	0.3	0.2	38	4.9	0	42.9	43.0
Feb	0.9	0.2	29	14.7	0	53.7	54.4
Mar	1.6	0.4	40	27.2	0	67.2	68.4
Apr	0.3	1.6	38	5.0	0	43.0	41.7
May	1.2	2.5	36	19.8	0	55.8	54.5
Jun	1.5	3.2	34	24.7	25	83.7	82.0
Jul	1.6	3.5	32	26.0	25	83.0	81.1
Aug	1.2	3.3	32	19.6	25	76.6	74.4
Sep	0.8	2.2	34	12.8	0	46.8	45.4
Oct	1.3	1.3	36	22.6	0	58.6	58.6
Nov	1.4	0.6	38	23.7	0	61.7	62.5
Dec	0.2	0.1	38	3.5	0	41.5	41.6

Pollutant inflow/outflow

During the two monitoring campaigns (February 2018 and April 2019) the input and output concentrations of the following pollutants were measured: $N\text{-}NH_4^+$ (ammonianitrogen), $N\text{-}NO_2^-$ (nitrous nitrogen), $N\text{-}NO_3^-$ (nitric nitrogen), TDIN (total dissolved inorganic nitrogen), DON (dissolved organic nitrogen), PIN (nitrogen bound to particulates), TN (total nitrogen), $P\text{-}PO^3{}_4^-$ (orthophosphate), SUP (total dissolved phosphorus), PP(phosphorus bound to particulates), TP (total phosphorus). The temporal trends are visible in annexes.

The input and output concentration of the pollutants used for the mass balance are the average monthly concentration values obtained during the monitoring campaigns. The pollutants analysed are: $N\text{-}NO_3$, TN, $P\text{-}PO_4$, TP and TSS.

The removed mass load is given as the difference between the input and output mass load, and expressed as a percentage. The mass load removed per unit of area, for each single month, is defined considering the effective surface that participates in the treatment process, equal to 2.9 ha (floodplains at an altitude of 6.5 m and pond area at an altitude of 6 m). Monthly analysis is reported in annexes, while the average percentage of pollutants removal, for the year 2018, is shown in **Table 7**.

Table 7. Average of pollutants removal for Rusteghin wetland, for the year 2018

YEAR_2018 Rusteghin wetland	M_{IN} **[t/y]**	M_{OUT} **[t/y]**	M_{REM} **[%]**	R_{REM} **[g m^{-2} y^{-1}]**
N-NO3	3	2.2	34%	26.2
TN	12.3	9.6	23%	93.1
P-PO4	0.2	0.1	52%	4.4
TP	0.9	0.7	19%	7.8
TSS	76.5	57.8	20%	644

3.2.1.2 Salzano wetland

Water inflow/outflow

The data obtained from the 2010 monitoring campaign and the routine monitoring carried out from June 2009 to June 2010 by the University of Padova are used for the calculation of the removal of mass loads. The hydraulic and mass balance are carried out for the years 2009 and 2010, considering the total wetland area of Salzano equal to 21.6 ha.

To verify the wetlands treatment capacity, four monitoring campaigns were conducted in 2010, where the average inlet and outlet flows were detected and 12 samples were analysed, to represent the trend of total phosphorus, total nitrogen and total suspended solids. During the 2010 campaign, an increase in the flow rates of the river during the winter and spring period did not affect the flow rates of the wetland, because the entrance section of the Salzano wetland is controlled by an electro-mechanical mobile sluice gates.

For this reason, the **inlet flow rate** considered for the hydraulic balance is obtained as the average of the inlet flow rates recorded during the 2010 monitoring campaign. This value is assumed to be constant for the years 2009 and 2010 and equal to 33.68 l/s.

The annual value of the potential evapotranspiration derives from the MIPAAF data (www.politicheagricole.it). This value is multiplied by the average crop coefficient for constructed wetlands, assumed equal to 1.66 according to literature value (Kadlec and Wallace, 2009). Infiltration has been considered negligible. The results of the hydraulic balance are shown in **Table 8**.

Table 8. Hydraulic balance for the Salzano wetland. The reported values are yearly mean average values.

Year	Q_{IN}	P	ET	Q_{OUT}
	[L/S]	[L/S]	[L/S]	[L/S]
2009	33.68	6.44	9.84	30.28
2010	33.68	7.68	9.32	32.03

Pollutant inflow/outflow

The pollutants analysed during the monitoring campaign are: total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). Analysed data are from the routine monitoring conducted from June 2009 to June 2010 by the University of Padova[7], of which the detailed analysis is visible in annex.

Due to the statistically difference registered between the influent and effluent concentrations (see annexes for details), the mass balances were done with a simplified approach at the year basis, assuming the average values for the whole 2010 year of monitored campaign.

The removed mass load is given by the difference from the input and output mass load and it is expressed as a percentage for the single year analysed. The mass load removed per unit area is indicated in **Table 9**. It is defined considering only the actual surface participating to the treatment processes, i.e. the area of the wetland dedicated to pond and free water surface (FWS) systems, which is equal to 7.14 ha. Indeed, the total area of the wetland is not all dedicated to treatment, with a good portion of the cave aimed to be more naturalistic and interested by influent loads only during flood events.

Table 9. Pollutant mass balances for the Salzano wetland.

YEAR_2009 Salzano wetland	C_{ING} [mg/L]	M_{IN} [kg/d]	C_{OUT} [mg/L]	M_{OUT} [kg/d]	M_{REM} [%]	R_{REM} [g m^{-2} y^{-1}]
TN	3.23	9.40	2.18	5.70	39%	18.9
TP	0.18	0.53	0.12	0.31	41%	1.13
TSS	32.81	95.47	21.44	56.09	41%	201.34
YEAR_2010 Salzano wetland	C_{ING} [mg/L]	M_{IN} [kg/d]	C_{OUT} [mg/L]	M_{OUT} [kg/d]	M_{REM} [%]	R_{REM} [g m^{-2} y^{-1}]
TN	3.35	9.76	1.96	5.43	44%	22.1
TP	0.14	0.4	0.07	0.20	50%	1.02
TSS	28.57	83.13	16.29	45.07	46%	194.60

[7] Università degli Studi di Padova Facoltà di Ingegneria Dipartimento di Processi Chimici dell'Ingegneria Laboratorio Analisi dei Sistemi Ambientali; *MONITORAGGIO DELLE CAVE DI SALZANO 2009 – 2010*

3.2.1.3 Scandolara buffer strip

The Scandolara buffer strip (BS) intercepts the nitrogen dissolved in the subsurface groundwater which flows from the adjacent cultivated crops (0.85 ha per 100 m of BS) toward the Scandolara stream. **Table 10** shows the main characteristics of the site:

Table 10. Main characteristics of the sites

		SCANDOLARA (upslope)	SCANDOLARA (downslope)
main characteristics of the sites	Width of BS (m)	4	7
	Vegetation cover	herbaceous	trees, shrubs, herbaceous
	Groundwater average slope (%)	1.1	2.0
	Groundwater average depth (cm below ground level)	168	37
	Groundwater discharge (m^3 y^{-1} per 100 m of BS)	3831	3831

The N mass balance referred to the subsurface flow and the removal efficiency in the groundwater are summarized in the following **Table 11**, both for inorganic nitrogen (more than 95% consists of $N\text{-}NO_3$) and for the total nitrogen. The data are expressed both in reference to 100 linear meters of buffer strips and in reference to 1 ha of buffer strip. Data concerning the "Upslope" and the "Downslope" sections (see **Figure 10**) are reported separately.

Table 11. Main characteristics of the sites and N mass balance

Scandolara (upslope)	**Input**	**Input**	**Output**	**Output**	**Removal**
	Kg $year^{-1}$ ha^{-1}	Kg $year^{-1}$ per 100m	Kg $year^{-1}$ ha^{-1}	Kg $year^{-1}$ per 100m	%
N_{inorg}	553.00 ± 45.00	22.12 ± 1.80	527.00 ± 41.00	21.08 ± 1.64	4.7
N_{tot}	571.50 ± 46.50	22.86 ± 1.86	544.50 ± 42.25	21.78 ± 1.69	4.7
Scandolara (downslope)	**Input**	**Input**	**Output**	**Output**	**Removal**
	Kg $year^{-1}$ ha^{-1}	Kg $year^{-1}$ per 100m	Kg $year^{-1}$ ha^{-1}	Kg $year^{-1}$ per 100m	%
N_{inorg}	301.14 ± 23.43	21.08 ± 1.64	77.00 ± 9.14	5.39 ± 0.64	75.3
N_{tot}	311.14 ± 24.14	21.78 ± 1.69	86.00 ± 10.14	6.02 ± 0.71	72.4

The concentration of groundwater $N\text{-}NO_3$ measured in section 1 (adjacent to farmland), ranged from 9 to 15 mg L^{-1} during the farming season (from April to the beginning of September), while during the following months values decreased to 1–4 mg L^{-1} (**Figure 20**).

The "Upslope" herbaceous buffer results very ineffective in nitrogen removal (removal efficiency 4,7%). On the contrary, the "Downslope" buffer removes 15,76 Kg $year^{-1}$ TN per 100 m of BS, corresponding to 225 Kg TN $year^{-1}$ ha^{-1} of BS, by reaching a removal rate of 72.4%. The values are similar for the total inorganic nitrogen. The total nitrogen transported through surface runoff is 1.99 Kg $year^{-1}$ TN per 100 m of BS, while its removal rate has not been measured.

The different efficiency between the two portions of the BS could be clearly explained by considering the graph reported in **Figure 20.**

In the upslope section, showing ineffective nitrate retention, at groundwater level (1.7 m below soil surface) soil resulted poor in organic matter (<1%) and there was no interaction between the subsurface flow and the upper soil layers richer in organic matter (2% in the first

50 cm). The restored section showed instead significant nitrate removal especially between line 2A and line 4A (see picture below: hotspot area for denitrification). Here, due to the lowering of the bank, groundwater flowed in correspondence with the soil surface, crossing soil layers very rich in organic matter (>3%), where subsurface flow interacted permanently with the roots of trees and of the herbaceous vegetation.

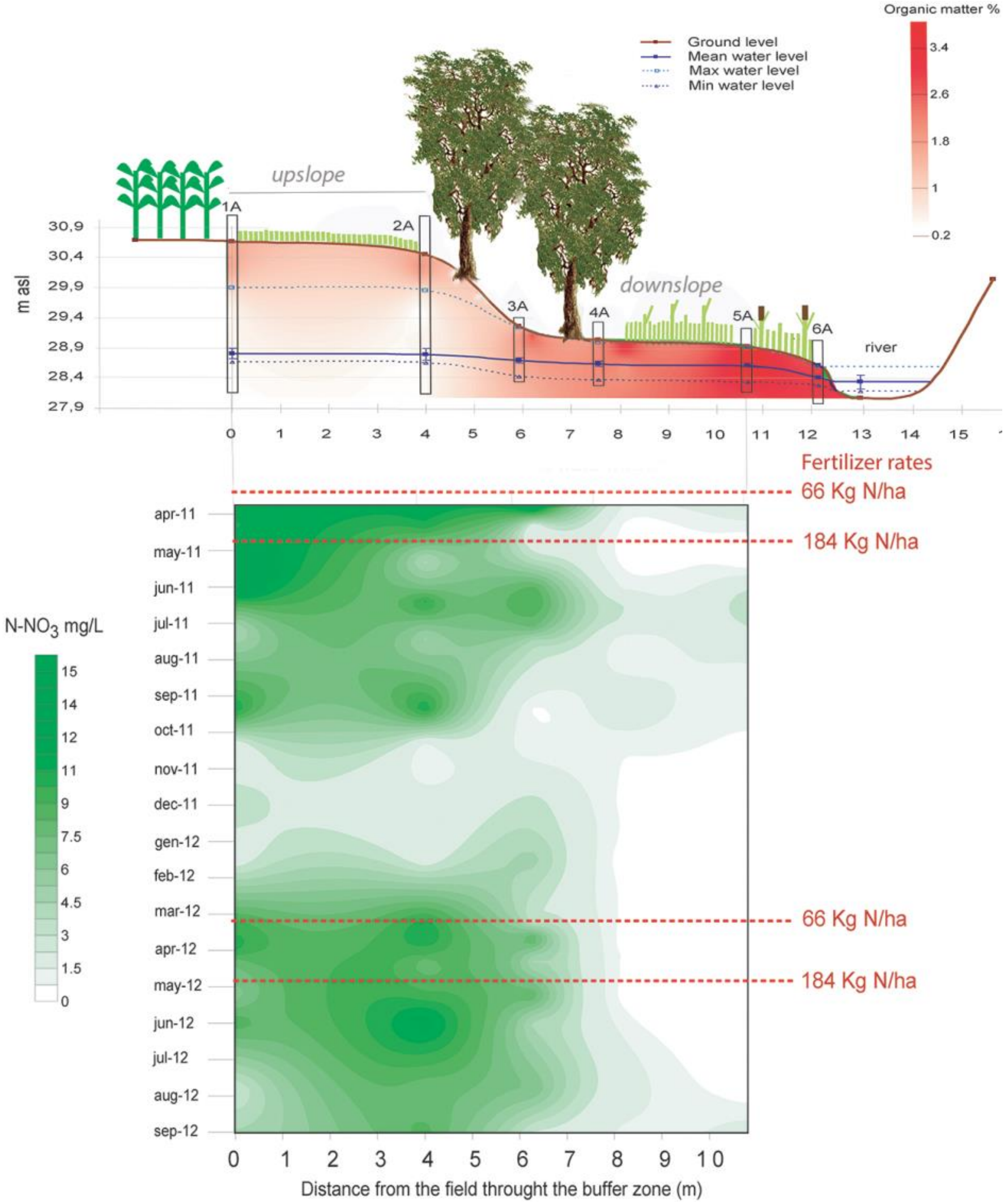


Figure 20. Soil organic matter content and spatial distribution of N-NO_3 concentration values across the Scandolara BS, including mean, maximum and minimum groundwater levels. The red dotted lines indicate periods of fertilizer applications on the adjacent maize crop. (Modified from Gumiero & Boz, 2017.

According to this evidence, the main driver for optimizing the buffer capacity is the groundwater depth, better than the width and the vegetation composition of the buffer strip. The presence of unmanaged helophytic vegetation favours the increase of organic matter in the soil, thus favouring the denitrification process. Consequently, both anaerobic conditions and high availability of OM provide optimal conditions for denitrification (Pinay et al., 2000).

3.2.1.4 NICOLAS buffer strip

The NICOLAS buffer strip intercepts the nitrogen dissolved in the subsurface groundwater which flows in continuous from the irrigation to the drainage ditches. The irrigation ditches are fed by the waters pumped from the Zero river.

Looking at the two 15 m wide experimental plots (2 replications), the irrigation volumes pumped during the monitored periods were:

1st PERIOD	**IRRIGATION (mc/ha/year)**
1999-2000*	51,917
2000-2001*	48,060
2001-2002*	48,600
2nd PERIOD	
2007-2008**	59,986
2009***	53,788
2010***	55,787

** From 01/11 to 30/10 ** From 01/09 to 31/10 *** From 01/01 to 31/12*

In term of total nitrogen, starting from the 2nd year, the removal rates range from 74 to 84 kg ha^{-1} (of BS) $year^{-1}$, with a retention capacity ranging from 55% to 64%.

During 2009 and 2010, the experimental site has been tested with a supplementary load of nitrogen added in the irrigation ditches (for experimental scopes); in this case the removal rates have reached the values of 141.8 and 106.3 Kg ha^{-1} (of BS) $year^{-1}$ respectively, with a retention capacity corresponding to 52% and 37% of the total input.

The N mass balance referred to the subsurface flow and the removal efficiencies are summarized in the following **Figure 21**, **Figure 22**, **Table 12** and **Table 13**.

Table 12. Nitrogen mass balance (2001-2008)

	2000				**2001**			
	Input	**Output**	**R_{rem}**	**M_{rem}**	**Input**	**Output**	**R_{rem}**	**M_{rem}**
	kg ha^{-1} $year^{-1}$			**%**	**kg ha^{-1} $year^{-1}$**			**%**
$N\text{-}NO_3$	107.6	66	41.6	**39**	85	12.3	72.7	**86**
$N\text{-}NO_2$	1.9	0.4	1.5	**77**	2.6	0.3	2.3	**88**
$N\text{-}NH_4$	14.7	9.6	5.1	**35**	18.7	10.8	7.9	**42**
N-Org	11.2	28.2	-17	**-152**	9.6	18	-8.4	**-87**
N-Tot	**135.3**	**104.1**	**31.2**	**23**	**116**	**41**	**75**	**64**
	2002				**2008**			
	Input	**Output**	**R_{rem}**	**M_{rem}**	**Input**	**Output**	**R_{rem}**	**M_{rem}**
	kg ha^{-1} $year^{-1}$			**%**	**kg ha^{-1} $year^{-1}$**			%
$N\text{-}NO_3$	85.2	11.6	73.6	**86**	102	24.5	77.5	**76**

$N\text{-}NO_2$	2.5	0.3	2.2	**87**	2.2	1	1.2	**53**
$N\text{-}NH_4$	18	18.1	0	**-0.1**	6.4	12.6	-6.3	**-99**
N-Org	12	13.3	-1.3	**-11**	43.3	31.8	11.5	**27**
N-Tot	**118**	**43**	**74**	**63**	**154**	**69.9**	**84**	**55**

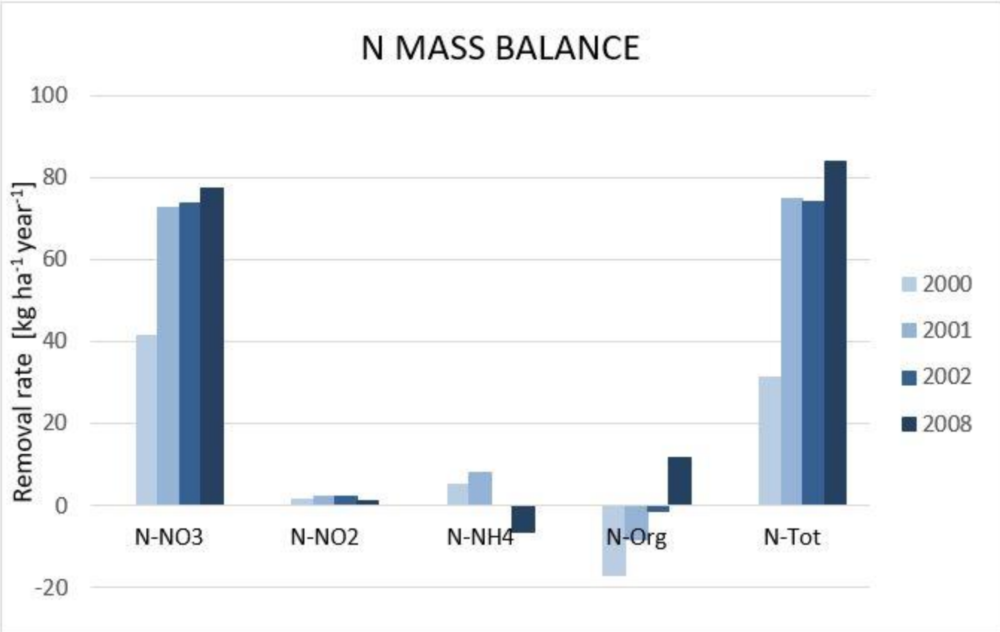


Figure 21. N mass balance in the NICOLAS buffer strips with ordinary load of Nitrogen in the irrigation ditches during the monitored years.

Table 13. Nitrogen mass balance (2008-2010)

	2008				2009				2010			
	Input	**Output**	R_{rem}	M_{rem}	**Input**	**Output**	R_{rem}	M_{rem}	**Input**	**Output**	R_{rem}	M_{rem}
	kg ha^{-1} $year^{-1}$			%	kg ha^{-1} $year^{-1}$			%	kg ha^{-1} $year^{-1}$			%
$N\text{-}NO_3$	102	24.5	77.5	**76**	226.9	72.7	154.2	**68**	241.7	138.2	103.4	**43**
$N\text{-}NO_2$	2.2	1	1.2	**53**	2.5	1.4	1.1	**45**	2.7	1.3	1.4	**51**
$N\text{-}NH_4$	6.4	12.6	-6.3	**-99**	6.9	16.6	-9.7	**-140**	6.8	13.5	-6.7	**-99**
N-Org	43.3	31.8	11.5	**27**	35.9	39.8	-3.9	**-11**	39.3	31.1	8.2	**21**
N-Tot	**153.9**	**69.9**	**83.9**	**55**	**272.2**	**130.5**	**141.8**	**52**	**290.4**	**184.1**	**106.3**	**37**

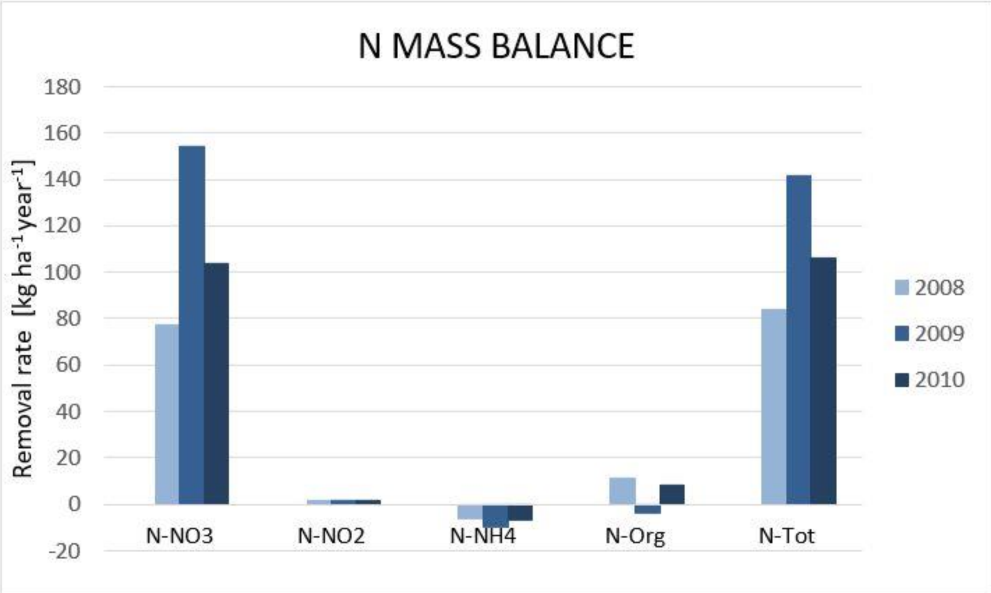


Figure 22. N mass balance in the NICOLAS buffer strips with ordinary (2008) and additional load of Nitrogen in the irrigation ditches during the second phase of the monitoring activities (buffer zones fully developed).

By assuming the same efficiency in nitrogen removal in the other plots, the Nicolas buffer system in its complex (30 ha) assures the removal of around 2.2 t year^{-1} of total N, while its maximum potential tested with in field experiments ranges from 3.2 to 4.2 t year^{-1}.

Table 14. N mass balance in the NICOLAS buffer strips with ordinary (2008) and additional load of Nitrogen in the irrigation ditches during the second phase of the monitoring activities (buffer zones fully developed).

Year	Experimental site TN removed (kg/y)	Whole wooden buffer strip (30 ha) (t y^{-1})	Whole wooden buffer strip (30 ha) Higher nitrogen loads (t y^{-1})
2000	31.2	0.936	
2001	75.0	2.235	
2002	74.0	2.234	
2009	141.8		4.253
2010	106.3		3.189

3.2.1.5 Summary of the results

This chapter presents a summary of the results for the four NBSs.

Rusteghin wetland: area equal to 3.5 ha, actual surface participating to the treatment processes equal to 2.9 ha. The data shown refer to the year 2018.

Rusteghin wetland	**IN**	**OUT**	**Areal removal [g m^{-2} y^{-1}]**	**Removal [t/y]**
Q [L/s]	59.5	59	-	-
N-NO3 [t/y]	3	2.2	26.2	0.92
TN [t/y]	12.3	9.6	93.1	3.26
P-PO4 [t/y]	0.2	0.1	4.4	0.15

Rusteghin wetland	IN	OUT	Areal removal [g m^{-2} y^{-1}]	Removal [t/y]
TP	0.9	0.7	7.8	0.27
TSS [t/y]	76.5	57.8	644	22.54

Salzano wetland: area equal to 7.14 ha (actual surface participating to the treatment processes). The data shown are calculated as the average of the years 2009 and 2010. The average removal percentages of total nitrogen, total phosphorus, and total suspended solids for the two years analysed are 42%, 46% and 44%, respectively.

Salzano wetland	IN	OUT	Areal removal [g m^{-2} y^{-1}]	Removal [t/y]
Q [L/s]	33.68	31.16	-	-
TN [t/y]	3.5	2.03	20.53	1.46
TP [t/y]	0.17	0.09	1.08	0.08
TSS [t/y]	32.59	18.46	197.97	14.14

Comparing the removal capacity per spatial unit of the two wetlands, Rusteghin shows to be around 4 times more effective for Nitrogen and 3 times for Phosphorus than Salzano wetland. Such a huge difference depends on the different design approach: Salzano wetland has been designed starting from an existing abandoned quarry with peculiar attention on the biodiversity conservation value. No specific care has been used to guarantee an even flow distribution in the system and avoid hydraulic bypass: thus large part of the available area doesn't contribute to the pollutant removal activity of the NBS.

Scandolara buffer strip:

- Upslope area = 0.38 ha
- Downslope area = 0.52 ha

Scandolara	IN	OUT	Areal removal [kg/y/ha]	Removal [t/y]
upslope				
N_{tot} [Kg/y/ha]	571.50 ± 46.50	544.50 ± 42.25	27	0.01
downslope				
N_{tot} [Kg/y/ha]	311.14 ± 24.14	86.00 ± 10.14	225.14	0.12

NICOLAS buffer strip: total area equal to 30 ha, the data shown is an average of the data from the years 2001 and 2002, i.e. without the supplementary load of nitrogen.

NICOLAS	IN	OUT	Areal removal [kg/y/ha]	Removal [t/y]
N_{tot} [Kg/y/ha]	117	42	74.5	2.2

Comparing the removal capacity of the two buffer strips, the Scandolara buffer strip shows an areal removal of total nitrogen around 3 times higher than the NICOLAS buffer strip, as it was to be expected since this site was designed with the aim of maximizing the interaction of the water flow with the root system. Considering the total nitrogen removed, the NICOLAS buffer strip shows better results due to its greater area, with around 2.2 t/year of nitrogen removed compared to the 0.12 t/y removed by the Scandolara buffer strip.

3.2.1.6 Additional pollutant removal based on literature values

A further analysis was carried out to investigate the pesticide removal capacity of the four NBSs, in particular, the removal of glyphosate and AMPA was analysed. In addition, the removal capacity of phosphorus (TP) and suspended solids (TSS) by the buffer strips was also evaluated (the removal of TP and TSS by wetlands is already reported in paragraph 3.2.1.1 and 3.2.1.2).

The literature review provides important data for an experience-based estimation of the areal removal efficiencies for those parameters (glyphosate, AMPA, TSS and TP) which were not previously included in the field investigations.

The procedure used for obtaining the estimations varied considering the characteristics of the NBSs studied. The estimation is done assuming the average removal efficiencies previously reported.

3.2.1.6.1 Pesticides

The monitoring of the 4 sites included in this case study did not concern any investigation on **pesticides**. Therefore, the estimation of pesticide removal capability of the studied NBS is done on the basis of scientific literature. The removal of pesticides by NBSs is obviously influenced by many factors but the research on the topic does not allow yet a clear determination of the impact of each of these factors on the removal efficiency of the NBSs. However, many authors (Arora et al., 2010; Vymazal and Březinová, 2015; Stehle et al.,2011) agree on the relevant impact of the soil adsorption coefficient (K_{oc}) on the pesticides removal by NBSs. The soil adsorption coefficient describes the intrinsic behaviour of a compound to adsorb onto the organic matter. In a paper review article, Vymazal and Březinová, 2015 indicated the existence of a general positive relationship between the K_{oc} and the pesticide removal rate in constructed wetlands.

When the K_{oc} of a molecule is lower than 100 (log K_{oc} <2) it shows low affinity for the organic matter and, consequently, a hydrophilic behaviour. These types of pesticides will be likely found in higher concentrations in surface water. On the other hand, pesticides with a K_{oc} between 100 and 1000 (2< log K_{oc} < 3) moderately adsorb on sediments while those with a K_{oc} > 1000 (log K_{oc} > 3) have a strong sorption (hydrophobic). These findings seem to be confirmed also by the more recent review work of Tournebize et al. (2017). Therefore, variable pesticide removal efficiencies are reported in literature in function of their chemical group, variable from 20% (triazinone) to >90% (organochlorine), as reviewed by Vymazal and Březinová, (2015). It's significant to refer that similar results were reported by the recent review of Ilyas et al. (2020) on other emerging organic contaminats similar to pesticides, i.e. pharmaceutical: despite NBS removal processes (plant uptake, photodegradation, sorption, adsorption, and biodegradation) can differently affect pharmacetutical removal in function of the different targeted pollutant, an overall successful regression equation was fitted (R^2 0.65) for general NBS pharmaceutical removal when only physico-chemical properties of the coumpound were considered (KOC, DOW – octanol-water distribution coefficient - and molecular weight); weaker and more incongruent correlations, instead, were observed for typical design parameters, such as hydraulic retention time (HRT), hydraulic and organic loading rate (HLR and OLR, respectively).

In order to simplify the estimation of pesticide removal for the 4 NBSs of this study, a "proxy" representative molecule was selected. According to the most used pesticides in Veneto region[8], the herbicide **Glyphosate** (log Koc=3.84, strongly adsorbed on soil) was taken as target

[8] ARPAV. Fitosanitari Ambiente Salute. Vendita di prodotti fitosanitari nella Regione Veneto. Rapporto anno 2017. https://www.arpa.veneto.it/dati-ambientali/open-data/fitosanitari-2017 (Accesso Aprile 2020)

pesticide for the mass balance analysis, investigating its specific removal mechanism in wetlands and buffer strips according to the most recent available literature.

a) Constructed wetlands

The research on fate, occurrence and removal capacity of the glyphosate in constructed wetlands is not well developed yet. However, the studies present in the literature show that the glyphosate has quite high removal percentages as it was expected from its K_{oc} value. Maillard et al. (2011), first, and then Imfeld et al. (2013) studied the capacity of a constructed wetland treating stormwater from a vineyard to remove the glyphosate, focusing their attention also on the behaviour of AMPA (main metabolite of glyphosate degradation). The authors found that the removal rate ranges of glyphosate and AMPA were 92-100% (Avg.= 96%) and 30-95% (Avg.= 67%). Other studies (Yang et al., 2013; Bois et al.,2013) obtained similar removal rates compared to the previous studies. Since Glyphosate has a K_{OC} equal to 6920 ml/g (Vymazal and Březinová, 2015), the observed high removal efficiencies are in line with the range reported for pesticides classified with a strong K_{OC} (> 1000 mL/g) by Tournebize et al. (2017): 1st quartile 30%, median 50%, 3rd quartile 70%, max 100%.

As it was not possible to find literature material that dealt with the removal of glyphosate by FWS wetlands with similar characteristics to ours studied NBS, the articles of Maillard et al. (2011) and Imfeld et al. (2013), that studied the glyphosate removal capacity of a constructed wetland (surface = 319 m^2, HRT 11±8 hours) treating stormwater from a vineyard, were chosen as a reference among the most recent articles as more representative of our case. The constructed wetland described in the papers is composed of two parts, a sediment deposition pond, and a deep filter bed, and can be assumed as an FWS-HF wetland. It was reported in the literature that the most common pathway of glyphosate degradation is the one that passes through the production of AMPA (Sviridov et al., 2015)[9], also confirmed by the findings of Imfeld et al. (2013). The degradation of AMPA is generally slower than that of glyphosate, possibly due to its capacity to be sorbed through the phosphonate group that results in lower desorption and consequently lower bioavailability.

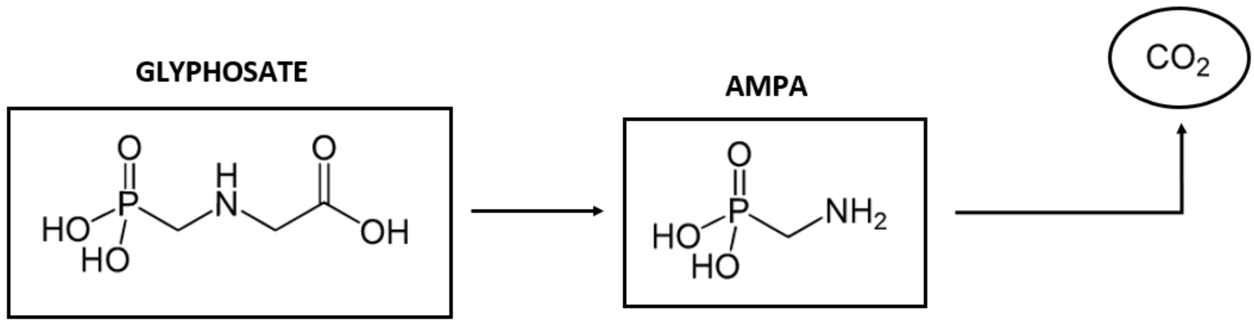


Figure 23. Schematic representation of the degradation of glyphosate through the formation of AMPA according to Imfeld et al. (2013).

The HRT and removal efficiencies of the constructed wetland found by the authors are reported in the **Table 15**. The Hydraulic Retention Times measured in the Salzano and Rusteghin wetlands are much higher than those of the constructed wetland described in the papers (144 hours for Salzano and 36 hours for Rusteghin), and to estimate the areal removal efficiencies of the wetlands it was decided to conservatively assume a removal efficiency equal to 90% for glyphosate and 60% for AMPA.

[9] Sviridov, A. V., Shushkova, T. V., Ermakova, I. T., Ivanova, E. V., Epiktetov, D. O., & Leontievsky, A. A. (2015). Microbial degradation of glyphosate herbicides. Applied Biochemistry and Microbiology, 51(2), 188.

Table 15. HRT and removal efficiencies reported by Imfeld et al., 2013.

	HRT [h] mean	Removal [%] Glyphosate	AMPA	
Imfeld et al., 2013	11.0 ± 8.3	92	30	2009
		95	76	2010
		100	95	2011

b) Buffer strips

The reduction of glyphosate and AMPA by buffer strips is documented by several authors (Lin et al., 2011; Syversen and Bechmann, 2004; Hénault-Ethier et al., 2017). Buffer strips are not as efficient as constructed wetlands in removing these compounds since the removal rates of glyphosate and AMPA are in the range of 37-79% (Average= 53.6%) and 51.6-64 (Avg.=57.8%), respectively. Therefore, the Scandolara and NICOLAS buffers are expected to show efficiency ranges between the values obtained from the literature or at least similar. It was decided to conservatively assume a removal efficiency equal to 50% for both glyphosate and AMPA.

Areal removal efficiencies for glyphosate and AMPA

The average concentrations and references used for the estimation of areal removal of glyphosate and AMPA are shown in the following **Table 16**. The references for the Scandolara buffer strip differ from the other NBS since Scandolara is a buffer strip properly designed for the interception of the contaminants in the groundwater, while the other NBS mostly receive the agricultural runoff.

Table 16. Glyphosate and AMPA concentrations found from the literature review.

	Glyphosate (μg/l)	AMPA (μg/l)	Reference
Salzano	19.87	3.3	Maillard et al., 2011 Imfeld et al., 2013
Rusteghin	19.87	3.3	Maillard et al., 2011 Imfeld et al., 2013
Scandolara	24	2.87	Horth and Blackmore, 2009 Van Stempvoort et al., 2014
NICOLAS	19.87	3.3	Maillard et al., 2011 Imfeld et al., 2013

The areal removal efficiencies of the 4 NBSs were estimated by multiplying first the average concentration found in the literature for glyphosate and AMPA by the water inflow rate to obtain the annual input load of pesticide. Then the annual input load was multiplied by the removal efficiency of the NBS in order to find the annual output load. Finally, the annual output load was subtracted from the input and the outcoming value divided by the area of the NBS (Hp 1). On the basis of the evidence given by Imfield et al. (2013), a more detailed mass balance estimation was also calculcated (Hp 2). According to the simplified degradation pathway reported in **Figure 23**, it was hypothesized that the annual removed load of glyphosate was all degraded in AMPA, thus this load was added to the input AMPA load (found in literature) and the same calculations used for glyphosate were carried out to obtain the areal removal efficiency of “glyphosate plus AMPA”. In this way, the areal removal efficiency are lower and effectlively estimate the overall removal pathway of the original glyphosate substance.

Table 17. Hp 1 - Glyphosate estimation areal removal efficiencies for the 4 NBS investigated

NBS	Area [ha]	Water inflow [l/s]	IN [g/y]	OUT [g/y]	Percentage removal	Areal removal [g/y/m^2]
Salzano	6.7	33.68	21104.6	2110.5	90%	0.283
Rusteghin	3.5	50	31331	3133.1	90%	0.806
Scandolara	0.011	0.008	5.8	2.9	50%	0.026
NICOLAS	30	50.44	31607	15803.5	50%	0.053

Table 18. Hp 2 - Glyphosate + AMPA estimation areal removal efficiencies for the 4 NBS investigated

NBS	Area [ha]	Water inflow [l/s]	IN [g/y]	OUT [g/y]	Percentage removal	Areal removal [g/y/m^2]
Salzano	6.7	33.68	22499.2	8999.7	60%	0.201
Rusteghin	3.5	50	33401.4	13360.5	60%	0.573
Scandolara	0.011	0.008	3.6	1.8	50%	0.016
NICOLAS*	30	50.44	21052.8	10526.4	50%	0.035

3.2.1.6.2 Suspended solids for buffer strips

Buffer strips are known to be an effective measure for the reduction of the erosion from agricultural fields but the monitoring campaign carried out in the Scandolara and Nicolas buffers did not concern the analysis of the sediments, since the main focus was removal of dissolved pollutants. However, it is possible to roughly estimate the amount of sediments from the analysis of the literature. Even if not always used in buffer investigations, sediments will be provided in form of TSS in order to use a comparable parameter with the constructed wetlands where the use of the TSS measurement is a common practice. Investigations carried out by different authors (Borin et al., 2005; Duchemin et al., 2009; Younos et al., 1998) showed that the buffer strips can remove from 0.02 to 47.9 ton ha^{-1} y^{-1}. The high variability is due to the different setting of the experiments that in some cases were planned to mime an extreme stormwater event. However, there is a general agreement on the fact that buffer strips result to be highly effective in removing the sediment loss from agricultural fields in terms of removal rate, showing an average of 86% (range= 53%-99,9%) (Dillaha et al., 1988; Younos et al., 1998; Mankin et al., 2007; Hay et al., 2006; Borin et al., 2005).

3.2.1.6.3 Total phosphorus for buffer strips

Buffer strips have been thoroughly investigated and applied in agricultural areas as important tools for controlling the diffusion of nutrients included phosphorus. These NBS have resulted to be effective and reduce the amount of phosphorus especially from agricultural runoff since a great part of the phosphorus present in runoff is absorbed to the suspended solids. Indeed, from a literature review it was found that the average removal rate for total phosphorus (TP) is 67% (Peterjohn et al., 1984; Younos et al., 1998; Borin et al., 2005; Tomer et al.,2007; Duchemin et al., 2009; Bu et al., 2016). However, it is important to underline that the phosphorus removal efficiency is highly variable (25% - 98%) and this can be addressed to many factors (age of the buffer strip, precipitation strength, amount of TSS in the runoff, etc..) (Dorioz et al., 2006). The observed variability of TP removal has been comprehensively analysed in Dorioz et al., 2006. In brief TP retention in buffer strips is mainly depending on the interception of surface runoff: the runoff water reaching a buffer strip flows over a rougher and more porous surface, causing it to slow down and infiltrate into the soil. Both the porosity of the surface and the infiltration capacity are depending on many factors (e.g. presence/absence of grass vegetation, slope, soil characteristic, hydrological situation, etc.) those vary over time, thus affecting the retention capacity. For example, in some periods the excess particles are progressively settled and trapped (Munos-Carpena et al., 1999), but these deposits could result in source for P release in surface water during subsequent rainfall events. Also, when runoff episodes follow one another too frequently, sediments deposited, but not consolidated, can be remobilised by subsequent erosion. The consolidation of deposits between periods of rainfall is therefore a critical aspect of the buffer effect (e.g., via stabilization by fine rootin-growth, tillering of grass roots and shoots, re-aggregation of fine particles into larger peds) (Dorioz et al., 2006).

<u>Areal removal efficiencies for TSS and TP</u>

The average concentrations and references used for the estimation of areal removal of TSS and TP are shown in the following **Table 19**.

Table 19. TSS and TP concentrations found from the literature review.

	TSS (mg/l)	TP (mg/l)	Reference
Scandolara	3500*	2.00**	*:Dillaha et al., 1988; Younos et al., 1998; Mankin et al., 2007; Hay et al., 2006; Borin et al., 2005. **: Peterjohn et al., 1984; Younos et al., 1998; Borin et al., 2005; Duchemin et al., 2009; Bu et al., 2016
NICOLAS	36.78	0.34	Data obtained averaging the average concentrations of TSS and TP in Salzano and Rusteghin wetlands

To obtain the areal removal efficiencies, for the two constructed wetlands and one buffer strip (NICOLAS), the annual areal input load of TSS and TP was estimated by multiplying the average concentration found in the literature (**Table 19**) by the water inflow rate. This procedure was not applicable for the buffer strip at Scandolara site because unfortunately no data on the inflow rate have been registered during the monitoring campaigns. Where not present, the flow rate was obtained by calculating the water runoff from the upland basin drained by the buffer strip using the following formula:

$Q = A * \Phi * Vp$

A= Basin area;

Φ= Runoff coefficient;

Vp= Volume of annual precipitation (annual average of the reference local rain station)

Once the annual input load was calculated, the **areal removal efficiencies** were estimated by multiplying the annual input load by the percentage removal efficiency of the NBS in order to find the annual output load, then this was subtracted from the annual input load to obtain the areal removal efficiency.

Table 20. TSS estimation areal removal efficiencies for the two buffer strips

NBS	Flow rate	IN [g/ha/y]	OUT [g/ha/y]	Percentage removal	Areal removal [g/y/m^2]
Scandolara	241.49 m^3/y	845197.5	118327.65	86%	6607.9
NICOLAS	53023 m^3/ha/y	195.02	27.3	86%	167.7

Table 21. TP estimation areal removal efficiencies for the two buffer strips

NBS	Flow rate	IN [g/ha/y]	OUT [g/ha/y]	Percentage removal	Areal removal [g/y/m^2]
Scandolara	241.49 m^3/y	482.97	159.38	67%	3.0
NICOLAS	53023 m^3/ha/y	1.78	0.59	67%	1.2

3.2.2 Literature verification of the dataset

3.2.2.1 Wetlands

The monitoring campaigns for the two wetlands (Salzano and Rusteghin) provided data on TSS, N and P, as it has been shown in the chapters 3.2.1.1 and 3.2.1.2. The removal rates of TSS found in Salzano wetland was around 43% which is about the double than the Rusteghin wetland (20%). These results are in agreement with the literature available for the agricultural constructed wetlands. Indeed, researches carried out by many authors determined a removal rate for the TSS in the range of 10-98% and an average removal rate of 59% (Diaz et al., 2012; Vymazal et al., 2018; Schulz et al., 2001a; Schulz et al. 2001b; Kadlec and Wallace, 2009). Moreover, a comparison with the literature data can be done taking into account the average TSS inflow and outflow concentrations of the two wetlands. The average concentrations in the Salzano wetland are 30 mg/l (inflow) and 16 mg/l (outflow). TSS concentrations in the Rusteghin wetland resulted doubled compared to the other, reaching values of around 43 mg/l (inflow) and 29 mg/l (outflow). Kadlec and Wallace (2009) found inflow and outflow concentration range of TSS, respectively 5-611 mg/l and 2-170 mg/l. If a comparison of the case study data and those obtained by Kadlec and Wallace (2009) is made, it is possible to see that the results of the case study fall within those of the literature.
The Salzano wetland was able to remove about 40% of the received TN and an average of around 45% for TP, while the Rusteghin wetland displayed lower efficiency rates (TN= 23%, TP=19%). The reported removal percentages are in line with those found in the literature. Indeed, Stevens and Quinton (2009) calculated the average nutrients removal rates for agricultural constructed wetlands, finding that TN is removed by 29% (in a range between

11% and 42%) and TP by 35%. However, the TP showed a wide range of removal rates varying from 1 to 91%. Arehimer and Pers (2017) extensively reviewed 1574 wetlands all over the Norwegian territory and estimated that the efficiency of wetlands varied between catchments in a range of 0.01–34 g $m^{-2}yr^{-1}$ for N and 0.001–3.7 g $m^{-2}yr^{-1}$ for P. These values are similar to the results found in the investigations carried out in the Salzano and Rusteghin wetlands.

3.2.2.2 Buffer strips

The Scandolara and Nicolas buffers have been compared with the network of experimental sites monitored within the MO.NA.CO[10] project (Gumiero et al., 2015 and Gumiero & Boz., 2017). Under this national project 7 buffer strips implemented according to the technical data contained in the Standard 5.2 of Cross compliance and located in different areas and climate contexts, were monitored for a period of two years.

It is noted that in term of sub-surface discharge and N_{inorg} input the Scandolara site is comparable with the highest values registered (FAGNA FT1, FAGNA FT2 and TORMA, monitored sites of the MO.NA.CO project), while its removal efficiency is significantly higher than in the other monitored sites. This confirms that the peculiar design of this buffer system results in high buffering capacity and highlights the importance of interaction between water flow and the rhizosphere for enhancing vegetation uptake and giving support to microbial activities by organic matter supply (Pinay et al., 2000; Sabater et al., 2003; Vidon and Hill, 2004; Gumiero et al., 2011; Boz et al. 2013). On the contrary in the Scandolara site the ratio between the area dedicated to the BS and the cultivated catchment appears too high (14.11%), being the limit of 5% considered as a good compromise between the 2 objectives.

Table 22. Comparison between the MO.NA.CO project experimental sites (data from Gumiero et al., 2015) and the Scandolara and Nicolas sites.

Experimental site	**FAGNA-FT1** ***CRA-ABP (Firenze)***	**FAGNA-FT2** ***CRA-ABP (Firenze)***	**DIANA-FT1** ***VENETO AGRIC.***	**DIANA-FT2** ***VENETO AGRIC.***	**TORMA-** ***CRA-RPS (Roma)***	**SCANDOLARA**	**NICOLAS site**
Period	01/01/2013 31/12/2013	01/02/2013 31/01/2014	01/05/2013 30/04/2014	01/01/2013 31/12/2013	01/05/2013 30/04/2014	01/08/2011 31/07/2012	
Area BS/area cultivated catchment (%)	3.70	3.57	33.33	27.8	4.80	14.11	*n.d.*
Subsurface flow discharge (m^3 $year^{-1}$ per 100 of BS)	3152	8587	919	1004	4726	3831	
N_{inorg} applied (Kg $ha^{-1}year^{-1}$)	72	120	250	170	96	250	
IN N_{inorg} sub-surface flow (Kg $year^{-1}$ ha^{-1} of farm field)	8.45±1.69	30.29±2.94	33.21±1.34	3.0±0.3	4.66±1.69	26.02±1.98	
N_{inorg} to BS by subsurface flow / N_{inorg} applied (%)	11.1	25.2	13.3	1.8	1.78	10.4	
OUT N_{inorg} sub-surface flow (Kg $year^{-1}$ ha^{-1} of farm field)	5.67±1.63	29.42±5.08	17.29±1.24	1.6±0.2	1.91±0.47	6.34±0.55	
N_{inorg} removal by the BS (Kg $year^{-1}$ ha^{-1} of farm field)	2.79	0.86	15.93	1.5	2.88	19,68	
Efficiency (%)	33.0	2.9	48.0	48.6	61.9	75.3	

[10] Work done under the Project MO.NA.CO. (National network for monitoring the environmental effectiveness of cross compliance and the differential of competitiveness charged against agricultural enterprises) funded by the Ministry of Agricultural, Food and Forestry Policies (MiPAAF) in the context of Action 1.2.2 "Interregional Workshops for development" of the Operational Programme called "National Rural Network 2007-2013", Coord. Paolo Bazzoffi

A more systematic comparison between the Scandolara site and 2 monitoring sites of the Project MO.NA.CO. has been proposed also in Gumiero & Boz, 2017. In the following **Table 23**, different parameters have been compared by confirming, once again, the high nitrogen removal efficiency of the "Scandolara like" buffer strips, designed to maximize the interaction of the root system with the N rich groundwater flow.

Table 23. Nitrogen removal efficiency and its limiting factors recorded at the 4 study sites. Upward (high), downward (insignificant) and horizontal (medium) arrows illustrate 3 qualitative degrees of buffer efficiency. From Gumiero & Boz, 2017.

Experimental sites	**SCANDOLARA (upslope)**	**SCANDOLARA (downslope)**	**FAGNA**	**TORMANCINA**
Removal efficiency	ineffective ↓	high ↑	ineffective ↓	high ↑
Removal efficiency	ineffective ↓	high ↑	ineffective ↓	low ↓
groundwater depth	deep ↓	shallow ↑	deep ↓	shallow ↑
soil organic matter content	low ↓	high ↑	low ↓	medium ↔
BS width	narrow ↓	medium ↔	narrow ↓	medium ↔
vegetation cover	bad ↓	good ↑	bad ↓	good ↑
N input from the basin	high ↑	high ↑	high ↑	low ↓

Removal efficiency (%): ineffective ≤ 30; 30 < medium ≤ 60; high > 60. See Gumiero et al., 2015
Removal efficiency (Kg ha^{-1} y^{-1} of N_{inorg}): ineffective ≤ 5; 5 < medium ≤ 15; high > 15.
Groundwater depth (cm b.g.l): deep ≤ 200; 100 < medium ≤ 200; shallow > 100. See Emilia Romagna and CIRF, 2012

Soil organic matter content (%): low ≤ 0.8; 0.8 < medium ≤ 4; high > 4. See ARPAV, 2004.
BS area/basin area (%): low ≤ 5; 5 < medium ≤ 10; high > 10
BS width (m): low ≤ 5; 5 < medium ≤ 15; high > 15
Vegetation cover: herbaceous + trees & shrubs = good; permanent grass = medium; disturbed and recently converted grass = bad.
N input by fertilization (Ntot Kg ha^{-1} y^{-1}): low ≤ 170; 170 < medium < 250; high ≥ 250. Based on reference values used to classify zones vulnerable to nitrogen pollution https://www.regione.veneto.it/web/agricoltura-e-foreste/zone-vulnerabili-nitrati

4 COST ANALYSIS

4.1 Investment costs

4.1.1 Investment costs for wetlands

4.1.1.1 Scolo Rusteghin

The investment costs of Scolo Rusteghin have been estimated on the basis of the **financial framework** of the detailed design delivered of 2014, which counts the following expenditure items:

- A: Working cost
    - A.1: Tendered work
        - A.1.1: Measure work
        - A.1.2: Supplementary work
        - A.1.3: Expenditure for safety not subjected to markdown
    - A.2: Internal work
        - A.2.1: Electricity connection
        - A.2.2: Movement and/or connection of public services
        - A.2.3: Landscaping
        - A.2.4 Reclamation of remnants of war explosive devices
        - A.2.5: Archaeological consultancy
- B: Funds for the authority (Sums available to the contracting authority)
    - B.1: Geotechnical investigation
    - B.2: Safety coordination
    - B.3: Topographic investigation
    - B.4: Expenditure for public commission judgement (VIA)
    - B.5: Expenditure for accounting and work assistance
    - B.6: Publicity expenditure
    - B.7: Design expenditure
- C: Expropriation and refunding
    - C.1: Land acquisition
    - C.2: Expenditure for fractionation of cadastre areas
-
- F: Contingencies

The bill of quantity was updated with the most recent price list of Veneto Region (2018). The comparison between the bill of quantities of original project (2014) and after the "reverse engineering" is summarized in **Table 26**. The total cost of work is **€ 642,894.25** in 2019, which results about 25% higher in comparison to the cost of five years ago (2014): the huge difference between the two depend on the underestimation of the prices of the original design of 2014 (the price list of the Regione Veneto has been updated in 2018 after more than 10 years and several voices underwent to a considerable increase).

Table 24. Bill of quantity for the original design (2004) and the "reverse engineering" (2019) of the wetland Scolo Rusteghin. Detailed costs of 2014 project are not given due to different organization of bill of quantity of the 2014 project

Wetland – Scolo Rusteghin			
n° Item	**Item/Work**	**Cost [€] 2014**	**2019**
1	**Measure work**		
1.1	*Wetland*		
1.1.1	Earthmoving and complementary structures		€ 193,731.66
1.1.2	Connection between wetland A and B		€ 6,660.05
1.1.3	Connection between wetland B and Buratti stream		€ 18,388.95
1.2	*Buratti stream*		
1.2.1	Ancillary works		€ 5,216.60
1.2.2	Syphon		€ 7,600.32
1.2.3	Crossing structure 1		€ 5,559.77
1.2.4	Crossing structure 2		€ 5,354.32
1.3	*Scolo Rusteghin*		
1.3.1	Overflow and weir		€ 15,993.25
2	**Work as a whole**		
2.1	*Wetland*		
2.1.1	Connection between wetland A and B		€ 41,349.49
2.1.2	Connection between wetland B and Buratti stream		€ 51,023.83
2.2	*Buratti stream*		
2.2.1	Syphon		€ 58,304.08
2.2.2	Crossing structure 1		€ 16,561.35
2.2.3	Crossing structure 2		€ 38,526.11
2.3	*Scolo Rusteghin*		
2.3.1	Overflow and weir		€ 152,579.52
3	**Supplementary work**		€ 26,044.95
Total		€ **512,313.75**	€ **642,894.25**

All the other expenditures of the financial framework have been calculated following a simplified approach, i.e. assuming a cost increase (+25.5%) equal to one obtained from the reverse engineering of the tendered working cost. The only exceptions were the land occupation and the general expenditure. The land occupation (**expenditure item C.1**) was maintained with the same cost, due to the low variation of land value in the last 15 years in Italy. The general expenditure (**expenditure item D**) was calculated according to the most recent tariffs of Italian Architects and Engineers[11], and they include the expenditure for all the design phases required by the Italian legislation for public works (Preliminary, Definitive, and Executive design) and for assistance to work execution. The financial framework for the Salzano wetland supposed to be built in 2019 is resumed in the financial framework given in **Table 27**, which corresponds to a total investment costs for the Rusteghin wetland in 2019 of **1,368,847.81 €**. All the reported costs are excluded VAT.

Table 25. Estimated financial framework for the Rusteghin Wetland in 2019.

	Wetland – Rusteghin	**2019**
A	WORKING COST	
A.1	Tendered work	
A.1.1	Measure work	642,894.25 €
A.1.2	Supplementary work	28,344.44 €
A.1.4	Expenditure for safety not subjected to markdown (4.9% of A.1.1)	31,501.82 €
	Total A.1	702,740.51 €
A.2	Internal work	
A.2.1	Electricity connection	10,039.07 €

[11] D.M. 17 giugno 2016, D.Lgs 50/2016 ex D.M. 143 del 31 ottobre 2013

	Wetland – Rusteghin	2019	
A.2.2	Movement and/or connection of public services	25,097.68 €	
A.2.3	Landscaping	25,097.68 €	
A.2.4	War remediation	6,274.42 €	
A.2.5	Archaeological consultancy	6,274.42 €	
	Total A.2	62,744.19 €	
	TOTAL A – WORKING COST	765,484.70 €	765,484.70 €
B	FUNDS FOR THE AUTHORITY		
B.1	Geotechnical investigation	3,764.65 €	
B.2	Safety coordination	20,078.14 €	
B.3	Topographic investigation	15,058.61 €	
B.4	Expenditure for public commission judgement (VIA)	31,372.10 €	
B.5	Expenditure for accounting and work assistance	20,078.14 €	
B.6	Publicity expenditure	6,274.42 €	
B.7	Design expenditure	46,454.10 €	
	TOTAL B – FUNDS FOR THE AUTHORITY		143,080.16 €
C	EXPROPIATION AND REFUNDING		
C.1	Land acquisition	430,000.00 €	
C.2	Expenditure for fractionation of cadastre areas	18,618.76 €	
	TOTAL C – EXPROPIATION AND REFUNDING		448,618.76 €
E:	Contingencies	11,664.20 €	
	TOTAL E – CONTINGENCIES		11,664.20 €
		TOTAL (excluded VAT)	**1,368,847.81 €**

4.1.1.2 Salzano

The investment costs of Scolo Rusteghin have been estimated on the basis of the **financial framework** of the detailed design delivered of 2014, which counts the following expenditure items:

- A: Working cost
  - A.1: Tendered work
    - A.1.1: Measure work
    - A.1.2: Work as a whole
    - A.1.3: Supplementary work
    - A.1.4: Expenditure for safety not subjected to markdown
  - A.2: Internal work
    - A.2.1: Measure work not included in the tender and carried out by the authority
    - A.2.2: Movement and/or connection of public services
    - A.2.3: war remediation
    - A.2.4: Naturalistic consultancy
    - A.2.5: Archaeological consultancy
- B: Funds for the authority

- B.1: Geotechnical investigation
- B.2: Safety coordination
- B.3: Chemical analysis
- B.4: Topographic investigation
- B.5: Publicity expenditure
- B.6: Expenditure for public commission judgement (VIA)
- B.7: Design expenditure

— C: Expropriation and refunding
- C.1: Land acquisition
- C.2: Temporary land occupation for building site
- C.3: Temporary land occupation for service life of the work
- C.4: Expenditure of expropriation procedure
- C.5: Expenditure for fractionation of cadastre areas

The **tendered working cost (expenditure item A.1)** of Salzano wetland was calculated on the basis of the "reverse engineering" of the detailed design delivered of 2004. The bill of quantity was updated with the most recent price list of Veneto Region (2018). The comparison between the bill of quantities of original project (2004) and after the "reverse engineering" is resumed in **Table 26**. The total costs of work are equal to **€ 1,551,563.54** in 2019, which results about 24% higher in comparison to the cost of fifteen years ago (2004).

Table 26. Bill of quantity for the original design (2004) and the "reverse engineering" (2019) of the wetland Salzano

Wetland – Salzano			
n° Item	**Item/Work**	**Cost [€] 2004**	**2019**
1	Mowing, earthmoving, embankment construction	€ 1,024,272.62	€ 1,285,930.33
2	Regulation and control structures		
2.1	Feeding	€ 64,226.81	€ 83,650.27
2.2	Drainage	€ 18,232.27	€ 23,967.03
2.3	By-Pass	€ 40,150.96	€ 55,965.80
2.4	Regulation structure and sluice gate	€ 91,451.45	€ 89,270.38
3	Weir	€ 11,665.89	€ 12,779.73
Total		**€ 1,250,000.00**	**€ 1,551,563.54**

All the other expenditures of the financial framework have been calculated following a simplified approach, i.e. assuming a cost increase (+24%) equal to one obtained from the reverse engineering of the tendered working cost. The only exceptions were the land occupation and the general expenditure. The land occupation (**expenditure item C.1**) was maintained with the same cost, due to the low variation of land value in the last 15 years in Italy. The general expenditure (**expenditure item D**) was calculated according to the most recent tariffs of Italian Architects and Engineers[12], and they includes the expenditure for all the design phases required by the Italian legislation for public works (Preliminary, Definitive, and Executive design) and for assistance to work execution. The financial framework for the Salzano wetland supposed to be built in 2019 is resumed in the financial framework given in

[12] D.M. 17 giugno 2016, D.Lgs 50/2016 ex D.M. 143 del 31 ottobre 2013

Table 27, which correspond to a <u>total investment cost for the Salzano wetland in 2019</u> of **2,455,939.14 €**. <u>All the reported costs are excluded VAT</u>.

Table 27. Estimated financial framework for the Salzano Wetland in 2019.

	Wetland – Salzano	2019	
A	WORKING COST		
A.1	Tendered work		
A.1.1	Measure work	1,551,563.54 €	
A.1.2	Work as a whole	- €	
A.1.3	Supplementary work	- €	
A.1.4	Expenditure for safety not subjected to markdown (3.5% of A.1.1)	54,304.72 €	
	Total A.1	1,605,868.26 €	
A.2	Internal work		
A.2.1	Measure work not included in the tender and carried out by the authority		
A.2.1.a	Plantation (Phragmitas Australis)	74,475.05 €	
A.2.2	Movement and/or connection of public services	12,412.51 €	
A.2.3	War remediation	12,412.51 €	
A.2.4	Naturalistic consultancy	6,206.25 €	
A.2.5	Archaeological consultancy	6,206.25 €	
	Total A.2	37,237.52 €	
	TOTAL A – WORKING COST	1,643,105.79 €	1,643,105.79 €
B	FUNDS FOR THE AUTHORITY		
B.1	Geotechnical investigation	3,847.88 €	
B.2	Safety coordination	32,396.65 €	
B.3	Chemical analysis	18,618.76 €	
B.4	Topographic investigation	22,714.89 €	
B.5	Publicity expenditure	19,860.01 €	
B.6	Expenditure for public commission judgement (VIA)	5,585.63 €	
B.7	Design expenditure	140,394.03 €	
	TOTAL B – FUNDS FOR THE AUTHORITY		243,417.85 €
C	EXPROPIATION AND REFUNDING		
C.1	Land acquisition	560,726.75 €	
C.2	Temporary land occupation for building site	- €	
C.3	Temporary land occupation for service life of the work	- €	
C.4	Expenditure of expropriation procedure	6,206.25 €	
C.5	Expenditure for fractionation of cadastre areas	2,482.50 €	
	TOTAL C – EXPROPIATION AND REFUNDING		569,415.51 €
		TOTAL (excluded VAT)	**2,455,939.14 €**

4.1.2 Investment costs for buffer strips

Buffer strips have a considerably lower level of complexity in comparison to wetland technology. As a consequence, they are often implemented with simplified procedures and without detailed designs. Therefore, the investment cost estimation of proposed buffer strips has been based on a simplified analysis, which has considered only the following expenditure items in the **financial framework**:

— A: Working cost:
    - A.1: Tendered work
        - A.1.1: Measure work
        - A.1.2: Expenditure for safety not subjected to markdown

— B: Funds for the authority:
    - B.1: Technical investigation and consultancy
    - B.2: Contingencies

— C: Expropriation and refunding
    - C.1: Land acquisition plus expenditure for the procedure

The **tendered working cost** (expenditure item A.1) of buffer strips was calculated on the basis of a simplified "reverse engineering", defining a bill of quantities only for the following most relevant items:

— Excavation, defining the parametric cost of 5.51 €/mc (price list of Veneto Region 2018)

— Embankment, defining the parametric cost of 10.8 €/mc (price list of Veneto Region 2018)

— Trees, assumed the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the design of the buffer strips, i.e. 5 €/tree (including acquisition, transport and placement)

— Feeding system (only for NICOLAS), assumed considering n°6 pumps (each € 600) and the installation with as a lump sum cost of € 2,000.00 (cost shared by Acque Risorgive Consorzio di Bonifica)

The simplified bill of quantities and the estimated tendered working cost are resumed in **Table 28**. The total costs of work are equal to **€ 145,268.03** and **€ 18,435.38** for Scandolara and NICOLAS, respectively.

Table 28. Simplified bill of quantities and estimated tendered working cost for Scandolara and NICOLAS buffer strips

	Unit	Scandolara	NICOLAS BS width 30 m	NICOLAS BS width 5 m	NICOLAS Total
Bill of quantity					
Total length	m	957	205	205	
Average width	m	7	34	7.67	
Total surface	ha	0.67	0.70	0.16	
n° of drainage channels to be excavated			1	1	
n° of existing drainage channels			1	1	
Drainage channel average depth	m		0.5	0.5	
Drainage channel average width			1.3	1.3	
Width of excavated area	m	6			
Average excavation depth	m	1.5			
Excavated volume	m^3	8613	136.3	136.3	
N° of tree lines		2	1	1	
Distance between the trees	m	2	1.5	1.5	
N° of trees per line		479	137	137	
N° of trees in total		958	137	137	
Work costs					

	Unit	Scandolara	NICOLAS BS width 30 m	NICOLAS BS width 5 m	NICOLAS Total
Excavation	€	47,457.63 €	751.15 €	751.15 €	2,253.45 €
Embankment	€	93,020.40 €	1,472.31 €	1,472.31 €	4,416.93 €
Trees	€	4,790.00 €	685.00 €	685.00 €	6,165.00 €
Feeding system	€				5,600.00 €
Total	**€**	**145,268.03 €**	**2,908.46 €**	**2,908.46 €**	**18,435.38 €**

All the other expenditures of the financial framework have been calculated with the following simplified expert-based assumptions:

— Expenditure for safety not subjected to markdown (expenditure item A.1.2): 3% of the working costs;

— Technical investigation and consultancy (expenditure item B.1): 12% of the working costs;

— Contingencies (expenditure item B.2): 1.2% of the working costs;

— Land acquisition plus expenditure for the procedure for Scandolara (expenditure item B.2): parametric cost function of occupied land, assumed equal to 12.8 €/m^2, i.e. the maximum value for the same expenditure items from detailed design of wetland system (i.e. Rusteghin);

— No expenditure for land acquisition for NICOLAS, since the NBS was installed on public area used by a private farmer; therefore, the NBS was constructed with an agreement, which included no expenditure for the land acquisition, hydraulic OPEX of responsibility of the Acque Risorgive Consorzio di Bonifica, and pruning activities of responsibility of the farmer.

The financial framework for the Scandolara and NICOLAS wetland supposed to be built in 2019 is summarized in the financial framework given in **Table 29**, which corresponds to a total investment costs for the studied buffer strip in 2019 of **245,667.08 €** and **21,421.91 €** for Scandolara and NICOLAS, respectively. All the reported costs are excluded VAT.

Table 29. Estimated financial framework for the Scandolara and NICOLAS buffer strips in 2019.

		Scandolara 2019	NICOLAS 2019
A	WORKING COST		
A.1	Tendered work		
A.1.1	Measure work	145,268.03 €	18,435.38 €
A.1.2	Expenditure for safety not subjected to markdown	4,358.04 €	553.06 €
	Total A.1	149,626.07 €	18,988.44 €
B	FUNDS FOR THE AUTHORITY		
B.1	Technical investigation and consultancy	17,432.16 €	2,215.25 €
B.2	Contingencies	1,743.22 €	221.22 €
	TOTAL B – FUNDS FOR THE AUTHORITY	19,175.38 €	2,433.47 €
C	EXPROPIATION AND REFUNDING		
C.1	Land acquisition plus expenditure for the procedure	85,865.63 €	0.00 €
	TOTAL C – EXPROPIATION AND REFUNDING	85,865.63 €	0.00 €
	TOTAL (excluded VAT)	**254,667.08 €**	**21,421.91 €**

4.2 Operational and Maintenance costs

4.2.1 O&M for wetlands

O&M have been detailed with interviews to the staff of the management Authority (Consorzio di Bonifica Acque Risorgive), following the approached already used by the Tenderer (Rizzo et al., 2018) and considering the following O&M items:

— Management of accumulated sediment: due to high naturalistic value of the wetland, the Consorzio expects a minimal maintenance activity for sediment management, and, up to now, neither the Salzano nor the Rusteghin wetlands have received any maintenance of accumulated sediment; therefore, the OPEX item was accounted with a simplified approach, i.e. considering an activity of excavation (parametric cost of 5.51 €/mc – price list of Veneto Region 2018) and embankment (parametric cost of 10.8 €/mc – price list of Veneto Region 2018) to be done every 25 years to recover the hydraulic functioning of the first settlement pond area of the wetland (1725 m^2 and 1565 m^2 for Salzano and Rusteghin, respectively), moving an accumulated layer of sediment equal to 80 cm;

— Energy consumption (only for Salzano wetland, for electro-mechanical regulation and control structure functioning): €1,500 per year based on the experience of Consorzio di Bonifica Acque Risorgive

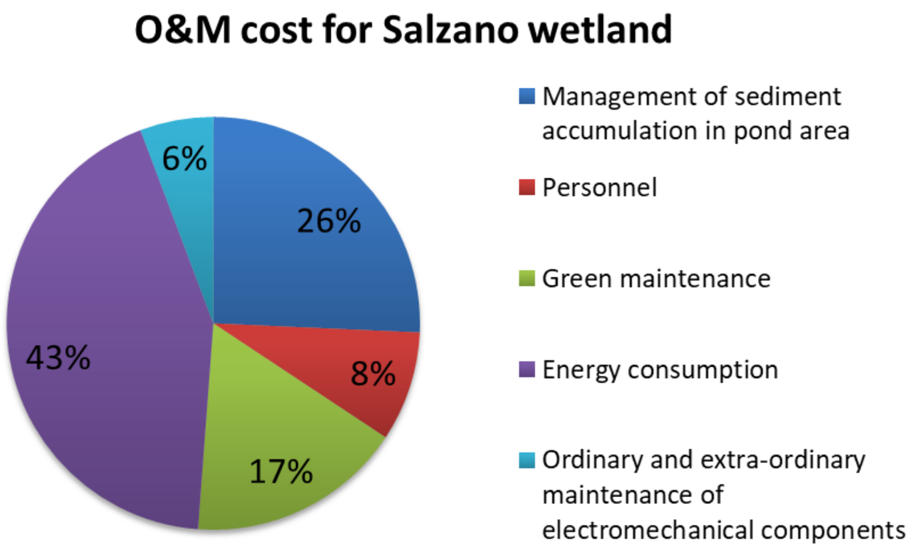
— Green maintenance: assumed the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the design maintenance activities, i.e. 330 €/km; the parametric cost was applied to the perimeter of the wetlands, i.e. 1.78 km and 1.0 km for Salzano and Rusteghin, respectively, and with a frequency of one per year;

— Ordinary and extraordinary maintenance of electromechanical components (only Salzano wetland): the O&M item was accounted with a simplified approach, i.e. considering a lump sum cost to maintain main electromechanical components (control panel and electric weirs) equal to €2,000, expected to be expensed every 10 years;

— Personnel: this O&M item was calculated on the basis of the visit frequency given by the Acque Risorgive Consorzio di Bonifica for ordinary maintenance and after heavy rainfalls, i.e. 4 and 12 for Salzano and Rusteghin, respectively; we assumed an average duration of the visit of 3 hours and the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the planning of O&M activities, i.e. 25 €/hour

Due to the lack of legal limits for discharge, the Acque Risorgive Consorzio di Bonifica does not regularly monitor the treatment performance of the wetlands, and no O&M expenses for water quality samples were assumed.

The details of the wetland O&M are resumed in **Table 30** and **Figure 24**, which corresponds to a total O&M costs for the Salzano wetland of **3,482.49 €/y** and for Rusteghin wetland of **2,046.80 €/y**. All the reported costs are excluded VAT. The O&M are rather low. Interestingly, the majority of the O&M can be considered as extraordinary activities (69% and 54% for Salzano and Rusteghin, respectively), leading to a very low yearly costs if only ordinary maintenance would be considered.



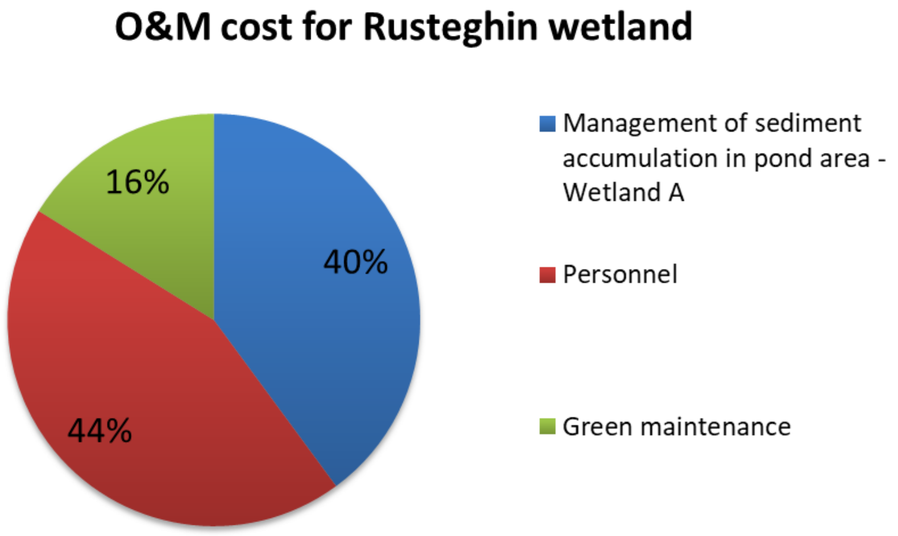


Figure 24. Distribution of O&M costs for the Salzano wetland (top) and Rusteghin (down)

Table 30. Detail of O&M for the wetlands per year

O&M Wetlands			
n° Item	**Item**	**O&M Cost [€/y] Salzano**	**Rusteghin**
1	Management of sediment accumulation in pond area	€ 895.09	€ 816.80
2	Energy consumption	€ 1,500.00	€ -
3	Green maintenance	€ 587.40	€ 330.00
4	Ordinary and extra-ordinary maintenance of electromechanical components	€ 200.00	€ -
5	Personnel	€ 300.00	€ 900.00
Total		**€ 3,482.49**	**€ 2,046.80**

4.2.2 O&M for buffer strips

4.2.2.1 Scandolara

O&M have been detailed with interviews to the staff of the management Authority (Consorzio di Bonifica Acque Risorgive), following the approached already used by Rizzo et al., 2018 and considering the following O&M items:

- Green maintenance: assumed the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the design maintenance activities, i.e. 330 €/km; the parametric cost was applied to the length of the buffer strip, i.e. 0.96 km and with a frequency of two per year;
- Manual pruning: assumed the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the design maintenance activities, i.e. 2300 €/km; the parametric cost was applied to the length of the buffer strip, i.e. 0.96 km and with a frequency of one manual pruning every 6 years;
- Mechanical pruning: assumed the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the design maintenance activities, i.e. 660 €/km; the parametric cost was applied to the length of the buffer strip, i.e. 0.96 km and with a frequency of one manual pruning every 12 years;
- Personnel: this O&M item was calculated on the basis of the visit frequency given by the Acque Risorgive Consorzio di Bonifica for ordinary maintenance and after heavy rainfalls, i.e. 2; we assumed an average duration of the visit of 2 hours and the parametric cost used by the Acque Risorgive Consorzio di Bonifica for the planning of O&M activities, i.e. 25 €/hour

The details of the wetland OPEX are resumed in **Table 31**, which corresponds to a total O&M costs for the Scandolara buffer strip of **1,151.11 €/y**. All the reported costs are excluded VAT.

Table 31. Detail of O&M for the Scandolara buffer strip per year

n° Item	Item	O&M Cost [€/y] Scandolara
1	Green maintenance	€ 631.62
2	Manual pruning	€ 366.85
3	Mechanical pruning	€ 52.64
4	Personnel	€ 100.00
Total		**€ 1,151.11**

4.2.2.2 NICOLAS

O&M have been detailed with interviews to the staff of the management Authority (Consorzio di Bonifica Acque Risorgive), following the approached already used by Rizzo et al., 2018. For the NICOLAS buffer strip, the O&M was calculated from the detailed cost of energy consumption for the whole NICOLAS site, considering the following O&M items:

- Energy consumption (pumping of water to be treated from the Zero river): the Consorzio di Bonifica Acque Risorgive estimates an energy consumption cost of € 7,500.00 for the whole NICOLAS site of 30 ha; the energy cost of the analysed buffer strip was calculated scaling according to the size of the analysed site, equal to 0.85 ha.
- Pruning: the Consorzio di Bonifica Acque Risorgive estimates a pruning cost of € 1,120.00 for the whole 30 drainage ditches of the NICOLAS site; the pruning cost of the analysed buffer strip was calculated scaling according to the n° of drainage ditches size of the analysed site, equal to 5;
- Maintenance of the drainage ditches: the Consorzio di Bonifica Acque Risorgive estimates a cost to maintain the drainage ditches of € 1,120.00 for 10 drainage ditches; the cost to

maintain the drainage ditches of the analysed buffer strip was calculated scaling according to the n° of drainage ditches size of the analysed site, equal to 5;

— General maintenance of the area: the Consorzio di Bonifica Acque Risorgive estimates a general cost to maintain the area of € 7,500.00 for the whole NICOLAS site of 30 ha; the energy cost of the analysed buffer strip was calculated scaling according to the size of the analysed site, equal to 0.85 ha.

— Ordinary and extraordinary maintenance of electromechanical: the O&M item was accounted with a simplified approach, i.e. considering the total cost of the main electromechanical components (pumping system) divided by the expected life span of 10 years;

The details of the wetland O&M are resumed in **Table 32**, which corresponds to a total O&M costs for the Scandolara buffer strip of **1,835.34 €/y**. All the reported costs are excluded VAT.

Table 32. Detail of O&M for the NICOLAS buffer strip per year

n° Item	Item	O&M Cost [€/y] NICOLAS
1	Energy	€ 213.56
2	Pruning	€ 187.67
3	Maintenance of drainage ditches	€ 448.00
4	General maintenance of the area	€ 427.12
5	Ordinary and extra-ordinary maintenance of electromechanical components	€ 560.00
Total		**€ 1,835.34**

4.3 Literature verification of working and O&M costs for the studied NBS and comparison with "grey solutions"

The unit construction costs for Rusteghin and Salzano wetland are **19** and **7 €/m²** respectively. They are lower than the costs typical of free water surface (FWS) CW, which are typically in the range of 20-60 €/m², principally depending if the FWS are or not waterproofed with plastic liners. For instance, the FWS tertiary stage of Castelluccio di Norcia, which was partially waterproofed (one portion was for infiltration and discharge on soil), cost 32 €/m² (Rizzo et al., 2018)**.** Therefore, the lower working costs obtained for two wetlands here investigated, Salzano and Rusteghin, are principally due to not waterproofing. Anyway, the costs remain comparable with the literature values.

O&M cost for the Rusteghin and Salzano are 2,046.80 and 3,482.49 €/y, respectively, corresponding to a range of **0.02-0.06 € m^{-2} y^{-1}.** These values are lower in comparison to those reported for CW treating municipal wastewater. For instance, Rizzo et al, 2018 reports 1.73 € m^{-2} y^{-1} for the CW treating the urban wastewater of Castelluccio di Norcia. The lower O&M parametric costs for the studied wetland remains in line with literature value, considering that several expenditure items occurring in CW for municipal wastewater are not required in CW for agricultural runoff, such as water quality sampling, sludge removal and ordinary and extraordinary maintenance of concrete structures and sewers. Moreover, CW for agricultural runoff, such as Rusteghin and Salzano, are extensive systems with larger surface area in comparison to subsurface CW for municipal wastewater, greatly reducing the parametric cost in terms of square meters.

The investment cost for Scandolara Buffer is **22 €/m²** (150 €/m). The presence of significant excavation and embankment works for the Scandolara buffer strip, useful to enlarge the ditch and to intercept the groundwater more efficiently, lead this work to have costs one order of magnitude higher in comparison to conventional buffer strips (5-10 €/m – CIRF[13]), in which trees are simply planted in proximity of the ditches, without excavation works. Therefore, the working costs for Scandolara must be considered representative only for buffer strips with river widening. Instead, O&M activities for Scandolara remain similar to those of any kinds of buffer strips. Indeed, the O&M costs per Scandolara buffer strip are equal to **1.20 € m^{-1} y^{-1}** (€ 0.17 € m^{-2} y^{-1}), comparable with the values reported by CIRF in Italy, ranging from 1.8 to 3.9 €m^{-1} y^{-1}.

Nicolas buffer corresponds to the category of woody buffer area, considering the CIRF classification of buffer strips. CIRF reports, for woody buffer areas, working cost in the range 1.2-1.8 €/m^2, in line with the value identified for Nicolas, equal to **2.7 €/m^2**; higher working costs can be attributed to the pumping system and the more complex network of drainage ditches installed in Nicolas. Also O&M costs for Nicolas, equal to **0.26 € m^{-2} y^{-1}**, result comparable with the range of O&M costs reported by CIRF for woody buffer areas (0.26-0.54 € m^{-2} y^{-1}).

A **simplified cost-effectiveness analysis** was done in terms of cost per tonne of TN removed, comparing the NBS discussed in this work with an estimation of nitrogen removal from conventional centralised grey solution based on parametric values for Italy (Masotti 2011)[14]. Results are summarised in **Table 33**. According to literature data the removal of 1 nitrogen ton from wastewater by conventional "grey solution" (nitro-denitro reactor) costs between 8,000 and 9,000 €/year, considering annualized investment and O&M costs, over a lifetime of 20 years.

The same approach (annualized total investment and O&M costs, but considering a lifetime of 30 years) applied to the analyzed NBS show worst performances. The removal cost of 1 ton of nitrogen ranges between 13,000 €/year for the most cost effective NBS (Rusteghin wetland) and 64.000 €/year of the Scandolara Buffer Strip.

Such results were expected: in fact, among the measures to reduce nutrient pollution envisaged by the Venice Lagoon Strategic Masterplan, first priority has been given to the upgrading of wastewater treatment plants adding nutrient removal tertiary treatment. "Grey solutions" applied to wastewater treatment, deal with wastewater, which have nutrients concentration 10 times higher than the concentration of agricultural runoff. All the removal processes are therefore much more effective with wastewater than they are with agricultural runoff. On the other hand, it is worth highlighting that more efficient wetland solutions (in this case Rusteghin) have a cost-effectiveness value in the same order of magnitude of centralised "grey" solution, showing the importance of a proper design of wetland solution when the main target of nutrient removal is much more important than other side-benefits (such as biodiversity).

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[13] Experts involved in this study, i.e. Bruno Boz and Giulio Conte, have been, and are still, involved within CIRF – Centro Italiano Riqualificazione Fluviale (Italian Centre River Restoration – www.cirf.org). CIRF has collaborated with the most important Italian stakeholders for the promotion of river restoration techniques. To the aim of this work, the reported parametric costs are extrapolated from the Bruno Boz experience with CIRF in the preparation of the guidelines for buffer strips installation in Emilia-Romagna Region ("Studio di fattibilità per la definizione di line guida per la progettazione e gestione di fasce tampone in Emilia-Romagna")

[14] The considered grey solution is an activated-sludge plant, in which the nitro-denitro CAPEX are assumed from 13.6 (100000 PE) to 22.9 €/PE (10000 PE) and nitro-denitro OPEX to the about 50% of the total operational and maintenance costs. Parametric values taken from Masotti (2011)

Table 33. Simplified cost-effectiveness anaysis between green solutions for diffuse nitrogen pollution control and centralised solutions for point nitrogen pollution control

	Unit	Wetland (2019)				Buffer strips (2019)			WWTP only nitro-denitro (2011)	
		Scolo Rusteghin		Salzano		Scandolara		Nicolas	medium (10000 PE)	large (100000 PE)
		with land cost	without land cost	with land cost	without land cost	with land cost	without land cost	without land cost		
Invest.	€	1,368,847	920,229	2,455,939	1,886,523	254,667	168,801	21,422	229,400	1,360,000
Life cycle	y	30	30	30	30	30	30	30	20	20
O&M	€/y	2,046	2,046	3,482	3,482	1,151	1,151	1,835	303,571	2,751,889
Total annual cost	€/y	47,675	32,721	85,347	66,366	9,640	6,778	2,549	315,041	2,819,889
N rem.	tonN/y	3.62	3.62	1.47	1.47	0.15	0.15	0.05	35.04	350.40
Cost effectiv.	€/tonN	13,170	9,039	58,059	45,147	63,956	44,967	49,877	8,991	8,048

4.4 Cash flow analysis

In the analysed case study, any direct and specific revenues correspond to the investment and O&M costs described in the previous paragraph. The *Consorzio di Bonifica Acque Risorgive*, now, covers the O&M costs relating to the NBS without increasing the fees requested from its users.

Then, the cash outflow are represented in 3 project phases: design, project implementation and project life cycle (see ***Figure 25***). In **Table 34** the cash outflow of 4 NBS is quantified. In this case, all costs are expressed in €/y because the hypothesis is that the length of all sub-phases are one year.

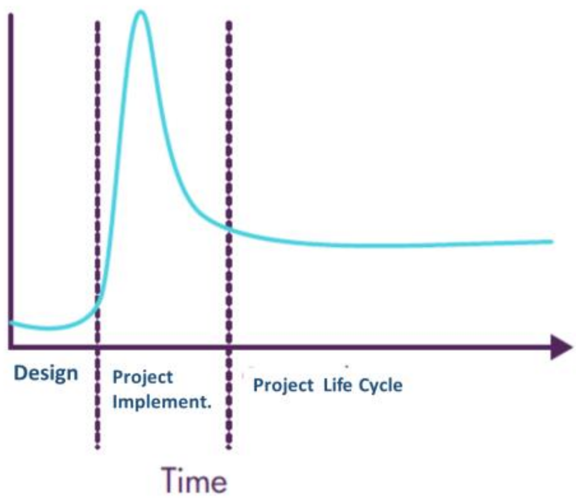


Figure 25. Cash outflow project phases

Table 34. Cash outflow of studied NBS [€/y]

Project Phases	Design	Project implementation		Project Life Cycle					
		Land Acquisition	Construction						
Years	-2	-1	0	1	2	…	10	…	50
Wetlands									
Scolo Rusteghin	46.000	448.618	827.776	3.641	3.641	3.641	3.641	3.641	3.641
Salzano	140.000	569.415	1.746.524	2.205	2.205	2.205	2.205	2.205	2.205
Buffer Strips									
Scandolara	19.175	86.000	149.626	1.151	1.151	1.151	1.151	1.151	1.151
Nicolas	2.433	-	18.988	1.835	1.835	1.835	1.835	1.835	1.835

5 SOCIAL ANALYSIS

5.1 Source of data and assumptions

This chapter outlines the main results and findings of the Social Analysis conducted by ARCO (Action Research for Co-development) between October 2019 and January 2020, with the general objective of collecting and analysing the issues affecting the social sustainability of the application of a NBS to treat diffuse in Venice Lagoon watershed.

The *Consorzio di Bonifica Acque Risorgive* is the organization in charge of the implementation of such interventions. The actions strongly affected the area, in social as well as environmental and economic terms.

Within the perspective of local development, based on the priorities and needs identified by local stakeholders and beneficiaries themselves, this part of the study has focused in particular on the following specific objectives:

4. To understand the main relations among relevant stakeholders and local actors and their perceptions about NBS;
5. To explore the main issues that affect the social sustainability of the area where the NBS solution is in place;
6. To collectively identify and evaluate the functional capacity of the case as local development success model.

The experience and the case study can be an example and favour the replicability of the adopted solutions also in other areas with similar production sectors.

At social level, in order to explore the perception, among farmers, citizens, and other stakeholders, of the installation of the NBS solution in the target area, a **Need Analysis** has been conducted. The Analysis adopted a participatory methodology based on the active involvement of the main stakeholders, using the methodology outlines in **Table 35**.

Table 35. Methodology, actors involved and objectives

Method and target	Objective
Conduction of **semi-structured interviews with representatives of the main institutions and stakeholders** (e.g. Regione Veneto, Municipalities, Drainage Authority, etc.)	To understand the main strengths and critical issues and to assess the role of each stakeholder within the value chain.
Conduction of **semi-structured interviews with the Farmer organisations**	To assess needs, economic and social conditions, services and governance, relations with relevant value chain actors.
Conduction of **semi-structured interviews with the local community** (e.g. citizens, environmental NGOs)	To discuss the main strengths, barriers and critical issues.

In this context, the involved interviewee contributed to identify the relevant social impacts through the definition of specific indicators of “social values”, as reported in the following table.

Table 36. Methodology, impacts and indicators (Da Rocha et al 2017, Church 2017)

SOCIAL VALUES	IMPACTS	INDICATORS	Parameters	Judgment
Awareness/ Educational	Research opportunities for educational purpose; environmental protection and awareness and greening activities; sharing knowledge, divulgation and dissemination	Organization of events for education and dissemination on NBS; scientific publications; elaboration of educational material	Number of events and activities carried out in the target area	Low/Medium /high
Reduce flood risk	Peak flow flood reduction	Increased perception of safety and increased resilience capacities with flood risk	Based on people's perception	Low/Medium /High
Visual Impact	Improve/Degradation of aesthetic quality of the landscape Enjoyment of sights	Regeneration of derelict areas Level of transformation of spaces, landscapes or natural environments through human action How people feel about their surroundings	Expert judgment (based on results of interviews)	Low/Medium /High
Nuisance (odours, noise, presence of insects, obstacles to common farming and citizen practises)	Mitigation of Odour; mitigation of Noise; Presence of insect; Obstacles to farming practises; plants emitting allergic pollen.	Noise	Noise nuisance based on people's perception	Low/Medium /High
		Odour	Odour nuisance based on people's perception	
		Increase in the no. Of mosquitoes	nuisance based on people's perception	
		Obstacles to farming practises	nuisance based on farmers perception	
		Increased in allergies and air humidity	nuisance based on people's perception	
Well-being and recreation	Improvement of recreation opportunities and health	Opportunities for outdoor and recreational activities (running, biking, fishing, bird watching etc..);	Tourism and visitors	Low/Medium /High

SOCIAL VALUES	IMPACTS	INDICATORS	Parameters	Judgment
		Opportunities for social interaction		

Each identified social value is assessed individually, according to the criteria defined below.

AWARENESS/EDUCATION

Level of awareness/education within a territory could be indirectly measured through the number of formal and informal education and research opportunities. Number of events and activities about nature protection and valorisation carried out in the target area was taken into account as parameters.

REDUCE FLOOD RISK

Currently, the adoption of NBS aims at reducing flood risks and enhancing urban ecosystems. Citizens' risk perception on flooding events is a relevant parameter to detect. In communities where the risk of flooding is perceived as low, an acceptance of the NBS can be indirectly considered.

VISUAL IMPACT

Visual impact has been measured following evidences and remarks about landscape and the comparison ex-ante and ex-post intervention. During semi-structured interviews comments and perceptions have been collected about: actual installation of the NBS in terms of distance and number of inhabitants; use of existing buildings/facilities; anthropisation level (e.g. level of transformation of spaces, landscapes or natural environments through human action); presence of amendments carried out to palliate the impact.

NUISANCE

In order to measure the impact in noise and odour generated in the surrounding area, qualitative information have been collected during semi-structured interviews.

WELL BEING AND RECREATION

Recreation has been measured in terms of number of organization of recreational and health activities and number of visitors per year.

5.2 Actors description

The practice of NBS for diffuse pollution control is ongoing in the target area since more than 20 years, therefore a collaboration among the key stakeholders is ongoing for some time. Stakeholders are in particular:

- Consorzio di Bonifica Acque Risorgive
- Farmer associations (Coldiretti Treviso, Confederazione Italiana Agricoltori Treviso, Confederazione Italiana Agricoltori Venezia, Confagricoltura Treviso)
- Municipalities and local communities (e.g. local WWF office)

In the following **Table 37**, the level of involvement of stakeholders is reported:

Table 37. Stakeholders involvement (Impronta Etica 2016)

Stakeholder	Type of interest	Involvement	Type of change	Connection level
Consorzio di Bonifica Acque Risorgive	Organization in charge of the NBS development and recipient of public funds for its construction	Support	Environmental benefits Social benefits/social resistances	High
Farmer Associations	Beneficiaries	Support/negative	Economic benefits/costs Environmental benefits	High
Local community	Beneficiaries	Support/negative	Social benefits/social resistances	High
Environmental Associations and NGOs	Users of the NBS results	Support	Environmental benefits Economic benefits	Medium

5.2.1 Consorzio Acque Risorgive

Consorzio di Bonifica Acque Risorgive is a public body, managed by its members, which coordinates public interventions and private activities in the areas of water protection and irrigation. It operates as Drainage Authority in safeguarding the territory of its competence, the environmental protection, the flood protection, the development of agriculture and the management of water.

The members are all the owners of properties (land and premises), included in the land reclamation district, a part of the territory identified by the Veneto Region.

The expenses for the maintenance, operation and guarding of reclamation works, are supported by Drainage Authority member and are distributed on the basis of the benefit derived from the works and land reclamation activities, in accordance with the criteria set out in the plan approved by the Veneto Region.

Through the "Strategic Master Plan", Veneto Region financed measures of rivers and ditches ecological restoration or enhancement to increase the residence time of water and self purification processes in the draining basin in order to address the eutrophication issues affecting the Venice Lagoon. Therefore, the Veneto Region Drainage Authorities can rely on funds and greater possibilities of intervention compared the other Drainage Authorities at national level. The main goal of these measures was the reduction of nitrogen and phosphorus loads from agricultural activities in the basin **through nature-based pollution control solutions**, thus reducing the amount of nutrients reaching the Venice Lagoon. However, at the same time, it was necessary to reduce the incidence and intensity of flood events in the area. Flooding issues had increased in the decades before the interventions mainly because the sections of the drainage channels were too narrow to contain water discharges in critical periods of the years. Over the years, the area has in fact been subject to massive urban development (new residential and industrial areas), with consequent soil sealing and culverted stream and ditches, having detrimental effects on the hydrological system. The strong floods of 2006 and 2007 affecting the city of Mestre, for example, were a consequence of this.

In this framework the Consorzio Acque Risorgive played a key role as implementing body of the required actions, mainly for two reasons:

1. almost half of the drainage basin that ends up in the Venice Lagoon is managed by the Consorzio Acque Risorgive;
2. they used regional funds to internalize and develop specific skills on Nature Based Solutions (NBS), by involving new environmental experts (from abroad as well) in their technical department.

In the mid-1990s, Acque Risorgive turned into the first experimental laboratory on diffuse pollution control NBS in Italy, with a multifunctional approach that would become their *modus operandi* in any type of action: achieving water purification with the broader perspective of water bodies ecological restoration, also in aesthetic terms through extensive interventions. This methodology generally required low maintenance costs, as the sites should be able to adjust to changing baseline conditions.

Today, with more than 15 years of experience, the Drainage Authority strives to serve as a centre of expertise for depuration in Italy, creating a successful model of proper land management. Consorzio Acque Risorgive plays a key role: it works as an *Utility* which provides and manages public utility services. It manages and supervises all the actions in the drainage basin.

In the framework of integrated landscape planning, the two objectives initially mentioned (the decrease in the quantities of phosphorus and nitrogen and the restoration of the draining channel network) are totally synergic.

The NBS installation was implemented on land acquired by the Consorzio di Bonifica from farmers through voluntary agreement. Land acquisition agreement is not always possible due to the high market price of land in the area.

In some cases, negotiations for land aquisition posed some challenges. At the beginning this caused strong resistance and conflicts with many farmers: the first interventions were particularly difficult in terms of management of relations with stakeholders (farmers, citizens, associations etc..), as the construction sites lasted for a long time. During the implementation phase, some residents complained about the annoyance (e.g. the dust lifted by the machinery). Also after implementation, there were some problems with farmers: in some cases, trees and plants cast shadows on crops.

From this perspective, the situation has greatly improved thanks to the participatory efforts of coordination, debate and sharing of results with the different actors involved.

Today, people generally trust the Consorzio Acque Risorgive and recognise the positive effects that the interventions have on the region, especially in terms of hydrogeological safety (rivers and channels do not overflow as before the implementations). The measures created pleasant natural environments that residents are now using for recreation (walking, biking, fishing). In the area managed by the Drainage Authority, there are 3 regional protected areas registered as SIC (Site of Community Importance), initially private and now belonging to the state owned and thus open to visitors (6).

Acque Risorgive collaborates with environmental associations, organizes and manages environmental education projects in schools, with an amount of 44 classes every year. It communicates its activities through newsletters and scientific dissemination (papers, participation in conferences etc..). Finally, he is the proposer of the *Contratto di Fiume*, a voluntary strategic planning and negotiated tool between the main parties involved in the management of river basins. However, the process leading to the signing of the river contract has been stopped and the action program for the protection and enhancement of riverside areas is still missing.

Finally, a high level of repeatability of the model can be observed. These types of measures can be seen as “standard” agricultural measures, and they can in principle be applied in all plain areas where intensive agriculture is practiced, with a dual objective (i) nutrient reduction and (ii) flood mitigation, while improving habitats and the environmental quality at the same time.

SOCIAL VALUES	IMPACTS
Awareness/ Educational	Organization and management of several environmental education projects in schools, with an amount of 44 classes every year with the elaboration of a final reports. Organization of an annual regional event of environmental education with *ANBI Veneto, the Regional Association of Drainage Authorities.*
Reduce flood risk	High contribution to the mitigation of floods: before implementation, intense precipitations would have caused overflowing of rivers and channels and flooding events. After implementation, precipitations with equal intensity do not cause such phenomena anymore.
Visual impact	They preferred extensive interventions with the aim of redevelop the river also in terms of aesthetics and visual impact
Nuisance (odours, noise, presence of insects, obstacles to common farming and citizen practises)	During the implementation phase, some residents complained for the annoyance (e.g. the dust lifted by the machinery) Initially, negotiations for land aquisition posed some challenges with farmers. Thanks to the participatory and sharing efforts, now farmers recognise the positive effects, especially in terms of hydrogeological safety.
Well-being and recreation	The measures created pleasant natural environments that residents are now using for recreation (walking, biking, fishing). In the area managed by the Drainage Authority, there are 3 regional protected areas registered as SIC (Site of Community Importance), initially private and now belonging to the state owned and thus open to visitors.

5.2.2 Farmer associations

Some of the main important farmer representatives have been contacted, in particular:

1. Coldiretti Treviso
2. Confederazione Italiana Agricoltori Treviso
3. Confederazione Italiana Agricoltori Venezia
4. Confagricoltura Treviso

According the collected data, it should be noted that, despite the initial scepticism of farmers, today they appreciate the work done by *Consorzio Acque Risorgive* and recognise the added value provided by the NBS, in terms of:

A. Improvement of water quality;
B. Improvement of the environmental quality of the areas thanks to the increase in biodiversity;
C. Reduction of flooding events in areas particularly exposed to the risk.

No particular conflict emerged. The only issue concerned the value of the land at the moment of its acquisition by the Consorzio Acque Risorgive: the choice of the area where to construct NBS was made taking into account the willingness of the farmers to sell the land at a “reasonable” price. Nowadays, conflicts and discussions occur sometimes between farmers and citizens who would like to walk even in private areas.

Farmers reported a lack of planning and an inadequate communication at the beginning of the activities. The situation improved in the operational phase, through the correct involvement of all stakeholders.

Presently farmers would appreciate their direct involvement for the construction and maintenance of NBS, if adequate funding could be guaranteed by public sources. In addition, young farmers would be available to develop a service-oriented agriculture, opening their farms to the general public visiting the NBS.

SOCIAL VALUES	**IMPACTS**
Awareness/ Educational	
Reduce flood risk	Farmers noted the reduction of flooding events in areas particularly exposed to the risk.
Visual Impact	
Nuisance (odours, noise, presence of insects, obstacles to common farming and citizen practises)	Initial scepticism of farmers. Initially lack of planning and an inadequate communications, resolved with the involvement of all stakeholders in the operational phase
Well being and recreation	

5.2.3 Local Community

Seven people representing the most important environmental and citizen associations have been contacted and interviewed.

Today, citizens recognize the value that these works provide in terms of environmental and landscape quality and are excited about the availability of new natural areas for recreation. They remarked the importance of the creation of a network of pedestrian/cycle paths to connect the whole region. However, it has to be underlined that not all the NBS constructed in the area are interesting for recreation: only the large wetlands or woods equipped for visitors are considered by the interviewed people.

According to a WWF volunteer involved in environmental education in the area, the possibility of doing recreational activities has raised residents’ awareness and interest towards the importance and role of NBS, as well as on the importance and value of natural areas. At the very beginning citizens did not appreciate that the area where not always accessible and regulated, but over time people embraced it and started to consider places from a fresh standpoint.

Several people have been visiting the areas equipped for visitors for years:

1. Schools of different order and grade: several guided tours have been organised and their frequency has increased over time. Schools have benefited from environmental education funding up to 5 years ago, since then they have slightly decreased. However, the trend is still positive. The creation of natural areas have been highly appreciated by schools as they represents the only few examples of what the natural environment was like before the 1950s;
2. Citizens frequenting the areas for simple enjoyment natural areas: NBS created pleasant natural environments and residents are now using the area for recreation (walking, biking, fishing). This is a great value for them, in an area otherwise dominated by monoculture;

3. Citizens frequenting the areas with great naturalistic awareness, with particular passion of nature photography and bird watching. This category has increased exponentially in recent years.

Asked if the recreational activities did generate significant improvement in terms of economy and labour opportunity, the WWF volunteer declared to have no direct information about that but most of the work was volunteer: the effect in terms of economy and labour occupation could be considered negligible.

According to the interviews with some representative citizens, the main conflicts related to the NBS are related to:

- the fragmentation in the ownership of the river/channel banks: it should be noted that some interventions have been conducted out only on private lands (so that there is simply one passage easement for the Drainage Authority). Therefore some areas are definitely not accessible to the public. This sometimes generates problems with the citizens that do not fully understand the situation;
- the spontaneous return of some invasive animal species. In fact, coypus (small aquatic rodents native of South America and now spread throughout all Italy) have been observed, especially in protected areas. Differently, the potential presence of mosquitoes or other insects does not represent a problem.

SOCIAL VALUES	**IMPACTS**
Awareness/ Educational	The creation of natural areas has been highly appreciated by schools as they represents the only few examples of what the natural environment was like before the 1950s. Several guided tours have been organized in the oasis areas and their frequency has increased over time. Schools have benefited from environmental education funding up to 5 years ago, since then they have slightly decreased. However, the trend is still positive. According to WWF, an average of 12-13 classes/year participates in guided tours (data relating to 1 large NBS equipped for visitors), mainly from local schools or from neighbouring municipal districts. Each class is generally composed of about 22 children.
Reduce flood risk	
Visual Impact	In general, there is a better perception of the areas from an aesthetic and environmental point of view, also in terms of quality of water and increase in biodiversity.
Nuisance (odours, noise, presence of insects, obstacles to common farming and citizen practises)	Fragmentation and partial accessibility to the river banks, as they remain often private. Spontaneous return of some invasive animal species as foxes and nutria have been observed, especially in protected areas.
Well-being and recreation	Bike and pedestrian trails have been constructed and residents can now use new areas where the old natural ecosystems have been recreated. Birdwatchers and passionate about nature photography has increased in recent years. An average of 30 visitors/day frequents the areas in the weekend, with peaks of in springtime. In addition to regular local visitors, several come from other Provinces (e.g. Treviso, Bassano ad Padova), and even from different regions, including Friuli and Trentino. An increase in tourism linked to carp fishing has been noted as well.

5.3 Analysis of the impacts

Considering the data obtained from the available literature and the interviews carried out, the following **Table 38** outlines the main results of the social impact analysis.

Table 38. Analysis of the social impacts of the NBS

SOCIAL VALUES	Potential OUTCOMES	INDICATOR	Results	Judgment
Awareness/Educational	Research opportunities for educational purpose; awareness and greening activities; scientific dissemination and communication	Organization of events for education and dissemination on NBS	According to the main environmental associations, schools of different order and grade have been involved in educational projects. Several guided tours have been organised in the oasis areas and their frequency has increased over time. Schools have benefited from environmental education funding up to 5 years ago, since then they have slightly decreased. However, the trend is still positive. According to WWF, an average of 12-13 classes/year participates in guided tours (data relating to 1 protected area), mainly from local schools or from neighbouring municipal districts. Each class is generally composed of about 22 children. Considering the 3 oasis on the area, more than 800 children visit the areas every year. The creation of natural areas have been highly appreciated by schools as they represents the only few examples of what the natural environment was like before the 1950s. Consorzio Acque Risorgive organises and manages environmental education projects in schools, with an amount of 44 classes every year with the elaboration of a final reports. Organization with Anbi Veneto of an annual regional event of environmental education. Scientific dissemination through the elaboration and publication of scientific papers on nature-based diffuse pollution control solutions, participation in congress, workshop and technical events. Winner in 2017 of two prestigious awards: Smau 2017 and Ecomondo. Hosting of 2 visiting researcher from Rural Research Institute of South Korea, to learn the NBS approach of Acque Risorgive. Communication of projects and activities through the website, newsletters and brochures.	High
Flood risk reduction			Before implementation, intense precipitations would have caused overflowing of rivers and channels and flooding events. According to the interviews to the Consorzio di Bonifica and to the farmers' associations, after the implementation of NBS, precipitations with equal intensity do not cause such phenomena anymore in the areas located downstream the interventions..	High
Visual impact	Improved aesthetic quality of the landscape	Conservation/change of the landscape	Following the construction of NBS, there is generally a better perception of the areas from an aesthetic and environmental point of view, also in terms of quality of water and increase in biodiversity	Medium

SOCIAL VALUES	Potential OUTCOMES	INDICATOR	Results	Judgment
Nuisance	Mitigation of Odour; mitigation of Noise; Presence of insect; Obstacles to farming and citizens practises	Odour	Not observed	-
		Noise	During the implementation phase, some residents complained for the annoyance (e.g. the dust lifted by the machinery).	Low
		Mosquitoes and other animals/insect	The spontaneous return of some invasive animal species. In fact, foxes and nutria have been observed, especially in protected areas.	Low
		Obstacles to farming and citizens practises	In some cases, negotiations for land aquisition posed some challenges. After implementation, there were some little problems with farmers: in some cases, trees and plants cast shadows on crops. Fragmentation and partial accessibility to the river banks has been observed and remarked by citizens.	Low
		Increased in allergies and air humidity	Not observed	-
Well-being and recreation	Improvement of recreation opportunities and health	Organization of outdoor and recreational activities	The creation of pleasant natural environments, where local inhabitants could spend time and enjoy recreational activity, is one of the most important co-benefits of the measures adopted by *Consorzio Acque Risorgive.* Bike and pedestrian trails have been constructed and residents can now using new areas where the old natural ecosystems have been recreated. In addition, a category of visitors has increased exponentially in recent years: birdwatchers and passionate about nature photography. According to some environmental and citizens associations, an average of 30 visitors/day in the weekend frequent the areas, with peaks of in springtime. In addition to regular local visitors, several come from other Provinces (e.g. Treviso, Bassano ad Padova), and even from different regions including Friuli and Trentino An increase in tourism linked to carp fishing has been noted as well. This has a great value in an area otherwise dominated by monoculture, with very little natural spaces. In general, the possibility of doing recreational activities has raised residents' awareness and interest towards the importance and role of measures, as well as on the importance and value of natural areas. Nicolas and Cuccobello sites, together with Scolo Comuna wetland are now open and thus accessible. For areas located on private properties, Acque Risorgive organizes guided tours. In addition, the wetland in Oasi Lycaena (Cave Villetta di Salzano), one of the protected areas registered as SIC, is managed by NAPEA (an environmental association) under the control of Metropolitan City of Venice. It is open by appointment.	High: 30 visitors per day per weekend

5.4 SWOT analysis

STRENGHTS	***WEAKNESSES***
Addressing two pressing environmental issues, raising at the same time environmental quality Availability of Regional funding for this type of intervention The key role of Acque Risorgive: it works as an *Utility*, providing services and supervising all the actions in the drainage basin. Internal knowledge on nature-based diffuse pollution control solutions. Medium state of awareness. Re-establishing of natural conditions with low maintenance costs (thanks to extensive interventions)	Expropriation posed challenges with farmers, especially for the compensation value Fragmentation in the regulation of the ownership of the river/channel banks: Cultural barriers. Some farmer still thinks about his own individual activity Spontaneous return of some invasive species (e.g. foxes and nutria) The river contract is still missing
OPPORTUNITIES	***THREATS***
Repeatability of the model: these types of measures can be seen as “standard” agricultural measures, and they can in principle be applied in all plain areas where intensive agriculture is practiced, with a dual objective (i) nutrient reduction and (ii) flood mitigation, while improving habitats and the environmental quality at the same time.	*Ad hoc* funding and regulatory measures are needed: *Acque Risorgive* was able to operate in the field of NBS thanks to the special support of Veneto Region and the funds obtained by the dedicated region law (Strategic Master Plan). Bureaucratic constraints.

6 QUANTIFICATION of DIRECT and INDIRECT BENEFITS

To assess direct and indirect benefits a Multi Criteria Analysis (MCA) has been proposed in the technical offer for the feasibility study, following the methodology already used to estimate the **Ecosystem Services of NBS** in the OpenNESS project (Liquete et al., 2016). Accordingly, in the technical offer, a preliminary list of criteria to be used for the quantification of the benefits has been provided (see table below), classified in 3 categories: social, environmental and economic benefits.

Benefits	**Objectives/criteria**	**Indicators**
Social benefits	Reduce flood risk	Peak flow reduction (retention volume)
	Improve people recreation and health	Number of visitors/year
Environmental benefits	Improve water quality	Yearly Reduction of (tons): • Nitrogen, • Phosphorus, • Pesticides
	Aquifer recharge	Infiltrated volumes
	Support biodiversity	Expert judgment and/or landscape diversity index
Economic benefits	Property appreciation, due to landscape improvement	€/m^2
	Economic activities linked to the use of the NBS area for recreation	Jobs/year

The list of criteria envisaged in the technical offer has to be reviewed and updated, according to the results of the analysis done and reported in the previous chapters. A review of the assessment criterion is provided in the next paragraph. The indicators used to quantify them are described in paragraph 6.2

6.1 Definition of evaluation criteria for direct and indirect benefits quantification

6.1.1 Social effects

According to the results of the social analysis (see **Table 38**) both the social criteria proposed are relevant.

The capacity to contribute to reduce **flood risk** is one important feature of NBS, which increased their acceptability, especially by farmers, the stakeholders group mostly affected by the NBS. Obviously not all NBS provide the ecosystem service of flow regulation, and the performance depend on several aspects: the intensity of flood risk in the basin, the location of the NBS and its design. A correct quantification of the flood risk reduction due to the flow regulation provided by NBS is very difficult; however the issue has to be considered, possibly using a "proxy" indicator.

For what concerns **recreation and health**, most of the NBS appear to provide a recreational service for the local population. The wetlands and the woods of the NBS are the only green "natural" spaces in the local intensively farmed landscape.

Other ecosystem services have been detected by the social analysis concerning the "family" of services recognised as "cultural services" (according to CICES 2020): the improvement of the **aesthetic quality of the landscape** and the **awareness/educational** service. The first one (aesthetic quality) is less important than other benefits according to the analysis of the social impacts. Since its quantification and prediction requires very complex methodologies that go far beyond the possibility of this study, it will be dropped off the evaluation, considering that the aesthetic value will be partially included in the "recreation" criterion.

"**Education**", according to the results of the social analysis, is an important added value provided by NBS: "*the creation of natural areas has been highly appreciated by schools as they represent the only few examples of what the natural environment was like before the 1950s*". It represents a different kind of cultural service, distinct by the "recreation" one, so it deserves to be included among the evaluation criteria.

6.1.2 Environmental effects

The main environmental benefits of the analysed NBS are the **improved water quality** thanks to diffuse pollution control. According to the analysis done in chapter 3 this benefit will be assessed and quantified by the amount of pollutant removed (or expected to be removed) per year.

The NBS proposed have no significant effect in terms of **aquifer recharge**, and therefore this criterion will be dropped off the evaluation process.

For what concerns **biodiversity**, the positive effects of newly created NBS in intensive agriculture landscapes is well known (Herzon and Helenius 2008; Gibbs, J. P. 2000. González et al. 2016; McCracken et al 2012; Strand and Weisner 2013). According to the cited references the benefit for biodiversity of wetlands is higher compared to buffer strips, since they creates habitats for important species (insects, amphibians, birds) strictly linked to aquatic ecosystems; habitats that have been heavily damaged and reduced in the past 150 years, by the land reclamation practice. Wooden buffer strips contribute to biodiversity thanks to the "ecotone" effect, while the positive effects of herbaceous buffer strips are nearly negligible.

Of the four NBS object of the present study, there are information available on the species and habitat of European interest only for 2 of them: the Salzano and the Nicolas sites. No quantitative monitoring has been done, but in both sites census of existing species of interest, from the conservation point of view, are periodically done.

The Salzano site is a large newly created wetland surrounded by a wood: an ideal condition to host interesting habitats and be colonized by plants and animals. That is why after a few years it has been identified as Special Conservation Zone according to the habitat Directive. In the following table the list of species and habitats of community interest found in the site is provided.

Table 39. Species and habitats of community interest found in the Salzano NBS

Salzano wetland (IT3250008)
Species of Community Interest (Annex II)
Amphibians
Hyla intermedia
Triturus carnifex
Reptiles
Emys orbicularis

Salzano wetland (IT3250008)
Arthropods
Lycaena dispar
Habitat of Community Interest (Annex II)
3150
6430
Bird species of *Annex* I of the *Birds Directive*
Alcedo atthis
Circus cyaneus
Egretta garzetta
Ixobrychus minutus *Lanius collurio*
Nycticorax nycticorax

The Nicolas site, is now a large wood crossed by a dense network of water ditches. Even though it has not been included among the sites of community interest according to the Habitat directive, some interesting species have been found in the site (see table below).

Table 40. Species and habitats of community interest found in the Nicolas NBS

Species of Community Interest (Annex II)
Amphibians
Hyla intermedia
Rana latastei
Triturus carnifex
Reptiles
Emys orbicularis

The criterion "biodiversity" will then be considered in the evaluation process, through an "expert judgment" approach.

6.1.3 Economic effects

The two possible economic benefits considered in hypothesis before the analysis appear not to be significant: in facts the NBS analysed are located far from residential property and therefore no **property appreciation** could have been recorded, due to landscape improvement. Similarly, the use of the NBS area for recreation is not so continuous and intensive to allow the set-up of new **economic activities**. Therefore, both the criteria will be dropped off the evaluation process.

However, the economic effects of NBS will be considered in the evaluation not as "benefits" but as "costs". Beside the **investment** and **Operation and Maintenance** costs, the "opportunity cost" of the use of productive farming land for the NBS (the criterion **loss of farmland income**) will be taken into account.

6.2 Prediction of the effects: quantification of criteria

Even though, as already said in the previous paragraph, in the present study there are no alternatives to be compared, and consequently a genuine MCA has not been made, nevertheless a multi-criteria (or multi-attribute) approach has been used: such approach involves the selection of appropriate indicators to quantify the benefits or the negative effect of the NBS. Since the analysis of benefits has been scaled up to the two sub-basins mostly interested by NBS in the area managed by the Consorzio di Bonifica Acque

Risorgive, the quantification also attains the whole system of NBS created in the last 20 years.

6.2.1 Flood risk

The capacity of NBS for diffuse pollution control, and in general of sparse wetland (the so-called geographically isolated wetland) to contribute to reduce flood risk, was a matter of discussion within the Scientific community. A number of recent works (e.g. Salazar et al., 2012; Acreman and Holden, 2013; Lane et al., 2018) have actually helped clarifying the role of NBS on this side benefit. Substantially, it is true that wetlands or buffer strips, if properly designed, are able to provide significant additional retention volumes. On the other hand, the provided additional volume is significant only for frequent rain events (return time maximum 2-5 years), i.e. of scarce relevance for extreme events (return time >30 years) usually targeted in flood protection policies[15]. This does not mean that NBS designed for flood protection cannot be multipurpose: for instance, big retention basins for flood protection can include a wetland inside for nutrient removal from the low flow of the river. However, this is not the scale and the target of the NBS here proposed; since they aim at intercepting diffuse pollution within the catchment, NBS need to be as much widespread as possible. Accordingly, NBS here proposed for diffuse pollution control can give some interesting benefits to farmer in terms of flood risk, reducing the disadvantages driven by rain event with low return time; for this reason the flood risk benefit is not excluded from the proposed analysis.

On the basis of the previous consideration, a full hydrological-hydraulic model is not significant for the scope of estimating the flood risk benefits of the proposed NBS. Therefore, we will use a "proxy" indicator to estimate the effects of NBS in term of flood risk reduction: the additional storage volume available thanks to the NBS. Since detailed information on the storage volume for each of the analysed NBS is not available, a simplified approach has been used. We have estimated that during high flow the water level in all the NBS could increase by 1 metre, retaining 1 cubic metre for each square metre of NBS. In order to estimate the relevance of this additional retention volume, the total retention volume is discussed considering the catchment area of the watershed basin. Therefore, the retention volume is calculated in terms of mm and m3/ha, considering both the gross watershed (37.8 ha) and the equivalent impervious watershed, assuming a runoff coefficient in line with the agricultural field (0.4, the value considered for Rusteghin watershed - 15.1 ha).

6.2.2 Recreation

Considering the results of the social analysis that highlighted the importance of the NBS for the local population, to quantify the effect we focused on the potential NBS accessibility (one of the key criteria to assess cultural services according to Church et al.2017).

Considering that not all the NBS can be accessible for recreation, a selection of those usually frequented by the local population has been done. According to the information provided by the Drainage Authority, most of the NBS are accessible, including those that are surrounded by private areas, with the exception of 4 areas: Nodo Carmason, Scolo Rusteghin (both the wetland and the buffer strip), Alto corso Fiume Zero.

To estimate the recreational potential of the NBS, the resident population living in a range of 1 km (walking/cycling distance) from the centre (identified roughly) of the NBS has been calculated using the georeferenced database of population available on the Regione Veneto Geoportal (possible overlapping of the ranges between two or more NBS has not been considered).

[15] For instance, the EU Floods Directive 2007/60/EC requires the identification of flood hazard maps for three scenarios: P1, low probability; P2, medium probability; P3, high probability. The most frequent flood scenario, i.e., it's commonly identified with a return time equal to 30 years in Italy, which is out of the range of effectiveness for the NBS targeted by this study.

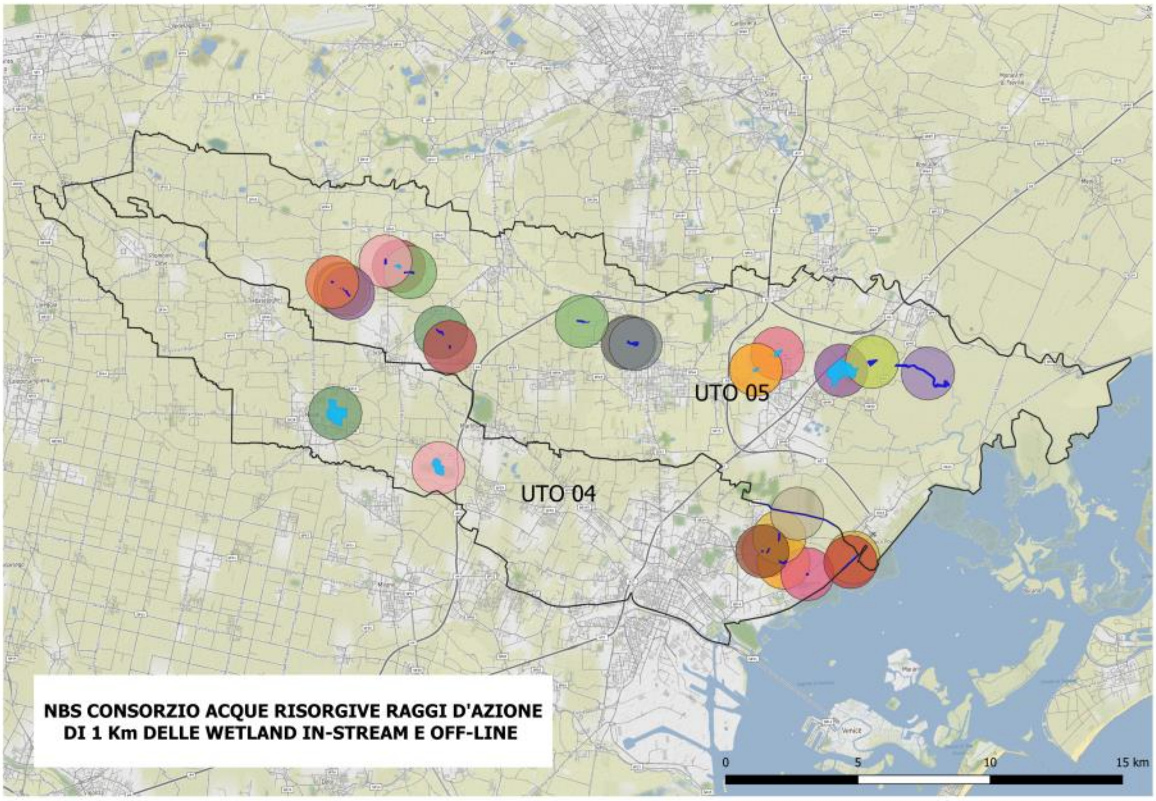


Figure 26. Areas in the range of 1km from the wetland defined as used for recreational activities by the Drainage authority.

So the indicator used to quantify the criterion recreation is: number of people living in a range of 1Km from the NBS (potential recreation users).

6.2.3 Education

According to the information collected through the social analysis the Drainage Authority itself is responsible of educational activity: such activities involved last year 44 school classes and take place in 14 of the 23 NBS listed in **Table 45**. Besides that, according to the social analysis, WWF organises in the Noale NBS 12 educational tours per year with groups by 22 pupils. Since WWF manages 3 of the 23 NBS we may estimate that the same amount of educational tours take place in each of them, for a total number of 36 groups by 22 pupils per year. Thus, the educational service provided by the NBS has been assessed through an estimation of the number of pupils involved yearly in educational activity: 80 groups with an average number of 22 pupils for group, 1760 pupils per year.

Data concerning the number of students frequenting the NBS for educational purposes are not available. According to the information collected through the social analysis the Drainage Authority itself is responsible of educational activity: such activities involved last year 44 school classes and take place in 14 of the 23 NBS listed in Table 28. Two of the NBS (Oasi di Noale and Oasi Salzano) are managed by NGOs dealing with environmental education that use them for educational purposes (not involving the Drainage Authority).

Thus, the educational service provided by the NBS has been assessed through expert judgment with an ordinal value function, orientation positive, expressed by an indicator ranging between 0 and 2, as follows:

Intensity of effect (from worst to best performance)	Scores
NBS not used for educational purposes	0
NBS used for educational purposes by the Drainage Authority	1
NBS used for educational purposes by the Drainage Authority and by NGOs	2

6.2.4 Water quality

NBS contribute to improve water quality. In this analysis, the pollutants considered are: total nitrogen (TN); total phosphorus (TP); sediment, considering the pollutant parameter TSS as a "proxy", to have an analogy between wetland and buffer strips; pesticides, considering glyphosate removal as a "proxy", in agreement with the literature analysis provided in section 3.2. The methodology for water quality estimation is reported in the following sections.

Wetlands

The criterion used is to define an areal removal value for wetlands based on the NBS analysed in this report. Average values, according to the estimated ones in section 3.2.1, have been assumed for Rusteghin and Salzano, i.e.:

— Rusteghin: TN **93.1** $\mathbf{g_N\ m^{-2}\ y^{-1}}$, TP **7.8** $\mathbf{g_P\ m^{-2}\ y^{-1}}$, TSS **650** $\mathbf{g_{TSS}\ m^{-2}\ y^{-1}}$.

— Salzano: TN **20.5** $\mathbf{g_N\ m^{-2}\ y^{-1}}$, TP **1.1** $\mathbf{g_P\ m^{-2}\ y^{-1}}$, TSS **200** $\mathbf{g_{TSS}\ m^{-2}\ y^{-1}}$.

Average values between Rusteghin and Salzano have been chosen to estimate the areal removal performance of other wetlands within the UTO 4 and UTO 5 watersheds with a surface smaller than Salzano wetland, i.e. **56.8** $\mathbf{g_N\ m^{-2}\ y^{-1}}$ for TN, and **4.4** $\mathbf{g_P\ m^{-2}\ y^{-1}}$ for TP, and **425** $\mathbf{g_{TSS}\ m^{-2}\ y^{-1}}$. Extensive and more natural-like area, such as Oasi Noale, have been assumed with a removal efficiency equal to the value observed for the Salzano wetland.

Values and relative methodology concerning the areal **removal of pesticides** estimation in constructed wetlands are displayed in section 3.2.1. Glyphosate+AMPA removal is taken as "proxy" of pesticide removal. Chosen parametric data are summed below:

— Rusteghin: Glyphosate **0.57** $\mathbf{g\ m^{-2}\ y^{-1}}$

— Salzano: Glyphosate **0.20** $\mathbf{g\ m^{-2}\ y^{-1}}$

Average values between Rusteghin and Salzano have been chosen to estimate the areal removal performance in terms of pesticides removal of other wetlands within the UTO 4 and UTO 5 watersheds

Buffer strips

Two types of buffer strips are present in the analysed watershed:

— Buffer strips associated with river widening (as Scandolara)

— Wooden buffer area, with the unique NBS system of type being represented by the Nicolas site

Areal removal efficiencies of wooden buffer area have been chosen in agreement with removal estimated in section 3.2.1. Particularly, the mass load removals, measured under normal conditions (i.e. 2001, 2002), have been taken as reference value, assuming a TN removal equal to **2.2 tN/y** for the whole surface of the Nicolas site, equal to about 30 hectares. This value corresponds to about 6 g/m2/y, i.e. the most conservative value observed during the monitoring of the Nicolas site.

Scandolara presents some unique features (high groundwater flow, very permeable soils) which led to very high nitrogen removal efficiencies in comparison to similar installations, as visible in **Table 22**. In terms of areal removal efficiency, Scandolara has shown a removal of TN equal, on average, to **22.5 g m^{-2} y^{-1}** (elaborated from efficiency reported in section 3.2.1). The assumption of this value to all the buffer strips of the UTO 4 and 5, without an analysis of hydrogeologic characteristics for each buffer strip, could lead to an overestimation of total N removal at watershed scale. Therefore, the removal of other buffer strips of the watershed have been estimated averaging the value of Scandolara with those monitored from other similar buffer strips, taking as reference the MO.NA.CO project (Gumiero et al., 2015; Gumiero and Boz, 2017). Data are summarised in **Table 41**, and the mean areal removal of TN has been chosen for other buffer strips of the UTO 4 and UTO5, i.e. equal to **10.2 gN $m^{-2}y^{-1}$**.

Table 41. Summarisation of areal removal of buffer strips considered to define water quality benefits of buffer strips for the UTO 4 and 5 watershed

	TN Areal removal of buffer strips [g m^{-2} y^{-1}]
Scandolara	22.5
Diana FT1	4.8
Torma	6.0
Fagna FT1	7.5
Average	**10.2**

Areal removal values glyphosate+AMPA, TP and TSS estimated in the section 3.2.1 have been taken as reference values for the estimation of the water quality benefits of buffer strips. Data of areal removal are showed below:

Pesticides:

— Buffer strips: Glyphosate+AMPA **0.017 g m^{-2} y^{-1}** (as Scandolara)

— Wooden buffer area: Glyphosate+AMPA **0.035 g m^{-2} y^{-1}** (as Nicolas)

TSS and TP:

— Buffer strips: TSS **6608 g m^{-2} y^{-1}**, TP **2.9 g m^{-2} y^{-1}** (as Scandolara)

— Wooden buffer area: TSS **168 g m^{-2} y^{-1}**, TP **1.2 g m^{-2} y^{-1}** (as Nicolas)

6.2.5 Biodiversity

As already said, the newly established ecosystems created by NBS create new habitat of interest for many species. Moreover, wetland habitat is the most important for biodiversity in the study area, for the loss of wetlands occurred in the past centuries due to land reclamation.

For what concerns buffer strips, we have to consider that all the BS object of the present study are wooded riparian corridors and that the originally artificial water course section has been reshaped to create new undisturbed habitat along the ditch. If you see **Figure 10**, this kind of BS create a 9 metres large strip of new semi-natural habitat (from the first tree line to the ditch banks) that could play a similar ecological role of the wetland habitat, at least for plants, insects, amphibians and reptiles.

Based on such considerations, we can quantify the capacity of NBS to support biodiversity using as a proxy the NBS area (extension of newly created natural habitat).

6.2.6 Investment costs and O&M costs

The investment costs[16] for wetland are assumed equal to the average of costs obtained for Rusteghin (39.1 €/m^2, **Table 27**) and Salzano (11.4 €/m^2, **Table 25**) at 2018, i.e. **25.2 €/m^2**. Similarly, O&M parametric costs are taken equal to the average of costs obtained for Rusteghin and (0.06 € m^{-2} y^{-1} and 0.02 m^{-2} y^{-1}, respectively; section 4.3), i.e. **0.04 €/m^2.** . Extensive and more naturalistic area, such as Oasi Noale, have assumed with investment costs equal to the lower value observed for the Salzano wetland.

Two types of buffer strips are present in the analysed watershed:

- Buffer strips associated with river widening (as Scandolara)
- Wooden buffer area, with the unique NBS system of type being represented by the Nicolas site

Investment and O&M costs of wooden buffer area have been chosen in agreement estimated value for Nicolas, i.e. **3.1 € m^{-2}** (**Table 29**) and **0.26 € m^{-2} y^{-1}**, respectively.

Differently from common implementation of buffer strips, the Acque Risorgive drainage authority decided to do river widening of channel in which new buffer strips are sited. Therefore, the Scandolara investment cost, higher if compared to conventional buffer strips (see section 4.3), is used as reference to define the parametric investment cost of all the buffer strips with river widening within the UTO 4 and 5, assuming **38 €/m^2**. Also O&M estimated for Salzano are used to define the parametric O&M cost for all the buffer strips with river widening within the UTO 4 and 5, assuming **0.17 € m^{-2} y^{-1}**.

6.2.7 Loss of farmland income

Loss of farmland income was assessed considering an estimation of the income per hectare of arable land of 1500 €. Such evaluation is based on the data used for the compensation for loss income used by the Rural Development Plan of Veneto Region.

[16] The criterion used to define the investment costs for wetlands and the buffer, is to define an average investment €/m^2 cost, based on the economic framework (i.e. cohomprehensive of working costs, land acquisition, services) of the NBS analyzed in this report. Indeed, the aim is to give a whole investment costs for the NBS of the watershed UTO 4 and 5, and not only the cost for construction of NBS (i.e. the cost reviewed in section 4.3).

6.3 Comparison among the 4 NBS by MCA

In the next tables and graphs the results of the MCA are reported. The 4 NBS are analyzed as "alternatives" together with the alternative "do nothing". The relative importance of the assessment criteria (the "weights" of **Table 42**) were assigned by the experts considering the main objective of the "Piano Direttore" (reduce the nutrient load to the Venice Lagoon) and the results of the social analysis: the higher weight was given to the nutrient removal capacity and to the costs minimization. Lower weights were assigned to flood reduction and other pollutant removal capacity and even lower to the other ecosystem services.

Table 42. Weights given to the assessment criteria

Criteria	**Relative importance** (range: 1-10)	**Weight**
Reduce flood risk	8	0.10
Use for recreation	6	0.07
Use for education	6	0.07
Contribute to water quality - TN removal	10	0.12
Contribute to water quality - TP removal	10	0.12
Contribute to water quality - Sediment removal	8	0.10
Contribute to water quality - Pesticide removal	8	0.10
Support biodiversity	5	0.06
CAPEX	10	0.12
OPEX	10	0.12
Total	**81**	**1.00**

The "effects matrix" (**Table 43**) reports the performance of each alternative quantified according to each criterion and indicator, while the "Assessment matrix" (**Table 44**) reports the performance of each alternative normalized between 0 and 1 and weighted.

The effect matrix shows that the 4 NBS have different performances with reference to the different criteria. Tha Salzano wetland has te best performances in terms of flood prevention, recreation, education but is weaker than the others for what concerns pollution removal, despite its large area. Buffer strips are quite effective in all pollutant removal capacity, but Rusteghin wetland has the highest performance on the most important pollutant (Nitrogen). A expected, the two larger NBS (Salzano and Nicolas) have the higher performance in terms of biodiversity support.

Table 43. Effects Matrix

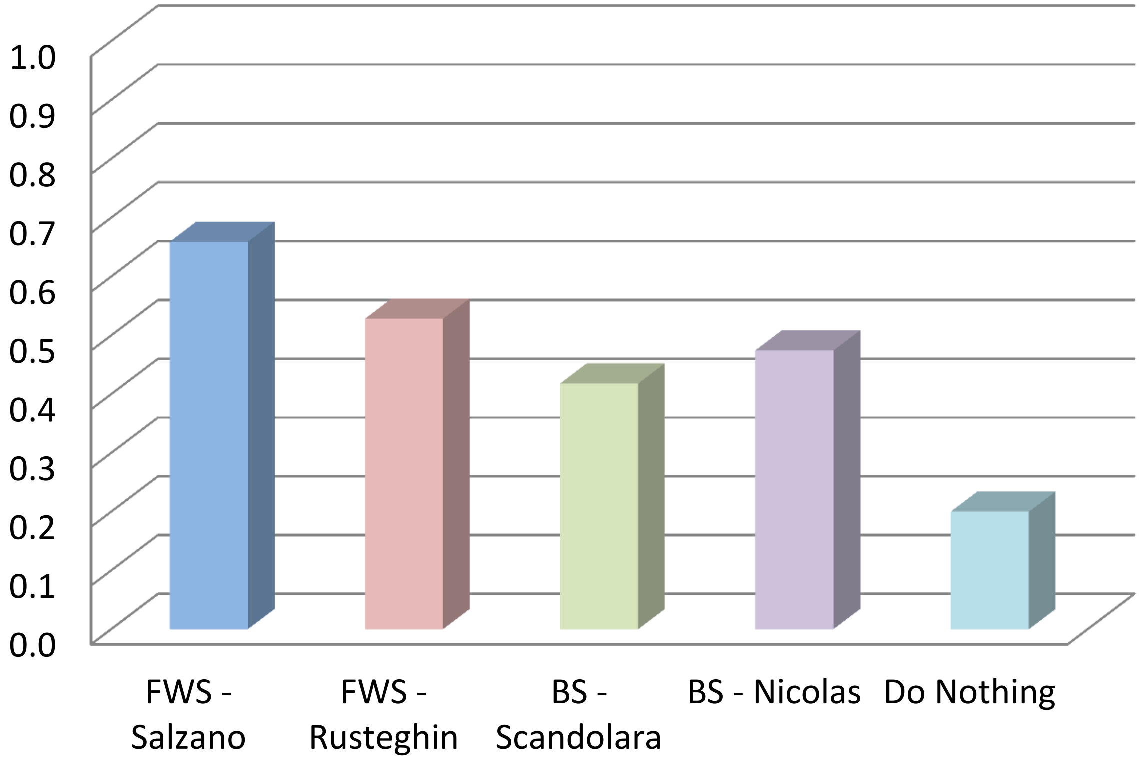
	Indicators			Alternatives				
Criteria	**Unit**	**Type**	**Orient.**	**FWS - Salzano**	**FWS - Rusteghin**	**BS - Scandolara**	**BS - Nicolas**	**Do Nothing**
Reduce flood risk	m3	Tipo: cardinale indicatore continuo su asse reale	↑	172654	38151	75199	0	0
Use for recreation	no. Inhabitans	Tipo: cardinale indicatore continuo su asse reale	↑	2404	0	0	0	0
Use for education	Expert judgement	Type: binario (discreto) x_{Nm} = 0; NBS not used for educational purposes xNm = 1; NBS used for educational purposes by the Drainage Authority xNm = 2; NBS used for educational purposes by the Drainage Authority and by NGOs	↑	2	1	1	1	0
Contribute to water quality - TN removal	tonN per year	Tipo: cardinale indicatore continuo su asse reale	↑	1,47	3,62	1,69	2,20	0,00
Contribute to water quality - TP removal	tonP per year	Tipo: cardinale indicatore continuo su asse reale	↑	0,08	0,29	0,22	0,38	0,00
Contribute to water quality - Sediment removal	tonTSS per year	Tipo: cardinale indicatore continuo su asse reale	↑	14,32	26,71	496,92	53,31	0,00
Contribute to water quality - Persicide removal	ton glyphosate per year	Tipo: cardinale indicatore continuo su asse reale	↑	0,020	0,022	0,002	0,017	0,000
Support biodiversity	ha	Tipo: cardinale indicatore continuo su asse reale	↑	21,6	3,8	10,6	31,7	0,0
CAPEX	€	Tipo: cardinale indicatore continuo su asse reale	↓	2462400	1368847	4041166	983676	0
OPEX	€/year	Tipo: cardinale indicatore continuo su asse reale	↓	3482	2046	18079	82502	0

Table 44. Assessment Matrix

Criteria	Alternatives				
	FWS - Salzano	FWS - Rusteghin	BS - Scandolara	BS - Nicolas	Do Nothing
Reduce flood risk	1,00	0,22	0,44	0,00	0,00
Use for recreation	1,00	0,00	0,00	0,00	0,00
Use for education	1,00	0,50	0,50	0,50	0,00
Contribute to water quality - TN removal	0,40	1,00	0,47	0,61	0,00
Contribute to water quality - TP removal	0,21	0,75	0,57	1,00	0,00
Contribute to water quality - Sediment removal	0,03	0,05	1,00	0,11	0,00
Contribute to water quality - Persicide removal	0,92	1,00	0,09	0,77	0,00
Support biodiversity	0,68	0,12	0,34	1,00	0,00
CAPEX	0,39	0,66	0,00	0,76	1,00
OPEX	0,96	0,98	0,78	0,00	1,00

In the following figure the final ranking of the compared alternatives is reported. Scandolara wetland, despite its low performance in pollution removal, shows the highest ranking, thanks to its capacity to provide several ecosystem services, followed by Rusteghin wetland, Nicolas and Scandolara buffer strips. The alternative "do nothing" is by far the least performing, showing that the cumulative benefits of the 4 NBS are more important than their costs.

Figure 27. The final ranking of the performances of 4 NBS considering all the assessment criteria.



6.4 Costs and benefits at basin scale

The MCA shows that different kind of NBS provide different Ecosystem services and that increase the performance of one service generally entails a reduction of the performance of another service (e.g. optimizing the pollution removal capacity decrease the capacity to support biodiversity). Beside the comparison of the 4 NBS object of the study is interesting, to scale up the analysis and to estimate costs and benefits of all the NBS implemented by the Consorzio di Bonifica Acque Risorgive in the two sub-basins objext of the present study (UTO 04 and 05, see **Figure 3**) providing a multicriteria Costs Benefits Analysis using a "value transfer" approach to monetize the value of "non monetary" criteria. The existing NBS in the two sub-basins are listed in **Table 45**.

Table 45. List of the existing NBS in Sub-basins UTO 4 and 5. Bold and underscored the 4 NBS analysed in the previous chapters

NAME OF THE PROJECT	NBS CATEGORY	UTO	Total area of the NBS [m^2]	Nutrient removal area [m^2]
Oasi Noale – Rio Draganziolo	wetland off – line	4	434,094.18	434,094.18
Collettore di Favaro	in-stream wetland	4	12,694.72	12,694.72
	BS associated to river widening	4	21,974.88	17,824.88
Fossa Pagana	in-stream wetland	4	32,267.40	29,361.40
	BS with river widening	4	17,140.39	12,982.47

NAME OF THE PROJECT	NBS CATEGORY	UTO	Total area of the NBS [m²]	Nutrient removal area [m²]
Forte Bazzera	wetland off – line	4	4,650.66	4,650.66
Golena Draganziolo	BS associated to river widening	4	13,130.02	10,630.02
Scolo Roviego	BS associated to river widening	4	21,965.96	21,082.27
Oasi Salzano	wetland off – line	4	172,654.07	172,654.07
Scolo Rio Storto	BS associated to river widening	4	8,056.99	5,628.99
Nicolas	woody buffer area	5	317,314.77	
Basso corso Fiume Zero	BS associated to river widening (embanked river)	5	249,085.91	85,000.00
Lago Pojan Fiume Zero	in-stream wetland	5	46,516.61	29,436.61
Cave di Gaggio (ex cave cavalli)	wetland off – line	5	593,845.95	593,845.95
Nodo "Carmason"	in-stream wetland	5	186,650.68	142,282.68
Scolo Zermason	wetland off – line	5	59,409.53	59,409.53
Rete di Bonifica Dese Zero SCANDOLARA	BS with river widening	5	216,000.00	75,199.36
Rete di Bonifica Dese Zero – other	in-stream wetland	5	66,171.63	60,129.46
	wetland off – line	5	18,889.36	18,889.36
Scolo Rusteghin	in-stream wetland	5	38,151.11	38,151.11
Scolo Rusteghin- other	BS associated to river widening	5	2,414.84	2,664.00
Scolo Zeretto	in-stream wetland	5	17,589.34	15,589.34
Alto corso Fiume Zero	BS associated to river widening	5	38,898.62	17,340.00
TOTAL			**2,523,260**	**1.859,541.06**

6.4.1 Estimation of costs and benefits at basin scale

To figure out the "cumulative" effects of all the 23 NBS implemented by the "Consorzio Acque Risorgive" on the two sub-basins UTO4 and UTO5, in the following table the performance of all the NBS is summarized, using the same criteria described in paragraph 6.1 and the indicators described in paragraph 6.2, with the exception of the indicator used to quantify the "education" ecosystem service, for which an estimate of the number of pupils that could benefit from the service has been attempted[17].

Table 46. Synthesis: criteria and indicators and ecosystem service evaluation

Objectives/criteria	**Indicators and units of measure**	
Reduce flood risk	Peak flow reduction (retention volume)	1,758,487 m3
Use for recreation	Accessibility: number of people leaving in a range of 1 Km from the NBS (potential recreation users)	21,322
Use for education	Number of pupils involved in educational activity per year	1760 n°/y
Contribute to water quality	Nitrogen removal:	48 tN/year
	Phosphorus removal:	3.8 tP/year
	Sediment removal:	2065tTSS/year
	Pesticide removal:	0.37 tglyphosate+AMPA/year
Support biodiversity	Extension of newly created natural habitat	2,523,260 m2
CAPEX	€	45,968,183 €
Annualized CAPEX*	€/year	1,532,273
OPEX	€/year	147,281.60 €/year
Loss of farmland income	€/year	378,489.00 €/year

* The total amount of investment costs divided 30 years. 30 years lifetime has been observed for wetlands systems designed by IRIDRA, however wetland lifetime could be higher than 30 years; thus the estimation has to be considered very conservative.

[17] According to the information collected through the social analysis the Drainage Authority itself is responsible of educational activity: such activities involved last year 44 school classes and take place in 14 of the 23 NBS. Beside that, according to the social analysis, WWF organises in the Noale NBS 12 educational tours per year with groups by 22 pupils. Since WWF manages 3 of the 23 NBS we may estimate that the same amount of educational tours take place in each of them, for a total number of 36 groups by 22 pupils per year. Thus, the educational service provided by the NBS has been assessed through an estimation of the number of pupils involved yearly in educational activity: 80 groups with an average number of 22 pupils for group, 1760 pupils per year.

The cumulative effect of the 23 NBS is discussed in paragraph 6.5. To better comprehend the value of the ecosystem services provided by the 23 NBS, a monetization exercise has been attempted, described in the next paragraph.

6.4.2 Monetization of ecosystem services by value transfer

The economic valuation of NBS (Wetland and Buffer strips) benefits have followed a detailed procedure: a summary of the method is included in this chapter but a more detailed methodological explanation of all the steps involved can be found in ANNEX 4.

First of all, a literature review has been carried out with the aim of recognizing the most common benefits (Ecosystem Services) deriving from wetland and buffer strips implementation. We have identified 19 benefits which have been filtered out to select the most appropriate ones in the rural context. Only for the selected environmental and social benefits (9 categories out of 19), a research on existing economic valuation methods has been carried out, to proceed with the Value Transfer (VT). In this report we only present the results concerning the 5 "non economic" criteria selected and listed above (flood risk, recreation, education, water quality, biodiversity).

Value transfer (VT) is an economic valuation method which can be applied to ecosystems, or goods and services from an ecosystem. VT provides empirical estimates of the subject of interest, when time, funding or other constraints prevent the use of primary research to generate these estimates. Indeed, it allows extrapolating research results of pre-existing primary studies at one or more *study sites* allowing an indirect estimation of the value of some characteristics of similar unstudied *policy sites* (Rolfe *et al.*, 2015). Among the four available VT techniques we decided for Adjusted Unit Value Transfer.

The study sites, collected as candidates, have two characteristics: they are located in regions with socio-economic characteristics similar to Italy (IT, EU, North America) and they focus on environmental goods and services relevant for the policy site.

Economic values resulting from this dataset have been adjusted to account for inflation, to control for differences in price levels, to control for the effect of income on the demand and value of ecosystem services and, finally, they have been converted to $euro_{2018}$. From the list of comparable values, candidate for the transfer, we selected the most suitable. The choice consisted on several criteria: values expressed in per hectare per year have been preferred; study sites with the most similar characteristics have been ranked; more recent studies have been prioritized.

The last step of the value transfer exercise has been the application of an additional correction factor. It is a measure of monetization reliability which allows to communicate economic transferred values as confidence intervals: the maximum value of the range is represented by the adjusted economic value before confidence level is applied (the highest value is opted for in case more than one suitable study site was selected); the minimum value of the range corresponds to the economic value after the confidence level is applied (in case of more than one study site the lowest value have been chosen). Indeed, we made a conservative choice by deciding to underestimate the original value.

In order to identify confidence levels, we developed three criteria, with associated scores.

Table 47. Criteria and associated scores for confidence level selection

	Criteria	Score	
i	Evaluation of the study site characteristics	Score: 1-5	1=weak fitness 5=great fitness
ii	Monetary valuation technique used for economic value calculation.	Score: 0-1	0=Value Transfer 1=Cost-based/direct market pricing if *per hectare* terms; Contingent Valuation/Choice experiment if *per beneficiary* terms

iii	Indicator used to quantify the magnitude of benefits	Score: 0-1	0=low reliability 1=high reliability

We applied the following confidence levels:

Table 48. Scores and associated confidence levels for monetization reliability application

Score 7	→	100% Confidence level
Score 6	→	90% Confidence level
Score 5	→	80% Confidence level
Score 4	→	70% Confidence level
Scores 3-2-1	→	50% Confidence level

Final values, transferred on policy site, are reported in **Table 49** and have been used to estimate the value given by the whole UTO 4 and UTO 5 watershed in terms of ecosystem services, summarised in

Table 50.

Table 49. Final transferred economic values for each NBS benefit

	WETLANDS			**BUFFER STRIPS**		
	Value - Confidence interval		**Units**	**Value - Confidence interval**		**Units**
FLOOD RISK	190	211	€/ha/yr	310	388	€/ha/yr
RECREATION and TOURISM	5584	6204	€/ha/yr	5441	6045	€/ha/yr
	4	8	€/person/visit	-	-	-
AWARENESS/EDUCATION	18	40	€/person/once	8	26	€/person/visit
WATER QUALITY	2959	9598	€/ha/yr	66	132	€/ha/yr
NATURAL HABITAT and BIODIVERSITY SUPPORT	448	498	€/ha/yr	29	36	€/ha/yr

Table 50. Ecosystem service monetization with value transfer method for the NBS within the UTO 4 and UTO 5 basins

Ecosystem services in UTO 4 and UTO 5 basins	Minimum ecosystem service value (€/y)	Maximum ecosystem service value (€/y)
Flood Risk	46,228	53,812
Recreation and Tourism*	964,318	1,071,388
Awareness/education	31,680	70,400
Water quality	450,582	1,456,894
Natural habitat and biodiversity support	79,676	88,868
Total	**1,572,485**	**2,741,362**

* Estimated on surface area of wetland and excluding the potential contribution of buffer strips

The ranking of values reported in

Table 50 shows the highest value for the "recreation and tourism" and for the "water quality" services. The value of the "flood risk prevention", "educational" and "biodiversity support" services is estimated 1 order of magnitude lower than the previous two.

Even considering the high value of uncertainty of this "value transfer exercise" it could be observed that the value of "water quality" (the main benefit expected by the NBS) it is most likely nearer to the maximum value than to the minimum. The value of the "recreation and tourism" is most likely overestimated even in the minimum value: the NBS of the present case study are considered interesting for recreation for local people but they are not enough attractive to generate tourism fluxes. The value of the "flood risk prevention" service it is reasonable, given the consideration on the return time of the targeted rain event, i.e. 2-5 years. The values estimated for the two services "education" and "biodiversity support" is probably underestimated, cause both the services have a great importance, that could be appreciated in the long run.

6.5 Final considerations on costs and benefits

According to estimation of the benefits provided in previous section, the NBS constructed up to now can remove nearly 50 tons per year of total nitrogen, 1/3 of the total amount of nitrogen to be removed on UTO 4 and 5 according to the "Venice Lagoon Masterplan" (150 tons/year).

The retention volume for flood risk protection corresponds to an equivalent rainfall depth spread on the watershed of about 5 mm on the gross catchment surface and 12 mm on the impervious equivalent surface, i.e. 50 m3/ha and 120 m3/ha_impervious. These values are significant for rainfall with low annual frequencies, but low if compared to the value of extreme events. Indeed, the rainfall depth for event with Tr= 2 years and rainfall duration of 5 minutes, registered by rainfall depth-return times curves for the area of interest (see ANNEX 2), is equal to about 10 mm. Therefore, the potential role of the proposed NBS on flood risk protection is confirmed only for event of low intensities.

The capital cost for the construction of the NBS amounts to 45 millions € (around 1 million per ton/year of total N removed) in around 20 years (2.25 millions € per year, considering the timespam of NBS construction and 1,5 million per year considering the annualized investment costs on a NBS lifetime estimated at 30 years). Considering the whole surface of the interested basin UTO4 and 5 (37,750 hectares) the NBS construction cost amounts to around 1,200 € per hectare.

O&M cost amounts to less than 150,000 €/year, fully acceptable for an administration (*Consorzio di Bonifica Acque Risorgive*) with a turnover of tens of millions €.

If we consider the ecosystem service monetization with value transfer method for the NBS within the UTO 4 and UTO 5 basins (

Table 50), the estimation results in an yearly value ranging between 1.5 and 2.7 millions euro, values comparable to the yearly expenditures for the sum of capital and O&M costs in the last 20 years (2,275,000 €/year).

7 BUSINESS MODEL ANALYSIS

7.1 Introduction

This chapter is dedicated to the analysis of the institutional, organizational and financial context that allowed the implementation of the 23 NBSs present in the study area. A business model canvas, developed specifically for the NBSs, was used to classify and describe all the elements of the framework.

Some weaknesses emerged from the analysis, in particular relating to the method of financing NBSs. Therefore, the study made some hypothesis of modification of the business model, evaluating the economic impact of this choice.

7.2 Business model canvas for NBS

A business model is a conceptual tool used in the market economy to help understand how a firm does business and can be used for analysis, comparison and performance assessment, management, communication, and innovation (Osterwalder and Pigneur, 2005). A business model could be defined by three main elements: the value proposition, value creation and delivery and value capture (**Figure 28**). Value creation is at the heart of any business model; businesses typically capture value by seizing new business opportunities, new markets and new revenue streams (Beltramello *et al.,* 2013; Teece, 2010). While the value proposition is typically concerned with the product and service offering to generate economic return, in a sustainable business, the value proposition would provide measurable ecological and/or social value in concert with economic value (Boons and Lüdeke-Freund, 2013). Value capture is about considering how to earn revenues (i.e. capture value) from the provision of good, services or information to users and customers (Teece, 2010).

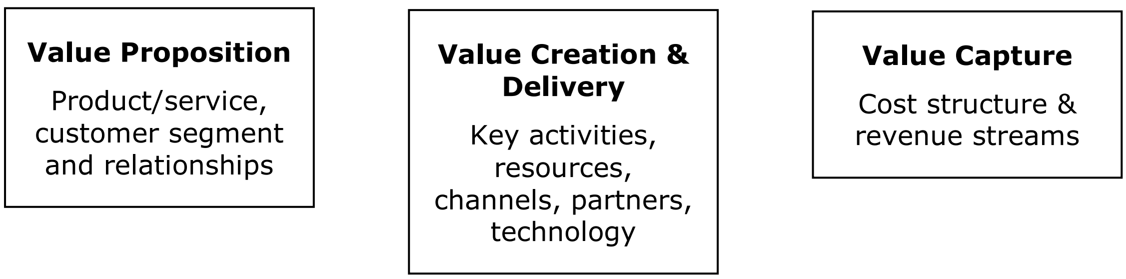


Figure 28. Conceptual business model framework. (Osterwalder and Pigneur, 2005).

Within the H2020 project Connecting Nature[18], McQuaid (2019) adapted the well-known business model canvas tool (Osterwalder & Pigneur 2010) to better capture the wider value proposition of nature-based solutions. The NBS Business Model Canvas is based on the three key building blocks showed in **Figure 28** but begins with an expansion of the value proposition (**Figure 29**). The NBS value proposition considers not just the benefits for end-users but also the broader environmental, economic and social value propositions. This is consistent with the EC definition of NBS. Value proposition remains

[18] Connecting Nature is a five year Horizon 2020 funded project which supports cities worldwide in the large-scale implementation of Nature-Based Solutions (NBS) addressing societal challenges. For more information: https://connectingnature.eu/

at the centre of the NBS Business Model Canvas but is expanded to consider the environmental, social and economic values.

The term Key Beneficiaries has been used instead of Customer Segments to broaden the consideration of possible 'Customers'. Key Partners and Key Beneficiaries have been positioned side-by-side in the NBS Business Model Canvas. This reflects the overlap that sometimes exists between partners and beneficiaries involved with NBS.

Governance is a new addition to the NBS Business Model Canvas. This reflects the importance of an early identification of the NBS construction and O&M scheme on an operational basis.

Cost Reduction is also a new addition to the NBS Business Model Canvas. This reflects the specific characteristics of NBS, which sometimes allow different ways to reduce direct costs

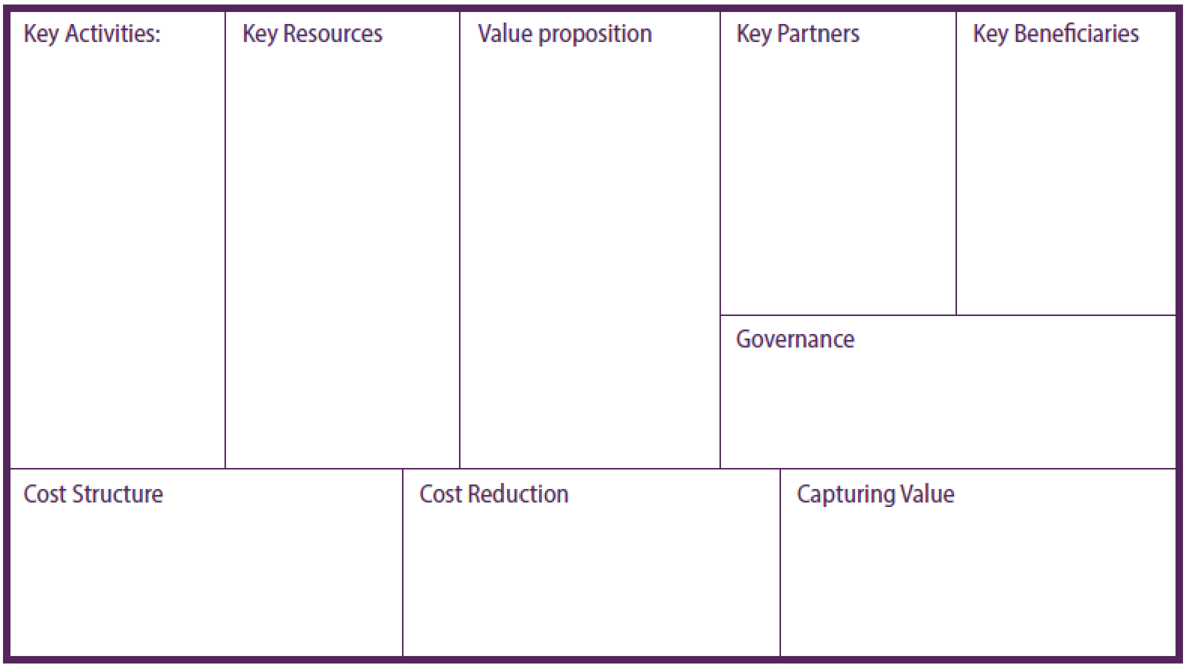


Figure 29. The Nature-Based Solutions Business Model Canvas.

Governance has been identified as one of the biggest challenges to the successful implementation of NBS. Governance in the context of NBS has been defined within Nature4Cities project as the "collective action arrangements designed to achieve the implementation of NBS". Egusquiza *et al.* (2019) identify five main clusters of governance models found in their study of 56 NBS case studies across Europe. These five clusters are summarized in **Table 51**.

Table 51. Clusters of governance models for NBS.

Cluster	**Description**
Traditional Public Administration	In the most traditional form this would include hierarchical governance structures and centralised government control of NBS but could also include measures such as participatory planning and participatory budgeting

Cluster	Description
New Public Management	NBS in this cluster are typically characterised by an emphasis on 'public-private partnerships' and the corresponding decline or 'hollowing-out' of government services.
Private-private partnerships	is a new type of governance model identified by Nature4Cities characterised by a lack of government involvement. This would include for example sole governance of the NBS by private sector or community organisations, joint community-private sector co-governance, Sustainable Local Enterprise Networks (SLEN) etc.
Societal resilience	is another type of NBS governance model characterised by a high level of community leadership in governance with a responsive, supporting, low-level role played by government
Network Governance	recognises the necessity to engage many different actors in service delivery and the complexity involved in managing such networks effectively. Collaborative and adaptive approaches to co-governance and co-management are key characteristics of this type of governance model

In order to describe better the context within the NBSs are developed, the NBS Business Model Canvas has been integrated with a new box named "Regulatory Framework" that provides the legislative and financial framing of NBS in the study specific area (Venice Lagoon).

7.3 Qualitative analysis of *ex-post* business model

7.3.1 Regulatory Framework

The special law for the protection of the Venice Lagoon is the key regulation background that allows the development of NBS in the area (see paragraph 1.2)

The funds made available by the "special Law" for Venice from 1984 until today made possible a radical action to clean up the Lagoon and its Draining Basin. Until 1991, funding was earmarked for the construction of sewers and WWTPs in 8 municipalities. From 1991 onwards, the loans were extended to the entire basin for works aimed at environmental remediation in the broad sense, that is actions aimed at limiting the effect of widespread pollution induced by agriculture and animal husbandry, to the improvement of the drainage network and the remediation of contaminated soils. The funds made available to the Veneto Region through the Special Law for Venice, on 30/06/2013, amounted to a total of 1,883.4 million euro, of which 63% destined to sewerages and WWTPs.

The actions to tackle diffuse pollution acquired more importance in the recent years, after the infrastructures to collect and treat point pollution sources were completed. Two different models to implement NBS are applied in the area. The first one is driven by public actors (the State, the Region and the Drainage Authority) and concerns larger systems. It involves the acquisition to the public property of the land where the NBS are constructed, paid with public money. O&M cost are covered by the citizens with their drainage fees.

The second one is driven by the farmers that implement – generally small extension of – NBS on their own land. They benefit of financial incentives and support through regional RDPs (Rural Development Programme, Regional plans implementing the CAP).

In the present study, only the first model has been considered, due to the fact that only the NBS constructed by the Drainage Authority have been regularly monitored and only for those NBS information on their effectiveness for diffuse pollution control is available.

7.3.2 Value Proposition

The value proposition for the NBS of the present case study could be summarized as follows:

Environmental: Diffuse pollution prevention to improve the environmental conditions of the Venice Lagoon; improved water quality of the drainage network; support to biodiversity (new aquatic and wooded habitats).

Social: Reduction of the incidence and intensity of flood events in the area; raising citizen awareness on water pollution and environmental issues; attractive recreation areas available for residents and visitors tanks to the aesthetic improvement.

Economic: New jobs created for the design, construction and maintenance of the NBS. Anyway, today this aspect is still negligible. In the future, with a view to an integrated model of NBS enhancement managed by the Metropolitan City in a common vision with the Municipalities and the Consorzio "Acque Risorgive", tourism and recreational activities have a potential for creating jobs and income. The recovery of ecological corridors through the NBS network would lead to valorization of the existing activities and to the development of new business initiatives related to service-oriented agriculture (e.g. farmhouses) and the creation of food and wine and tourist routes.

The last part of this analysis considers potential **trade-offs** between the Value Propositions: can the different value proposition generate any potential negative impact on each other?
For example, does the Economic Value Proposition generate any potential negative impact on the Environmental or Social Value propositions?
According to the results of the social analysis, the main trade-offs emerged are:

a) the creation of natural areas favored the spontaneous return of some wild species (Coypus and crows), seen as problematic by some people;
b) the land aquisition issue poses some challenges for the high costs of land;
c) noise pollution during the implementation phase.

7.3.3 Value Creation & Delivery

The **Key Activities** detected in the case study are: Land acquisition; Design and construction of NBS (some of them equipped for recreational and education activity); Maintenance of NBS and water quality monitoring; Organization of events and project for environmental education and dissemination by Consorzio Acque Risorgive and other organizations; Research on NBS performance and dissemination of results.

The **Key Resources** identified to develop the activities are: Land available for "collective" benefits (possibly accessible to the public); Special funds through Venice

Lagoon Master Plan; Internal technical expertise and skills on nature-based diffuse pollution control solutions, including the design, construction and maintenance.

The **Key Partners** are Italian government (main funder), Veneto Region, Consorzio Acque Risorgive. Environmental Association and local NGOs are an important actor to promote the NBS use for recreation and awareness raising. A minor role is played by Farmers and Municipalities, that financially contribute to NGOs educational activities.

The **Key Beneficiaries** are Venice Lagoon (and the international community), for pollution reduction; among the local communities, according to the social analysis the most relevant beneficiaries are the urban inhabitants, most interested to the use of NBS for leisure; schools and environmental NGOs showed to be interested to use the NBS for education; in a limited way also farmers did benefit of the NBS contribution to flood risk reduction.The **governance model** could be classified as a "**Network Governance**". First, the regulatory framework, designed by Venice Lagoon Master Plan, allows the Drainage Authority to play a new key role in the model working as a utility: in addition to traditional irrigation and drainage services, it provides a public utility services, it ensures a service of diffused water pollution remediation. Second, the local WWF (NGO) manages the recreation activities in wetlands becoming a "natural oasis", contributing to raise the awareness of citizen and scholars, supported by Municipality funding.

7.3.4 Value Capture

The O&M costs of NBS (5k euro/yr for wetland, 2k euro/yr for buffer strips, as detailed in par. 4.2) are incurred by the Drainage Authority through its own budget, made by an annual fee paid by property owners (both farmers and residents in urban settlements), without additional contribution from its members. NGOs and Environmental Associations involved in recreation activities, spends 6K euro/yr to maintain trails, signage, booklets, etc. Volunteer labour by NGOs allows delivering most of the social benefits included in the value proposition (recreation and education). No direct revenue could be generated by the NBS. Most important indirect values are: diffuse pollution control, flood protection, support to biodiversity, recreation, awareness and education

Table 52. The NBS Business Model of selected study site.

Regulatory Framework
The Venice Lagoon Master Plan (VLMP) desings a long-run strategy to improve the environmental status of the Venice Lagoon. Among the planned actions, VLMP identifies NBS as a solutions to address the diffuse pollution issue. The VLMP allocates coherent national funds to implement NBS.

Key Activities	Key Resources	Value Proposition	Key Partners	Key Beneficiaries
1. Land acquisition; **2.** Design and realization of NBS (some of them equipped for recreational and education activity) ; **3.** Maintenance of NBS and water quality monitoring; **4.** Organization of events and project for environmental education and dissemination by Consorzio Acque Risorgive and other organizations; **5.** research on NBS performance and dissemination of results	**1.** Land available for "collective" benefits (possibly accessible to the public); **2.** Special funds through VLMP; **3.** Internal technical expertise and skills on nature-based diffuse pollution control solutions, including the design, realization and maintenance.	**Environmental** Diffuse pollution prevention to improve the environmental conditions of the Venice Lagoon; improved water quality of the drainage network; support to biodiversity (new aquatic and wooded habitats). **Social** Reduction of the incidence and intensity of flood events in the area; raising citizen awareness on water pollution and environmental issues; attractive recreation areas available for residents and visitors tanks to the aesthetic improvement. **Economic** New jobs created for the design, realization and maintenance of the NBS. Anyway, today this aspect is still negligible. In the future, NBS could improve the attractiveness of the area for business and lead to an increase in property prices and related taxes. **Trade-off** Expropriation challenges; diffusion of invasive species; noise pollution during the implementation phases.	Italian government (main funder), Veneto Region, Consorzio Acque Risorgive, Environmental Association and local NGOs (*minor role for Farmers, Municipalities*)	Venice Lagoon, local communities, including schools and environmentalNGOs; in a limited way also farmers (flood risk)

Governance
The regulatory framework, designed by Venice Lagoon Master Plan, allows the Drainage Authority to play a new key role in the model working as an Utility: in addition to traditional irrigation and drainage services, it provides a public utility services, it ensures a service of diffused water pollution remediation. Municipalities and NGO are also involved by managing the ricreation activities in some area and mantaining the related facilities. The governance model could by classified as a "**Network governmen**t"

Cost Structure	Cost Reduction	Capturing Value
NBS O&M costs (5k euro/yr for wetland, 2k euro/yr for buffer strips) are incurred by the Drainage Authority through its budget, without additional contribution of its members. NGO, involved in recreation activities, spends 6K euro/yr to maintain trails, signages, booklets, ...	Volunteer labour by NGOs allows to deliver most of the social benefits included in the value proposition	No direct revenue could be generated by the NBS. Most important indirect values are: diffuse pollution control, flood protection, support to biodiversity, recreation, awareness and education

CAPEX Costs	Source of Capital Investment
The total investment is estimated in about 4 milion euro (revaluated in euro 2018): for the 2 wetlands the investment is 3,7 milion (euro 2018), 300.000 euro for buffer streeps	Total capital Investment funded by the Italian Government and managed by the Veneto Region through the Venice Lagoon Master Plan - “Plan for diffuse pollution prevention and restoration of water in the draining basins of the Venice Lagoon”, entered into force in 2000.

7.4 Possible alternatives to the existing business model

One of the aspects that may limit future development of the NBSs is the lack of continuity of funding for their construction and management. The analysed case had continuity of financing thanks to a special law, therefore not ordinary, with an elevated risk of funding limitation for the future.

It was then considered appropriate to hypothesize a possible source of resources, as an alternative to the funds of the Special Law for Venice, in order to verify the replicability of the business model in other territorial contexts.

Currently the reclamation contributions that residents annually pay to the "Acque Risorgive" Consortium, have the only aim of covering the costs relating to the reduction of hydraulic risk and – to a lesser extent in this area – supplying water for irrigation. The Consortium has no competence outside of these specific functions, nor could the resources collected through the reclamation contributions be used for other purposes.

The study carried out highlighted that the NBSs do not only meet the primary objective of the Master Plan for the Venice lagoon (pollutants reduction) and the "Consorzio di Bonifica" purposes (hydraulic risk reduction), but also allow an improvement of the ecosystems and the landscape, creating a favourable context for the use of these places for recreation and environmental education, which mainly benefit the residents in the area. It is therefore possible to imagine a form of contribution, different and additional to the reclamation contribution, which can finance the implementation of NBSs.

Taking into consideration the NBSs implemented in the last twenty years, the total investment was equal to 45 million euros (Table 1). Having to estimate an average annual investment, two estimates were made, based on two different service lives: 20 and 30 years. An average annual investment of between 1.5 and 2.25 million euros/yr is obtained. By adding this value to the OPEX we obtain a total annual cost between 1.65 and 2.4 million euros/yr. the average annual cost per inhabitant for the implementation of the NBSs currently present in the area of the Acque Risorgive Consortium is between 8 and 11 euros/yr/inhabitant (17 – 25 euros/yr/family) [19].

The total nitrogen removal of the 23 NBSs is estimated to be equal to 48 t_N/yr, while the removal target is 150 t_N/yr. Therefore, it is necessary to triple the area destined to NBSs. On the basis of this hypothesis, the impact of a total investment of 135 million euros – of which a third has already been made – has been estimated (**Table 53**): the total annual cost per inhabitant would be between 23 and 33 euros/yr/inhabitant (52 – 76 euro/yr/family).

These are order of magnitude of cost that are generally bearable, also assuming redistributive mechanisms that allow low-income families to be exempted by slightly increasing the burden on wealthier families or by providing a share of the contributions to be borne by businesses.

A possible regulatory tool that can be used to collect the necessary resources for the implementation of the NBSs is the "purpose tax". It is a municipal tax (Imposta di scopo comunale – ISCOP) whose proceeds are intended to finance public works, events with high tourist interest, urban mobility, kindergartens, etc. it was introduced with law no. 296/2006 and subsequently modified and integrated by the legislative decree of 14 March 2011 no. 23. It gives municipalities the possibility of financing the cost for the construction of public works. The law provides that the tax base of the purpose tax is the Single Municipal Tax (Imposta Municipale Unica - IMU) proportional to the cadastral value of the properties.

[19] The inhabitants of the UTO 4 and 5 were taken into consideration, equal to about 219.000 inhabitants. It was assumed a number of family members equal to 2,3.

Table 53. Economic impact of NBS per inhabitants and families .

	UoM	Realized NBS	Needed NBS
		Value	Value
Total investment	Mil. euro	45	135
Annual investment	Mil. euro/yr	1.5 - 2.25	4.5 - 6.75
OPEX	Mil. euro/yr	0.15	0.45
Total annual costs	Mil. euro/yr	1.65 - 2.40	4.95 - 7.20
Annual costs per inhabitants	euro/yr/inhabitant	8 - 11	23 - 33
Annual costs per family	euro/yr/family	17 - 25	52 - 76

In its current configuration, however, the purpose tax has several limitations:

- It has a limited duration in time (it can be imposed for a maximum of 10 years);
- it is used to finance "public works" (to which NBSs are not easily assimilated);
- finally, it is not quantified on people but on the value of properties.

However, this is the regulatory instrument closest to the needs of the case in question, and it could be easily reformed to fit the use.

7.5 Final consideration on business model

The main conditions that allow the Venice Lagoon watershed business model being effective in the construction and maintenance of NBS for diffuse water pollution control are:

- The availability of funds to cover the construction costs, including land acquisition;
- The role played by the Drainage Authority "Consorzio di Bonifica delle Acque Risorgive", highly qualified and innovative in its technical approach.

The funds provided by the "special law" did guarantee the availability of financial resources over a long period of time: in fact some of the NBS required a very long time (up to 20 years) from the feasibility analysis to the final construction. Only the possibility to rely on a continue and certain source of financial resources allows the progressive construction of new green infrastructures, starting from the easier and better accepted projects up to the most time requiring ones: an alternative hipothesis of financial source could be could be a "purpose local tax", that from the preliminary estimations provided in paragraph 7.4 could be bearable by the local community.

Drainage Authorities (Consorzi di Bonifica) are a very peculiar kind of public bodies. According to the Italian legislation, they are Public Economic Entities, but they are an association of private citizens – mainly the farmer owners of the land managed by the authority – who pay for the O&M costs. Their governance system strongly depends on the farmers who elect their representative in the Authority Council. So, there is generally a good "feeling" between the local farmers' community and the drainage authority: differently by other public bodies, the drainage authority is recognised by the farmers as a trustable partner, with a high technical knowledge in the field of water management.

The technical approach of Drainage Authorities in Italy is always been very far from the "green infrastructure" idea: their technical background lies in the conventional hydraulic engineering and land reclamation practises. It happened that at the end of the nineties the technical direction of the "Consorzio Acque Risorgive" (at that time called "Dese Sile") met some river restoration experts and developed an interest on new possible approaches of the drainage network maintenance. Since then, new technical figures have been recruited and the operational staff has been trained to guarantee a more "ecology oriented" approach.

The presence of a skilled technical direction in the "Consorzio Acque Risorgive" has been an important added value for the NBS constructed over the last 20 years. Indeed, even though the financial resources of the "special law" were available for other Drainage Authorities of the Venice Lagoon, the experience of the Acque Risorgive is by far the most important in terms of number of NBS done, and of quality and effectiveness of the results.

Another key aspect for the acceptability of the NBS by the local farmer community is the high attention given to the flood risk prevention, in the NBS design. All the NBS are designed to provide, beside the ecological services, also extra volume for stormwater storage (e.g. all the buffer strips envisage earth movements to enlarge the stream section, to guarantee the hydraulic functionality even with a higher roughness due to the presence of vegetation). Such solution increases the construction costs of the NBS but contributes to show the multi-functionality of NBS, and specifically their effectiveness in flood risk prevention, an issue perceived as very important, particularly in reclaimed landscapes.

The involvement of the "urban population" (not farmers) – even though their "power" as stakeholder in the decision process concerning NBS in the agriculture landscape is weaker, compared to farmers – can ease the construction of NBS. Their interest concerns mainly the recreation opportunities: the main condition to satisfy such a demand is that NBS are accessible. To increase the interest of the local community towards NBS a specific attention should be taken in the design phase, taking care of possible tourist itineraries, possibly linking between them different NBS locations. Even when NBS are accessible only by crossing private land, agreement with farmers could be found, particularly if the farmer itself can take advantage by the presence of tourists (direct selling of farm products, agritourism).

The analysis reported above in paragraph 9.4 shows that – given the current legislation – the Consorzi di Bonifica would find it difficult to replicate the experience of this case study in other areas of Italy and that the involvement of the Municipalities and recourse to specific instruments such as the Imposta Comunale di Scopo (Municipal Purpose Tax) would be necessary. This suggests the opportunity of a legislation reform on the Consorzi di Bonifica, rethinking the role of these organisations, born for the management of land reclamation, but which over time have assumed an increasingly important role in the management of water and territory. However, the situation differs from Region to Region and also from *consortium* to *consortium*: if some *consortia* (in particular in the North) actually exercise important environmental skills, others are strictly limited to guaranteeing the drainage of reclaimed areas and supplying water for irrigation.

Yet the Consorzi di Bonifica are, in Italy, the organizations most similar to those which, in other European countries, are responsible for the correct management of the minor hydrographic network in rural areas (e.g. the "district water boards" in the Netherlands). A reform that reviews its competences and financing mechanisms, and adequate training on modern approaches to water management and hydraulic risk aimed at recovering the ecosystem services of the agricultural territory (NWRM, NBS, multifunctional "win win" solutions), would be the main way to allow the diffusion on a national scale of experiences similar to the one described in the present case study.

As a final remark, it has to be underlined that NBS could be constructed and actually are diffusing all over Europe, including the area object of the present study, following a complete different business model: that is the construction and maintenance of NBS on private land, by subsidizing directly farmers using the PAC funds. Some considerations on the differences among the two business models will be provided in the conclusions of this report.

8 CONCLUSIONS

The contribute of 4 Nature-based solutions (NBS), two wetlands (Rusteghin and Salzano) and two buffer strips (Scandolara and Nicolas), to reduce water pollution by retaining and processing diffuse pollutants generated by farming practices (Nitrogen, Phosphorus, sediments and pesticides) has been analysed together with their capacity to delivering, at the same time, other benefits beyond water pollution control, such as flood risk prevention, habitat for biodiversity, recreational and educational opportunities.

The performance of the 4 NBS to reduce pollution in terms of pollutant mass per m^2 of NBS appears to be in line with the existing scientific literature. Wetlands (Rusteghin) show better removal rates per m^2 than buffer strips for all parameters with the exception of sediments (SS), for which the best removal rate has been detected at Scandolara buffer strip. It has to be underlined that wetlands, differently by buffer strips, have not been designed following strict scientific criteria to maximize their pollutant removal capacity: for example the Salzano wetland clearly shows the existence of hydraulic bypass that sharply reduce the removal effectiveness. Therefore the pollutant removal capacity could be significantly higher – with a minimum loss of side benefits – had a more "target oriented" design taken place. (**paragraph 3.2.1**)

The construction parametric cost of NBS ranges between 10 and 40 €/m^2 for the two wetlands and the BS of Scandolara, while decreases by an order of magnitude (around 3 €/m^2) for the Nicolas BS, a value that is in line with costs of "conventional" buffer strip according to literature data (1.5-2 €/m^2). (**paragraph** 4)

The reason why the cost of Scandolara BS is much higher than "conventional" buffer strips is that Scandolara system, as well as most of the BS constructed by Consorzio Acque Risorgive, includes significant earth moving works needed to enlarge the width of the draining stream or canal (see **Figure 10**). This is a conceptually different system that could be considered a sort of "integrated buffer strip" which include a wet ecosystem downstream the wooded part of the system, while integrated buffer strips create it upstream (Zak et al.2019). The main reason why this kind of system has been chosen as preferred by the Drainage Authority is that it increases the hydraulic capacity of the stream channel, allowing the increasing of roughness due to vegetation without worsening the flood risk of the area. This solution, however, is valuable also in terms of effectiveness, at least for nitrogen removal capacity. In fact this kind of BS shows rates from 2 to 3 times higher than that of conventional BS. (**paragraph 4.1.2**)

For what concerns "side benefits", the analysed NBS appear to provide several ecosystem services considered valuable by the local community. All the NBS have been designed to store excess water during extreme events: the positive role of these solutions for flood prevention has been acknowledged by the farmer community and is one of the main reasons why they do not oppose to their construction. (**paragraph 6**)

A positive effect for biodiversity has also been detected, at least for the NBS where biodiversity checks did take place. Several species (mainly arthropods, amphibians, reptiles and birds) and habitat of Community interest has been found in some of the NBS and some of them have been identified as Special Conservation Zones. (**paragraph 6.1.2**)

According to the key stakeholders interviewed all the newly built NBS are appreciated by the local community and most of them are somehow used for recreational purposes. Some of them (Salzano) is specifically equipped to host visitors.

The social analysis also highlighted that the local community uses the newly built NBS for educational and awareness raising purposes. The Consorzio Acque Risorgive organises educational activity involving more than 40 school classes per year, while Salzano wetland is managed by an NGO using it for its Environmental Education activity. (**paragraph 6.1.1**)

The quantification of direct and indirect benefits and their valuation through appropriate value transfer methods has been done for the 4 studied NBS and scaled up to the whole basin (37,750 hectares), considering a total of 23 NBS constructed in the area in the last 20 years and covering a total area of 252 hectares (0,67% of the drainage basin area). (**paragraph 6.2**)

Table 54. Summary of the costs and benefits provided by the 23 NBS

Objectives/ criteria	**Indicators**	**Performance**	**Range of monetary values by value transfer €/year**
Reduce flood risk	Peak flow reduction (retention volume) m^3	1,758,487 m^3	46,000 – 53,000
Use for recreation	Accessibility: number of people leaving in a range of 1 Km from the NBS (potential recreation users)	21,322	960,000 – 1,070,000
Use for education	Number of pupils involved in educational activity	1760 n°/y	30,000 – 70,000
Contribute to water quality	Nitrogen removal: t_N/year	48 t_N/year	450,000 – 1,450,000
	Phosphorus removal: t_P/year	3.4 t_P/year	
	Sediment removal: t_{TSS}/year	2073 t_{TSS}/year	
	Pesticide removal: $t_{glyphosate}$/year	0.5 $t_{glyphosate}$/year	
Support biodiversity	Extension of newly created natural habitat	2,523,260 m^2	80,000 – 90,000
Annualized CAPEX*	€/year	1,532,273	
OPEX	€/year	147,281	
Loss of farmland income	€/year	378,489	

According to the quantification of the benefits, the NBS constructed up to now can remove nearly 50 tons per year of total nitrogen: 1/3 of the total amount of nitrogen to be removed on the studied drainage basin according to the "Venice Lagoon Masterplan" (150 tons/year). (**paragraph 1.2**).

The estimated monetary value of the pollutant removal capacity ranges between 500,000 and 1,500,000 €/year. Of the same order of magnitude is the recreational value, estimated around one million €/year, while the other ecosystem services are estimated lower by one order of magnitude, between 50,000 and 100,000 €/year. The reason why the monetary value of flood prevention – an ecosystem service that may be expected of high value – is estimated only around 50,000 €/year, depend on the specific features of the study area. The NBS developed do not contribute to reduce flood risk of the urban centres of the area, but just of the farmland, that is mainly arable land, able to bear some periodic flooding, so long as they're not too frequent. Then, the value used to monetize the flood prevention service in similar geographic context brought to the estimate reported.

The capital cost for the construction of all the NBS amounts to 45 millions € (around 1 million for tons/year of total N removed), spent in a period of 20 years (2.25 millions € per year). Considering the whole surface of the interested basin the NBS construction cost amounts to around 1,200 € per hectare. O&M cost range between 0,02 and 0,26 €/m^2: and amounts to less than 150,000 €/year for all the 23 NBS. Moreover, NBS creation allows a significant reduction of O&M costs compared to conventional drainage network maintenance: all the NBS envisages a widening of the stream channels that doesn't require vegetation cutting, while conventional drainage ditch requires 1 or 2 vegetation cut a year.

Quantifying the value of ecosystem services provided by a value transfer method, the estimation results in an yearly value ranging between 1.5 and 2.7 millions euro, values comparable to the yearly expenditures for the sum of capital and O&M costs in the last 20 years (ca. 2.3 million €/year). (**paragraph 6.4.2**)

The average diffuse pollutant removal costs by NBS appears to be significantly higher compared to technical solutions applied to point sources (see **Table 33** at **paragraph 4.3**): the cost per tonne of nitrogen removed range from 1,5 to 7 times the costs of a nitrification-denitrification reactor applied to a wastewater treatment plant. Such a huge cost difference could not be compensated by the value of the side benefits provided by NBS. This result, however, is not unexpected: the removal effectiveness of any kind of treatment process depends on the inflow concentration of pollutant; the higher is the concentration, the more effective is the process. Nitrogen concentration in wastewater after secondary treatment is on average around 30 mg/l, almost constant al year round, while the diffuse pollution concentration ranges between 2-8 mg/l in surface water and 10-20 mg/l in groundwater and the concentration is highly depending by the rain pattern. Moreover, the removal costs of the sole nitro-denitro reactor doesn't include the costs of the wastewater collection (the sewage network) that allows the treatment to take place at the final discharge point. Finally, very often there's no alternative to action to remove diffuse pollution simply because the source of pollution is diffused, and is not possible to collect it and treat it as point source. The Venice Lagoon Masterplan estimated the amount of Nitrogen generated by different sources and nitrogen due to treatment plants discharging directly into the lagoon or on the drainage area: it amounts to less than 500 tons/year, while the nitrogen generated by farming (3300 tons/year) and breeding activity (2200 tons/year) amounts to more than 10 times such value.

In conclusion the experience of the Consorzio Acque Risorgive appears to be successful. A significant extension of NBS have been constructed, which show a pollutant removal capacity in line with the scientific data, reasonable construction and O&M costs, while supplying several benefits that, if monetized through a "value transfer" exercise, shows high value provided by the NBS every year for the community. (**paragraph 6.5**)

The final question is: "is the model applied in this case study replicable somewhere else?" Apparently it is, if the two main conditions that allow the success of the present case study are fulfilled:

- The availability of funds (state or local taxes, provided by private companies for marketing reason, raised among sensitive population, etc.) to cover most part of the construction costs, including land acquisition;
- The presence of a "centralized governance" actor covering the role played by the Drainage Authority "Consorzio di Bonifica delle Acque Risorgive", highly qualified and innovative in its technical approach.

It has to be underlined that the "business model" applied in this case study (that could be called "centralized governance") is different from the most diffused model, that is the construction and maintenance of NBS (specifically buffer strips or very small wetlands) on private land, by subsidizing directly farmers using the PAC funds (that could be called "diffuse governance").

A system based on the "diffused governance" would probably allow a reduction of parametric costs of NBS (both capital and O&M), thanks to the recourse to the work time of farmers. Consequently, it could obtain a wider diffusion of NBS in terms of total NBS area by using the same amount of money. However, the effectiveness regarding pollutant removal and several other benefits would be highly uncertain. For example, buffer strips to be effective need to be located and designed carefully, in order to obtain significant removal capacity. According to the experience of the technical staff of the Consorzio Acque Risorgive, farmers who access for subsidies for BS locate them to minimize their negative effects on agriculture production, rather than to maximize environmental benefits.

A system of "centralized governance" can secure the effectiveness of environmental benefits much more than a "diffuse governance" system. Moreover, the approach used by Consorzio Acque Risorgive to acquire to the public property the land where the NBS are constructed guarantees that, in the long term, the areas involved do not change their destination. (**paragraph 7**)

The business model analysis (**paragraph 9**) shows that – given the current legislation – the Consorzi di Bonifica would find it difficult to replicate the experience of this case study in other areas of Italy and that the involvement of the Municipalities and recourse to specific instruments such as the Imposta Comunale di Scopo (Municipal Purpose Tax) would be necessary. This suggests the opportunity of a legislation reform on the Consorzi di Bonifica, rethinking the role of these organisations, born for the management of land reclamation, but which over time have assumed an increasingly important role in the management of water and territory. However, the situation differs from Region to Region and also from *consortium* to *consortium*: if some *consortia* (in particular in the North) actually exercise important environmental skills, others are strictly limited to guaranteeing the drainage of reclaimed areas and supplying water for irrigation.

Yet the Consorzi di Bonifica are, in Italy, the organizations most similar to those which, in other European countries, are responsible for the correct management of the minor hydrographic network in rural areas (e.g. the "district water boards" in the Netherlands). A reform that reviews its competences and financing mechanisms, and adequate training on modern approaches to water management and hydraulic risk aimed at recovering the ecosystem services of the agricultural territory (NWRM, NBS, multifunctional "win win" solutions), would be the main way to allow the diffusion on a national scale of experiences similar to the one described in the present case study.

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ANNEX 1: Landscape framework maps

Landscape is investigated considering the following features and sources:

- Satellite view: Google Earth
- Land use and infrastructure: Corine Land Cover (https://land.copernicus.eu/)
- Topography: technical regional map (Carta Tecnica Regionale – CTR - https://www.regione.veneto.it/))
- Soil type: Regional soil type map (https://www.regione.veneto.it/)
- Flood maps (PGRA – Piano Gestione Rischio Alluvioni): River Basin District of Eastern Alps (http://www.alpiorientali.it/)
- Maps of the depth of the subsurface water (https://www.regione.veneto.it/)

Drawings for each feature and each NBS are given in following pages, in A3 format and in scale.

All the drawings attached drawings are summarised in the following table.

ID	Title	Scale
01	Satellite view	1:6000
02	Topography	1:6000
03	Soil type	1:55000
04	Land use and infrastructure	1:55000
05a	PGRA (Flood maps)	1:55000
05b	PGRA (Flood maps)	1:6000
06	Depth of the subsurface water	1:100000

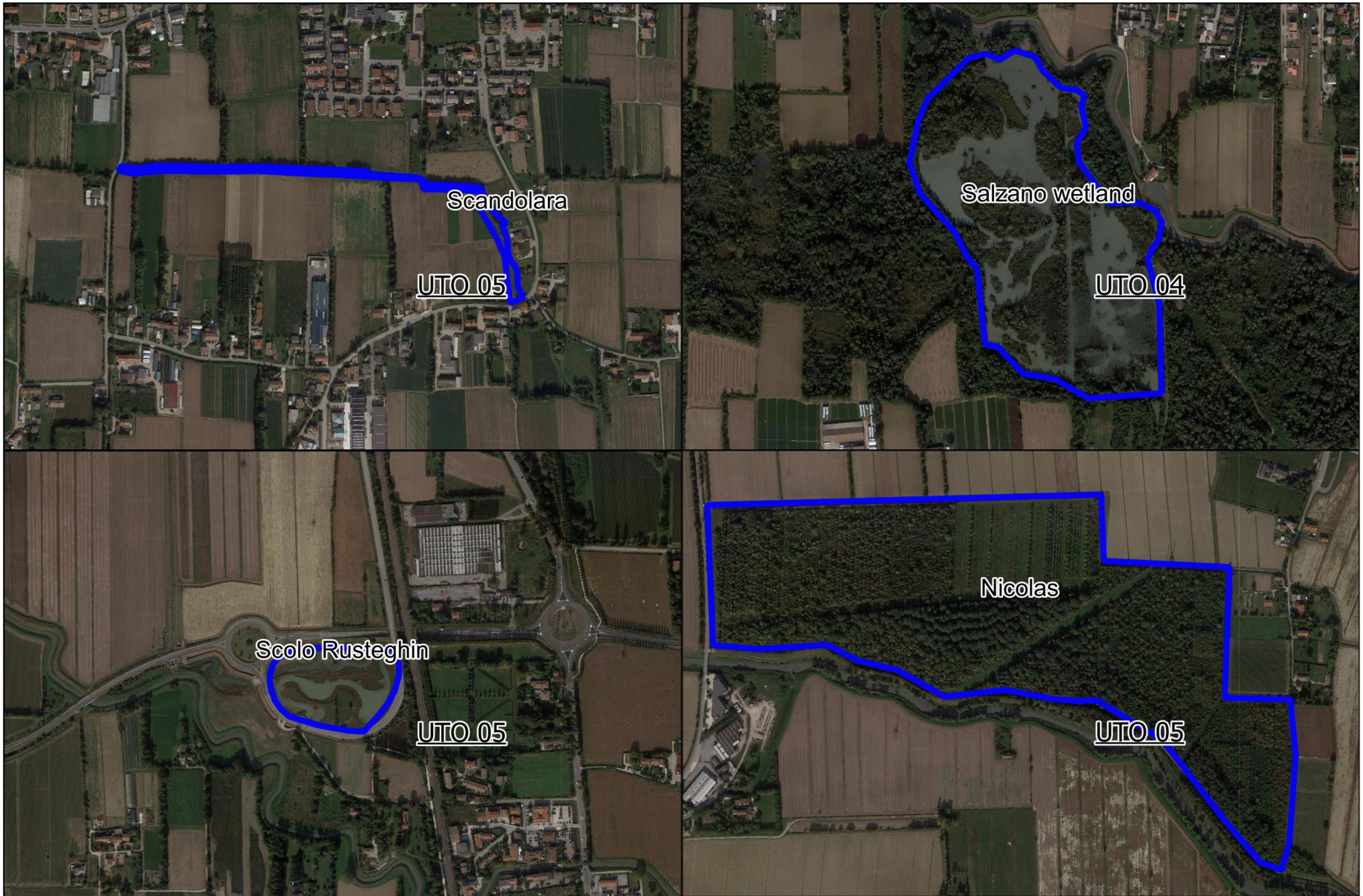
Summarize the features of the sites.

NBS	Features of Soil Type
Scandolara	Strongly calcareous sands and silts
Salzano wetland	Strongly calcareous silts
Scolo Rusteghin	Strongly calcareous sands and silts; Strongly calcareous silts
Nicolas	Strongly calcareous silts and clays

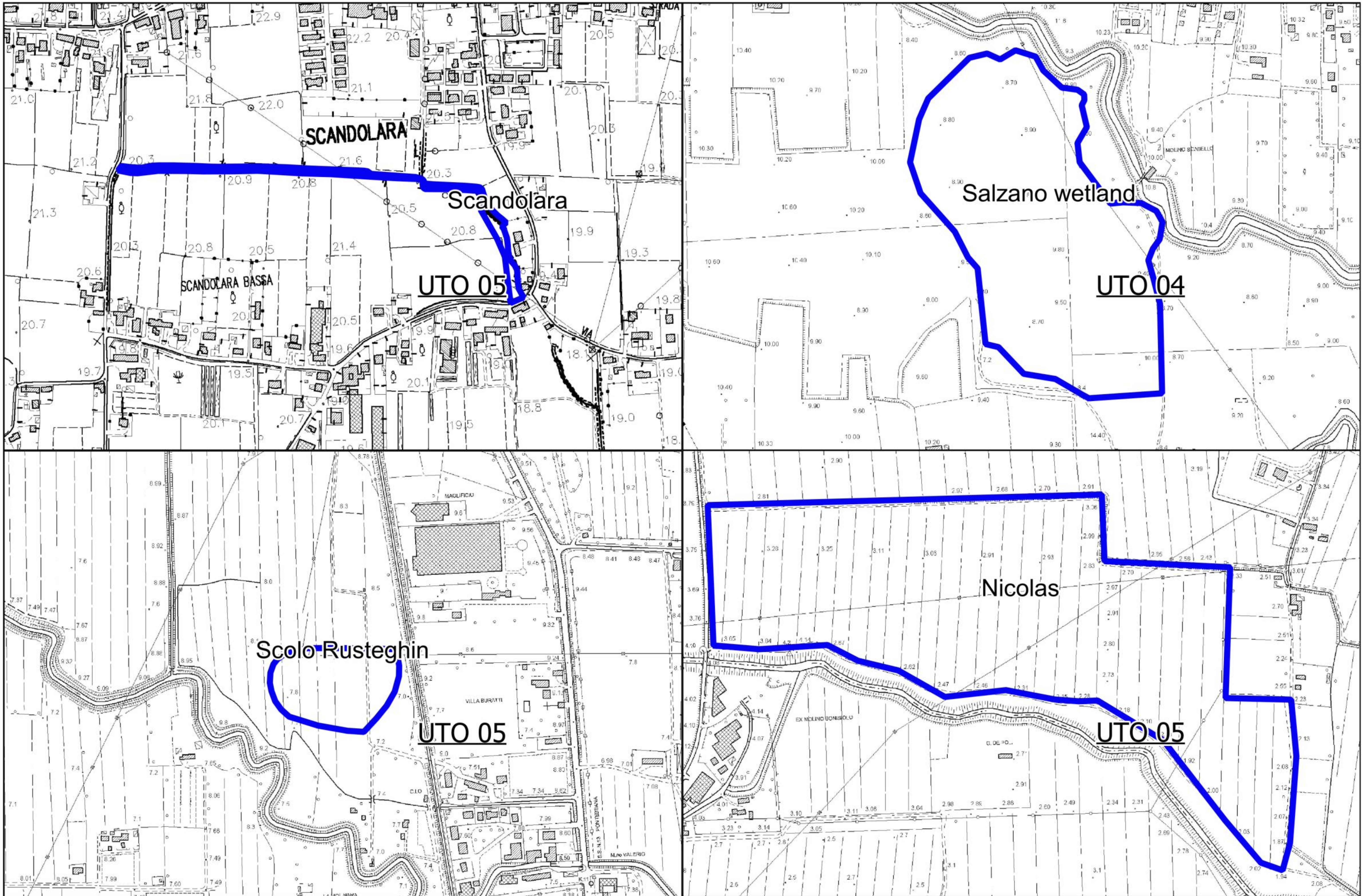
NBS	Features of Land use and infrastructure (Corine)
Scandolara	Non-irrigated arable land
Salzano wetland	Broad-leaved forest
Scolo Rusteghin	Non-irrigated arable land; Complex cultivation patterns
Nicolas	Non-irrigated arable land; Broad-leaved forest

NBS	Features of Flood maps (PGRA)
Scandolara	-
Salzano wetland	Low flood probability
Scolo Rusteghin	-
Nicolas	-

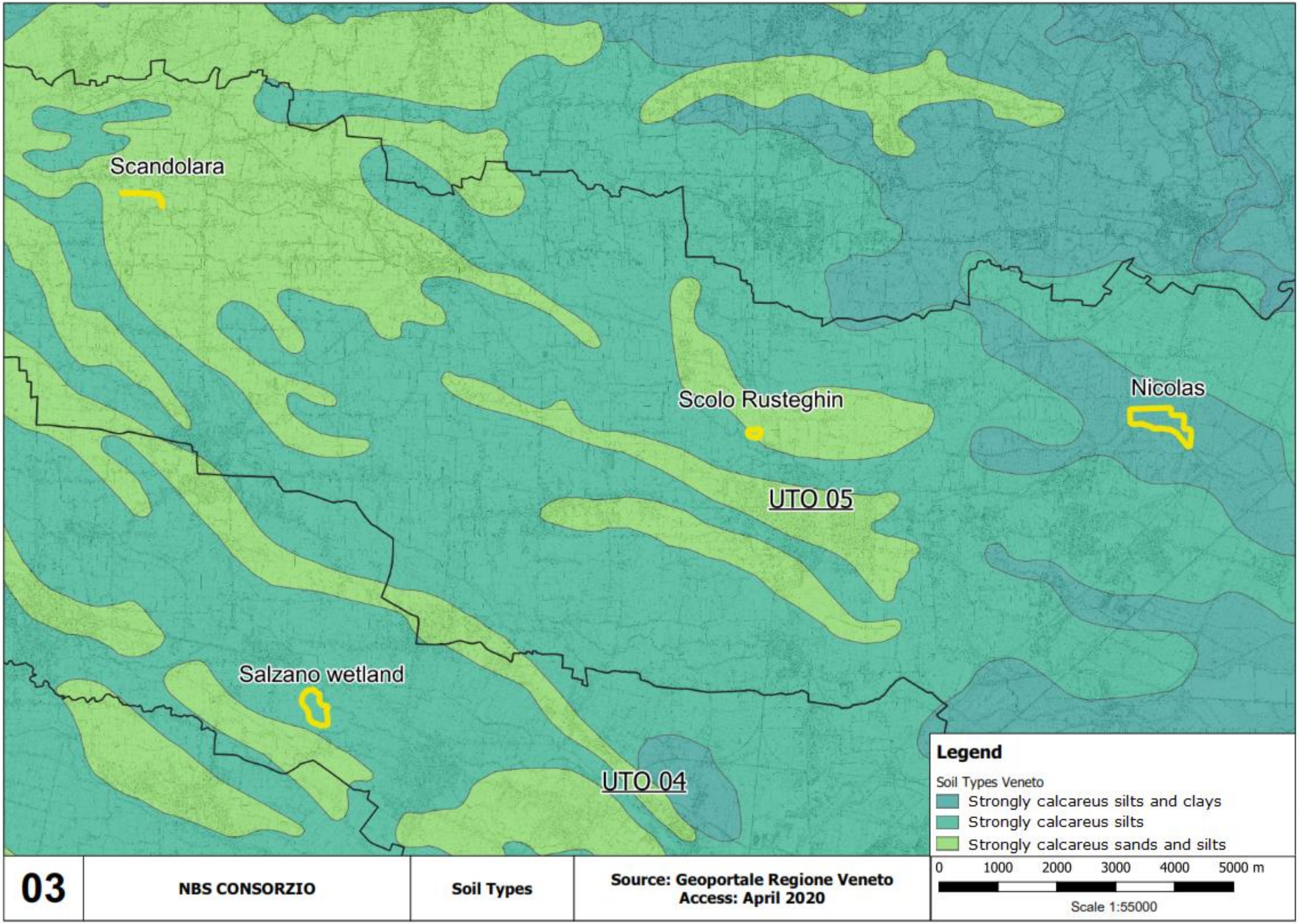
NBS	Features of groundwater depth
Scandolara	Water table depth 100-150cm
Salzano wetland	Water table depth 100-150cm
Scolo Rusteghin	Water table depth 100-150cm
Nicolas	Water table depth 100-150cm



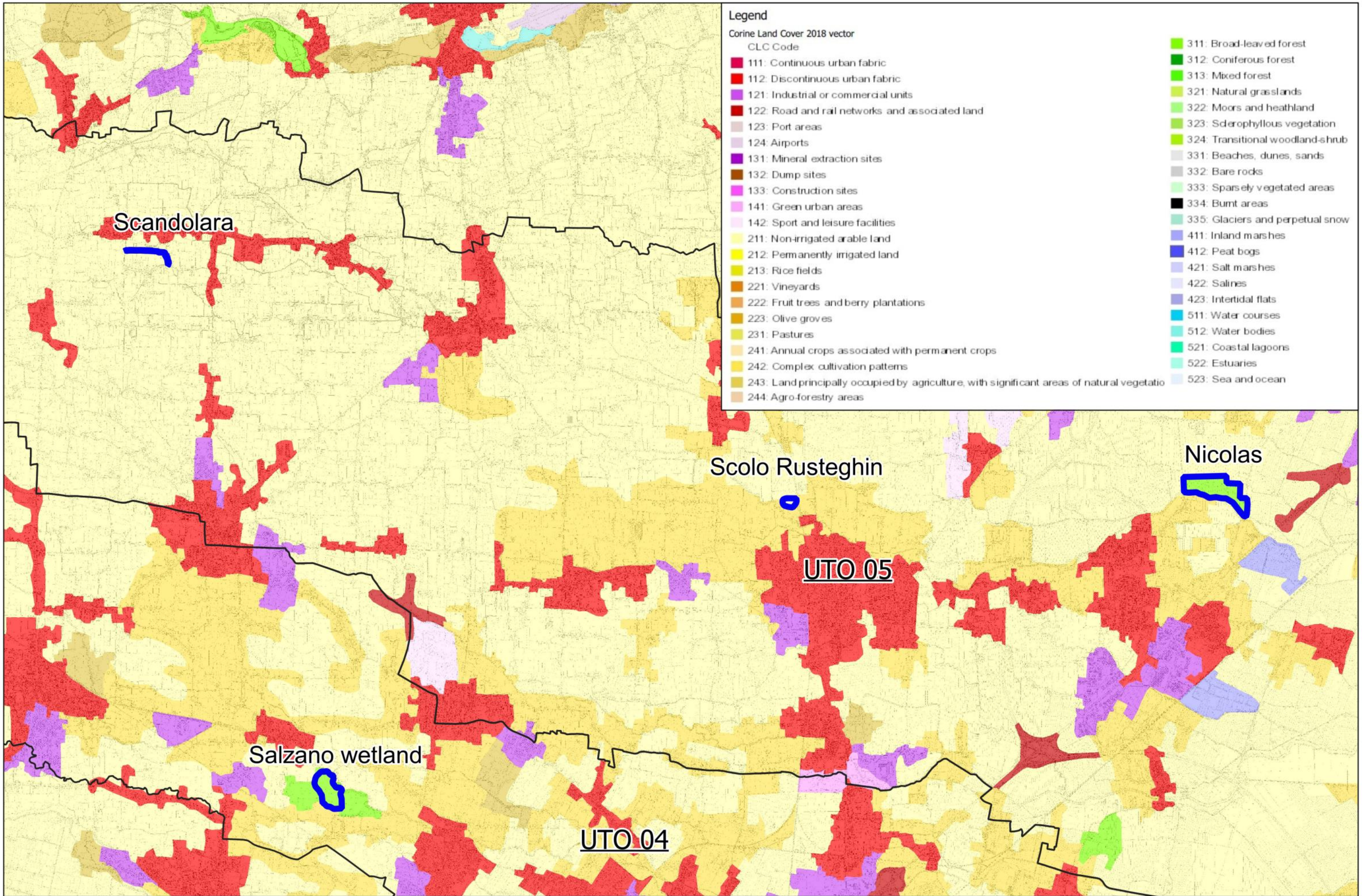
01	**NBS CONSORZIO**	**Satellite View**	**Source: Google Satellite** **Access: April 2020**	0 100 200 300 400 500 m Scale 1:6000



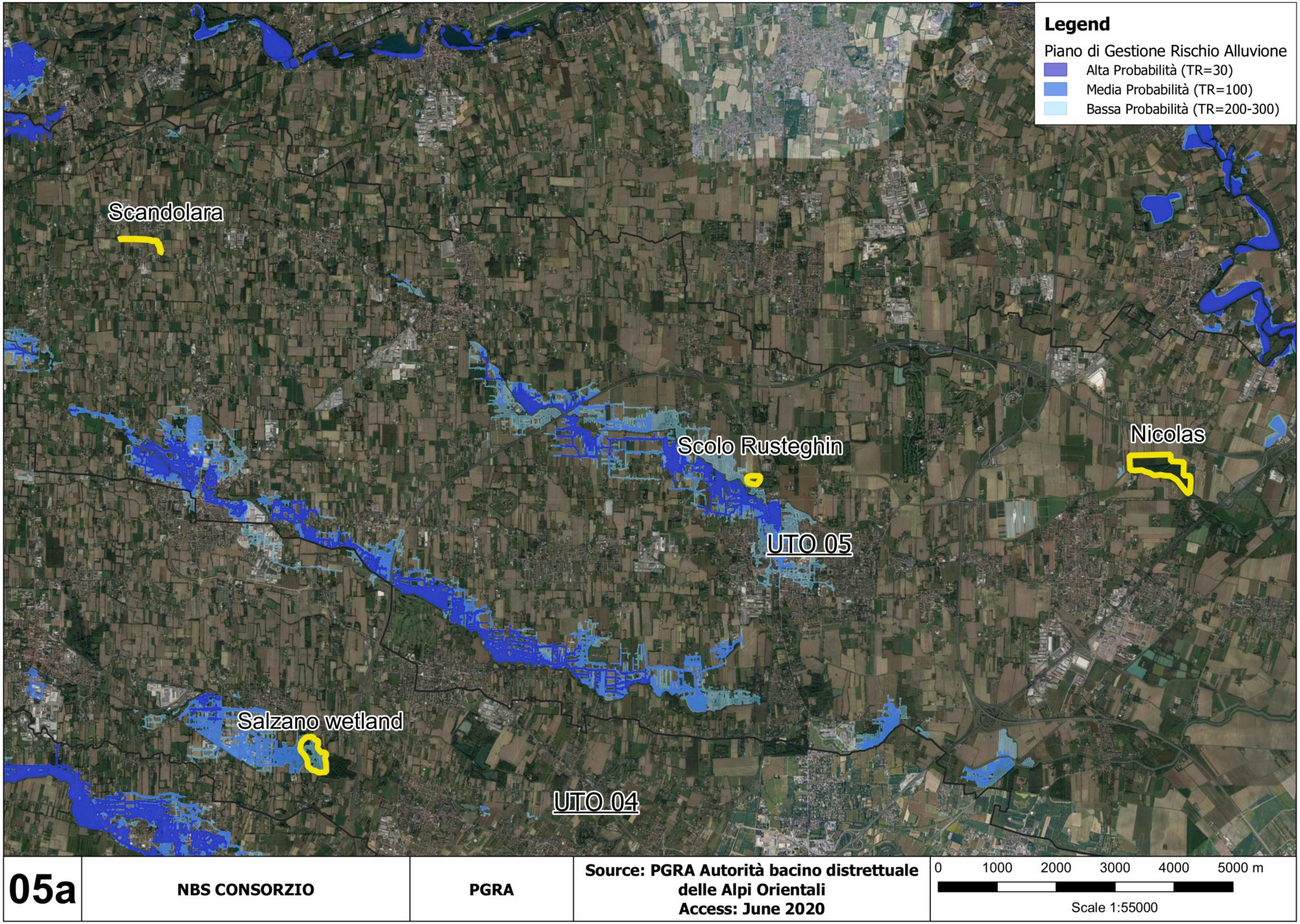
02	**NBS CONSORZIO**	**Topography**	**Source: Geoportale Regione Veneto** **Access: April 2020**	0 100 200 300 400 500 m Scale 1:6000



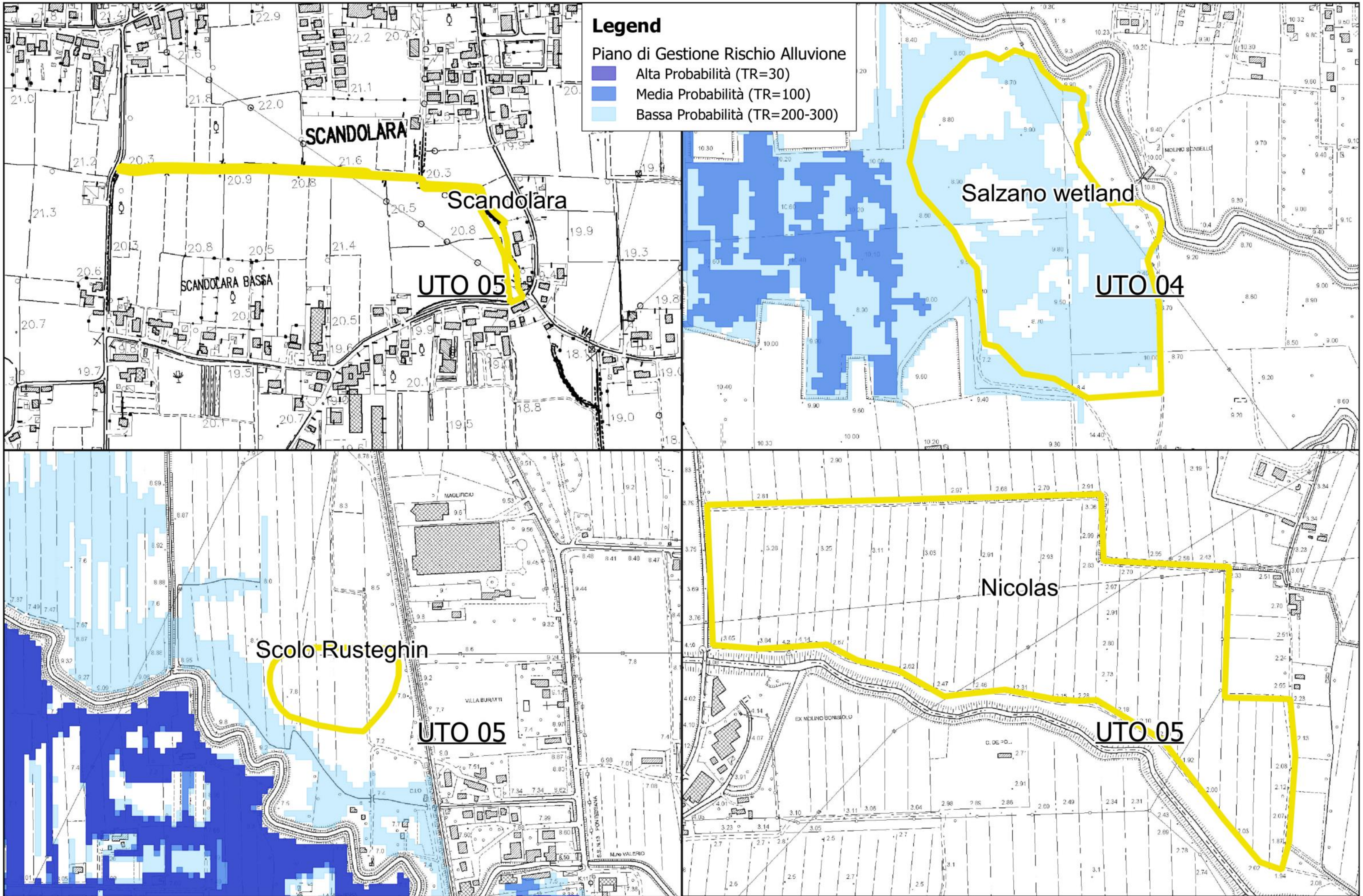
03	NBS CONSORZIO	Soil Types	Source: Geoportale Regione Veneto Access: April 2020



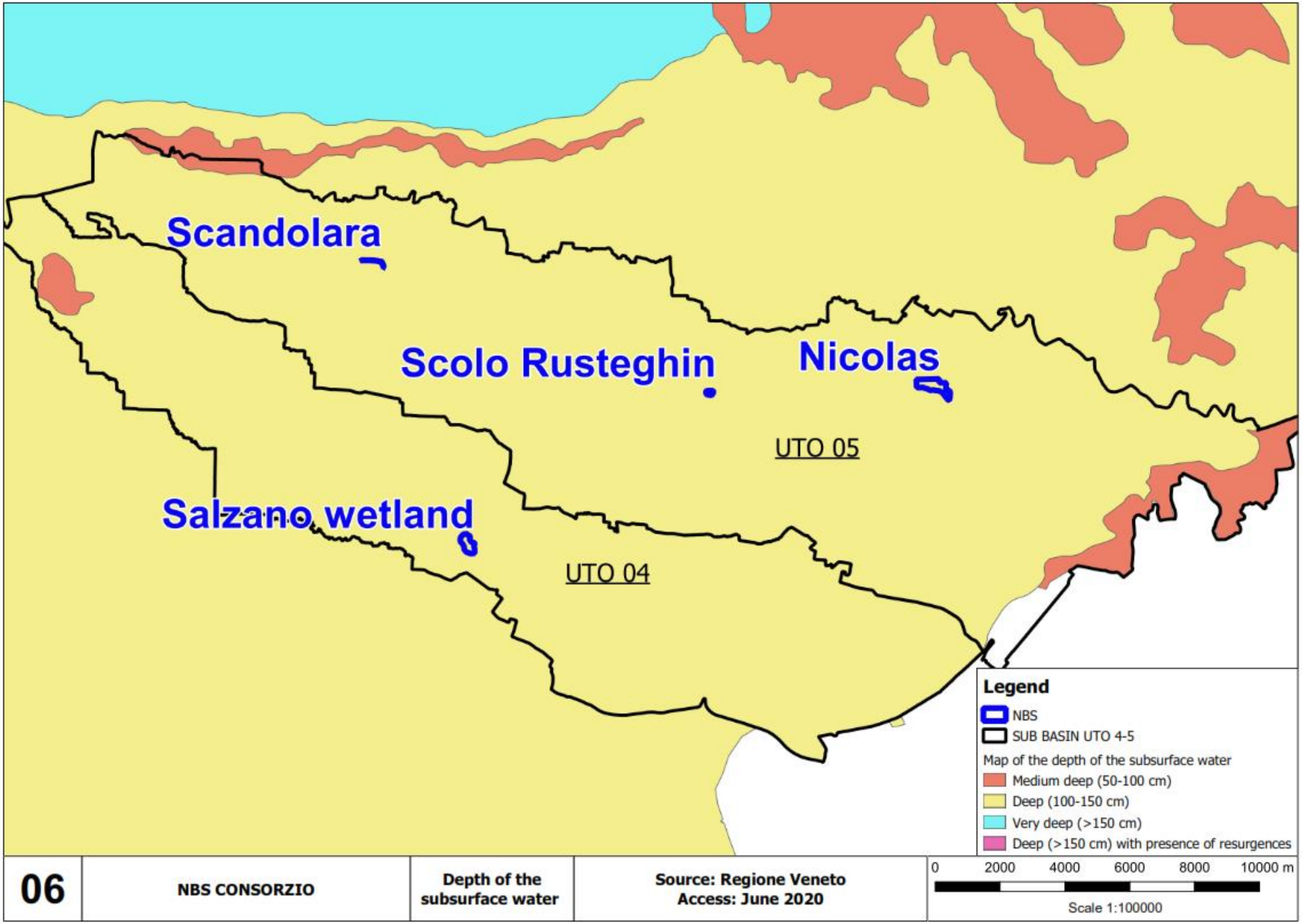
04	NBS CONSORZIO	Land Use and infrastructure	Source: Corine Land Cover 2018 Access: April 2020	0 1000 2000 3000 4000 5000 m Scale 1:55000



05a	**NBS CONSORZIO**	**PGRA**	**Source: PGRA Autorità bacino distrettuale delle Alpi Orientali Access: June 2020**



05b	NBS CONSORZIO	PGRA 2	Source: PGRA Autorità bacino distrettuale delle Alpi Orientali Access: June 2020	0 100 200 300 400 500 m Scale 1:6000



06	NBS CONSORZIO	Depth of the subsurface water	Source: Regione Veneto Access: June 2020

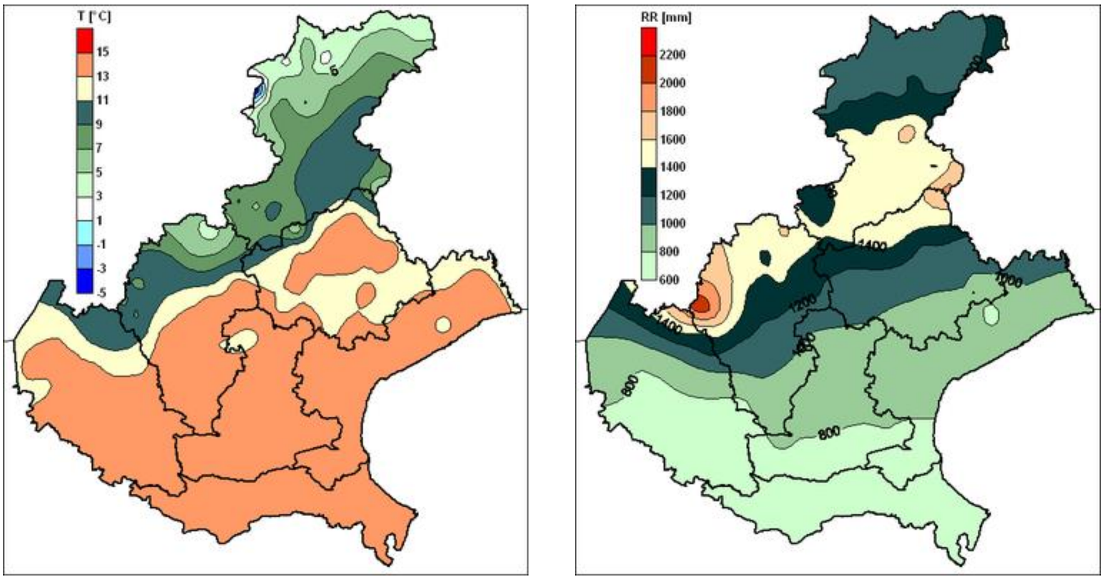
ANNEX 2: Detailed climatic analysis

Climatic framework

Veneto region can be divided into three main mesoclimatic zones: plain, pre-Alpine and alpine.

According to the thermal classification of Pinna (1978), the prevailing climate in the plains and pre-Alpine valleys is temperate sub-continental. On the other hand, the climate is cool-cold and cold temperate, respectively for the pre-Alpine areas and the alpine culmination areas.

The area under investigation is located in the plain mesoclimate zone, characterized by average temperatures between 13° and 15° C and uniformly distributed annual rainfall between 600 and 1100 mm.



www.arpa.veneto.it

Figure 30. Maps of average temperatures and average annual rainfall (1985 – 2009)

The agro-climatic trend of Veneto region for the years 2009, 2010 and 2018 is derived from the annual bulletins prepared by ARPAV.

In 2009, total rainfall varies between 650 and 2950 mm and the evapotranspiration value estimated in the plains with the Hargreaves equation is between 850 mm and 900 mm. The estimated hydro-climatic balance in the plains is between -275 and 600 mm, as shown in **Figure 31**.

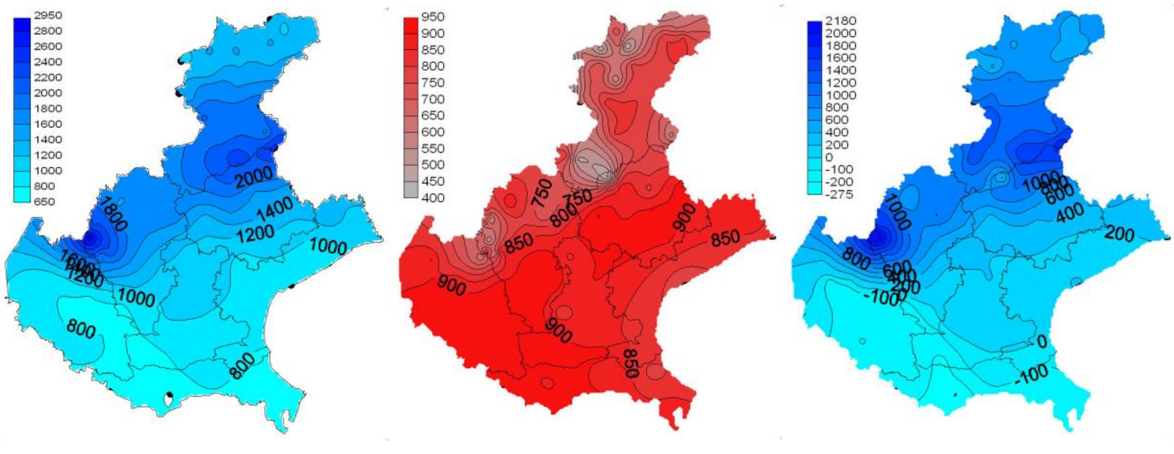


Figure 31. Total rainfall 2009 - Potential evapotranspiration 2009 - Hydro-climatic balance 2009 (ARPAV)

In 2010 the total cumulative rainfall varies between 800 and 3900 mm and estimated evapotranspiration in the plains is between 700 and 900 mm, recording a hydro-climatic balance between -70 and +3000 mm (**Figure 32**).

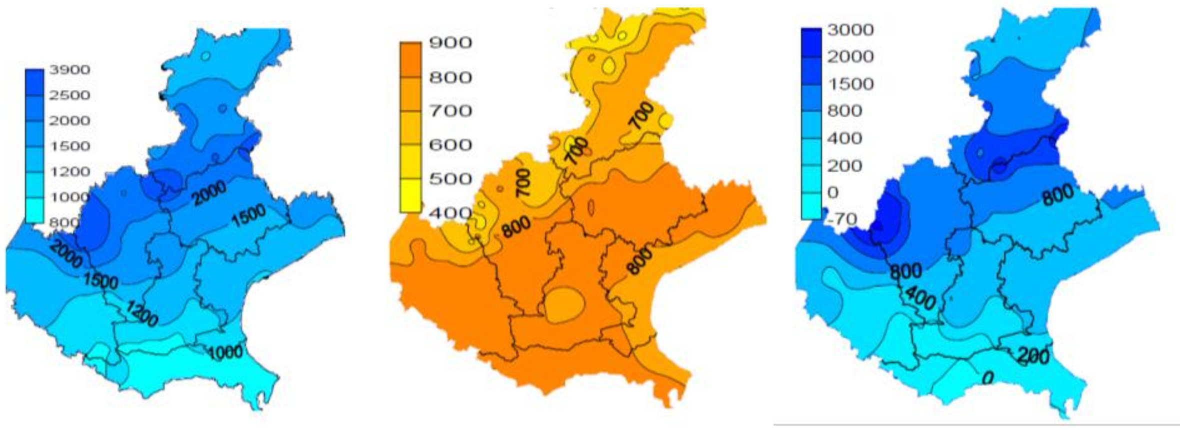


Figure 32 Total rainfall 2010 - Potential evapotranspiration 2010 - Hydro-climatic balance 2010 (ARPAV)

In 2018 the rainfall distribution was rather uneven and the rainfall estimate for the Veneto region is 1306 mm. The evapotranspiration is between 450 and 1000 mm, while the hydrological balance was positive on central-northern areas and negative in the central-eastern plain **Figure 33**.

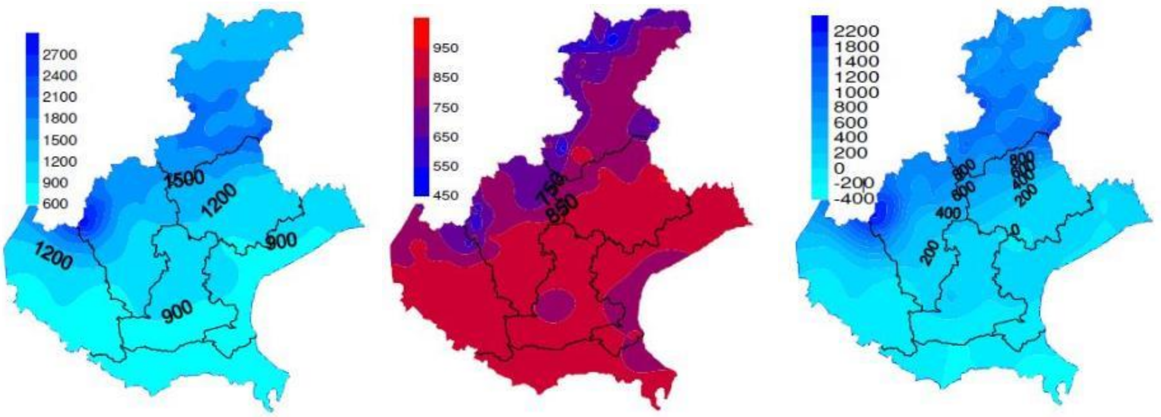


Figure 33. Total rainfall 2018 – Potential evapotranspiration 2018 – Hydro-climatic balance 2018 (ARPAV)

Among the various measuring stations present in the Veneto region, the stations near the area under investigation are: Trebaseleghe (station n ° 122), Mira (station n ° 167), Zero Branco (station n ° 184) and Moglaino Veneto (station n° 227) (**Figure 34**).

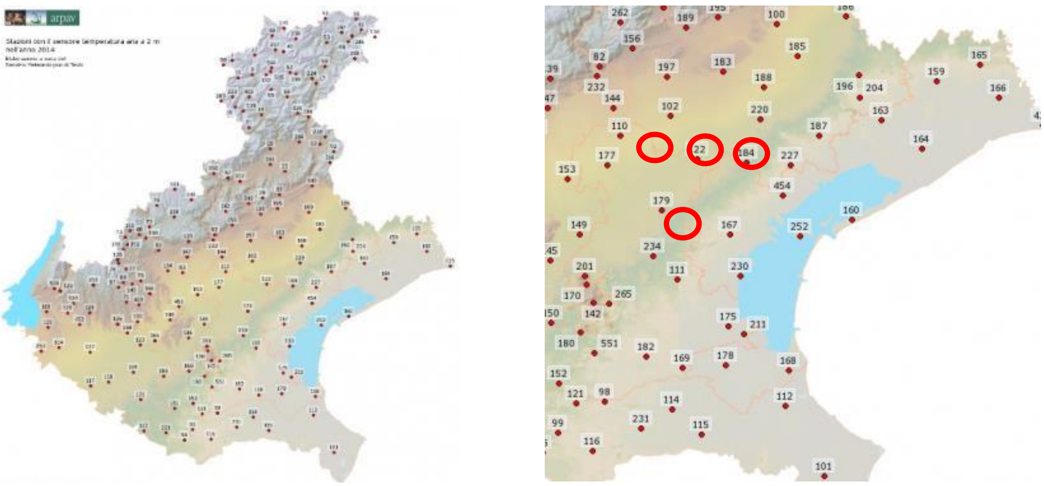


Figure 34. Veneto region meteo-climatic station (ARPAV)

The monthly average climatic values, calculated as the average of the data recorded by the stations for the years 1994-2018, are shown in the following tables and figures.

Table 55. Monthly average climatic values for the years 1994-2018 – Zero Branco and Trebaseleghe stations (ARPAV)

Month	Zero Branco				Trebaseleghe			
	P	T_{MED_MIN}	T_{MED_MAX}	T_{MED_MED}	P	T_{MED_MIN}	T_{MED_MAX}	T_{MED_MED}
	[mm]	[°C]	[°C]	[°C]	[mm]	[°C]	[°C]	[°C]
Jan	53.9	-0.7	7.5	2.8	57.2	-0.5	7.8	3.1
Feb	62.2	0	9.5	4.2	60.4	0.1	9.7	4.5
Mar	65.6	3.5	14.3	8.5	66.4	3.7	14.4	8.8
Apr	83.4	7.5	18.8	12.9	80	8	19	13.4
May	95.5	12.2	24	17.9	103.5	12.7	23.9	18.2
Jun	94.1	15.8	28.1	21.8	88.3	16.1	28	22
Jul	78.3	17.3	30.6	23.7	85.3	17.3	30.3	23.7
Aug	76.3	16.7	30.3	23	87.7	16.6	30.2	23
Sep	101.8	12.7	25.3	18.3	98	13	25.2	18.6
Oct	88	8.8	19.4	13.4	93.9	9.3	19.4	13.8
Nov	105.8	4.6	13	8.3	111.9	4.7	13.2	8.6
Dec	64.2	0	8.2	3.5	70.5	0.1	8.5	3.8

Table 56. Monthly average climatic values for the years 1994-2018 – Mira and Mogliano Veneto stations (ARPAV)

Month	Mira				Mogliano Veneto			
	P	T_{MED_MIN}	T_{MED_MED}	T_{MED_MAX}	P	T_{MED_MIN}	T_{MED_MAX}	T_{MED_MED}
	[mm]	[°C]	[°C]	[°C]	[mm]	[°C]	[°C]	[°C]
Jan	47.6	-0.3	3.1	7.4	52.9	-0.2	7.4	3.2
Feb	55.8	0.3	4.5	9.4	67.6	0.7	9.5	4.7
Mar	65.2	3.7	8.7	14	70.7	4.2	14	8.9

Apr	75.5	7.8	13	18.3	73.7	8.5	18.5	13.5
May	91.8	12.5	17.9	23.2	94	13	23.3	18.2
Jun	81.4	15.9	21.8	27.2	79	16.8	27.5	22.3
Jul	87.6	17.3	23.7	29.7	69.8	18.4	29.7	24.1
Aug	73.2	16.8	23.1	29.7	74	18	29.6	23.7
Sep	92.7	12.9	18.5	25	105.5	13.9	24.8	19
Oct	88.8	9.1	13.6	19.4	86.2	10	19.2	14.1
Nov	89.4	4.9	8.5	13	108.5	5.4	13.2	8.9
Dec	60.1	0.4	3.7	8	63	0.6	8.3	4

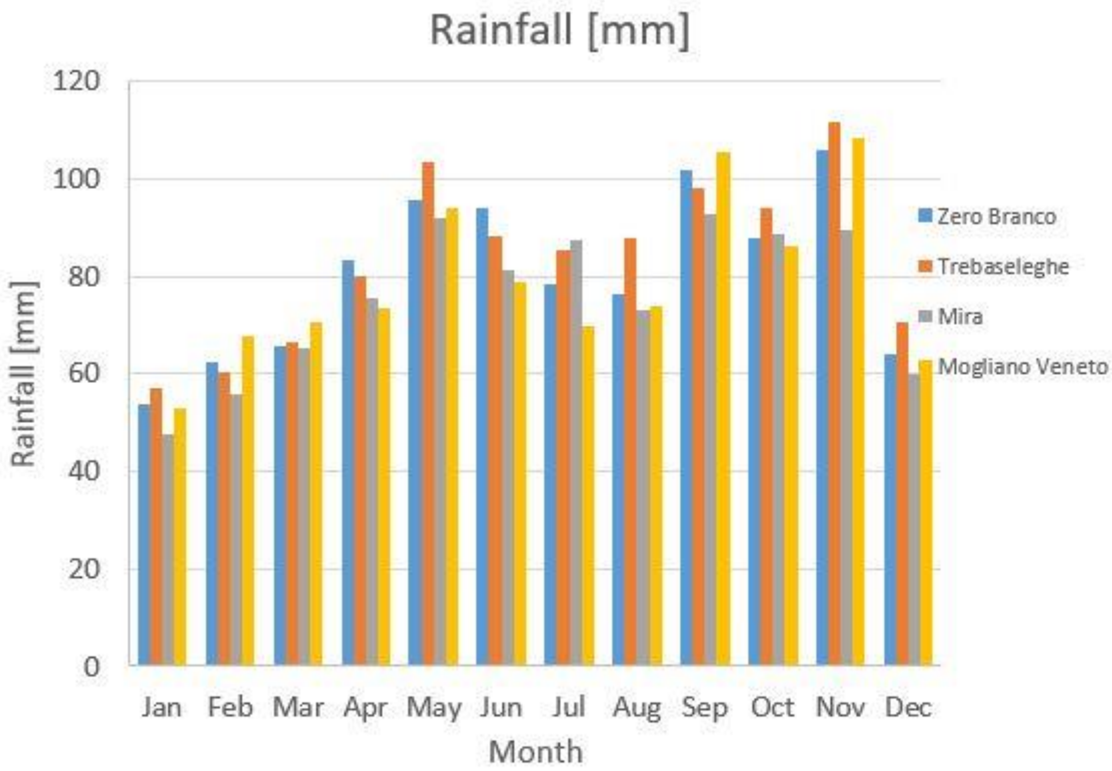


Figure 35 Monthly average rainfall (1994-2018)

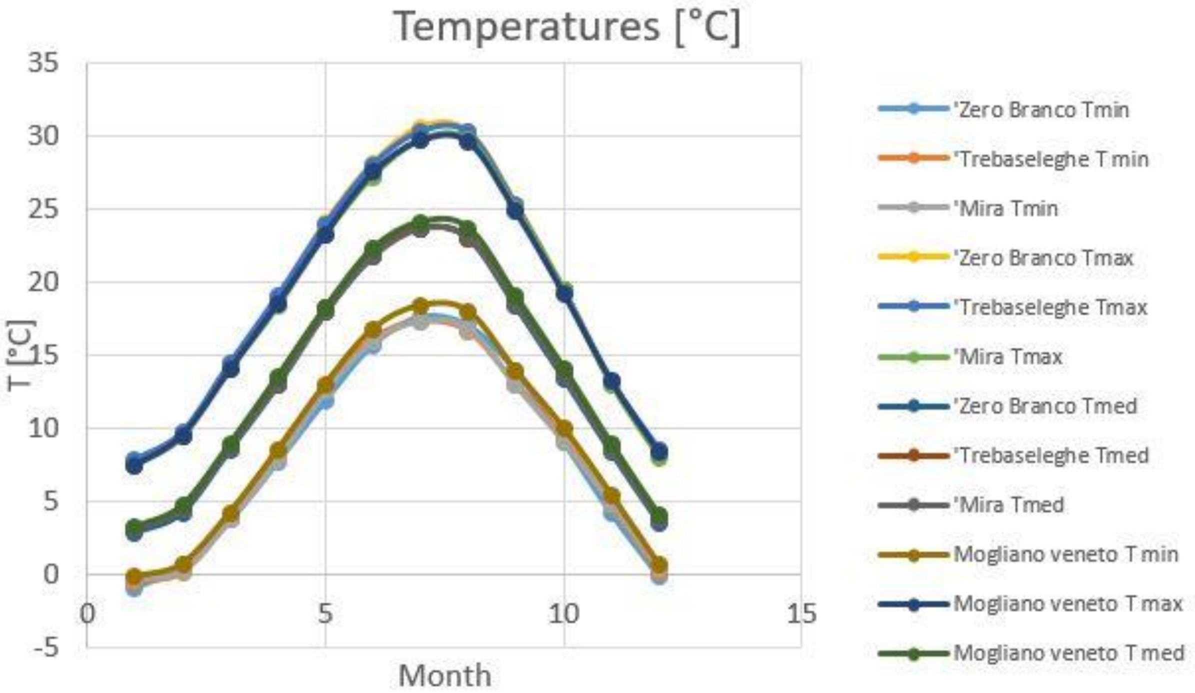


Figure 36. Monthly average temperatures (1994-2018)

Starting from the monthly temperature data recorded by the weather stations, the monthly evapotranspiration value, expressed in mm/month, was defined applying the Thornthwaite method. Through the Thornthwaite formula it is possible to calculate potential evapotranspiration using only the climatic parameter of temperature and latitude.

$$ET_0=16\left(10\ \frac{T_i}{I}\right)^a L_i \qquad (1)$$

The annual thermal index "I" is defined according to the formula

$$\sum_{i=1}^{12} \frac{T_i}{5}^{1.514} \qquad (2)$$

where T_i is the average of the monthly temperatures. Parameter "a" is calculated according to the formula

$$a = 675x10^{-9}xI^3 - 771X10^{-7}xI^{-5}xI + 0.49239 \qquad (3)$$

The parameter "L_i" is a corrective parameter to consider the latitude of the area under investigation.

Fixed north latitude of 45° for Venice, for every month, the L_i value is provided by **Figure 37**.

Latitudine Nord	MESE G	F	M	A	M	G	L	A	S	O	N	D
39°	0,85	0,84	1,03	1,11	1,23	1,24	1,26	1,18	1,04	0,96	0,84	0,82
40°	0,84	0,83	1,03	1,11	1,24	1,25	1,27	1,18	1,04	0,96	0,83	0,81
41°	0,83	0,83	1,03	1,11	1,25	1,26	1,27	1,19	1,04	0,96	0,82	0,80
42°	0,82	0,83	1,03	1,12	1,26	1,27	1,28	1,19	1,04	0,95	0,82	0,79
43°	0,81	0,82	1,02	1,12	1,26	1,28	1,29	1,20	1,04	0,95	0,81	0,77
44°	0,81	0,82	1,02	1,13	1,27	1,29	1,30	1,20	1,04	0,95	0,80	0,76
45°	0,80	0,81	1,02	1,13	1,28	1,29	1,31	1,21	1,04	0,94	0,79	0,75

Figure 37. Astronomical corrective values of ET_0 calculated according to the relation of Thornthwaite[20]

The average evapotranspiration calculated for the years 1984-2018 for the three weather stations analysed, are shown in the **Table 57**, where the monthly average temperatures shown in the following tables.

.

Table 57. Average monthly evapotranspiration for years 1984-2018

Mounth	Zero Branco	Trebaseleghe	Mira	Mogliano Veneto
	ETP	ETP	ETP	ETP
	[mm]	[mm]	[mm]	[mm]
Gen	4.5	4.9	5.1	5.3
Feb	8.1	8.5	8.7	9.3
Mar	27.5	28.2	28.1	29.0
Apr	55.1	57.2	55.2	58.3
Mag	99.2	100.7	98.7	101.1
Giu	132.1	133.3	131.8	136.2
Lug	151.0	150.6	150.8	154.5
Ago	133.7	133.2	134.3	139.3
Set	83.1	84.4	84.1	87.4
Ott	48.3	49.7	49.0	51.6
Nov	20.6	21.1	21.1	22.5
Dic	5.8	6.2	6.1	6.8

Hydrological framework

The hydrological framework is done on the basis of the rainfall depth-duration frequency curves provided by Veneto Region guidelines for flood mitigation measures[21]. The guidelines divide Veneto region in four homogeneous areas from a hydrological perspectives, and provides different rainfall depth-duration frequency curves for each one. As visible from the following picture, the NBS of interest for this study are included in two different homogeneous areas:

- Nicolas buffer strip and Rusteghin wetland: South East coastal area
- Scandolara buffer strip and Salzano wetland: North-East area

The rainfall depth-duration frequency curves provided by Veneto Region, for the two homogeneous areas of interest, are pictured in **Figure 39**, and **Figure 40**.

[20] Antonio Leone; Ambiente e territorio agroforestale: linee guida per la pianificazione sostenibile e gli studi di impatto ambientale

[21] https://www.regione.veneto.it/web/ambiente-e-territorio/compatibilita-idraulica. Access: June 2020

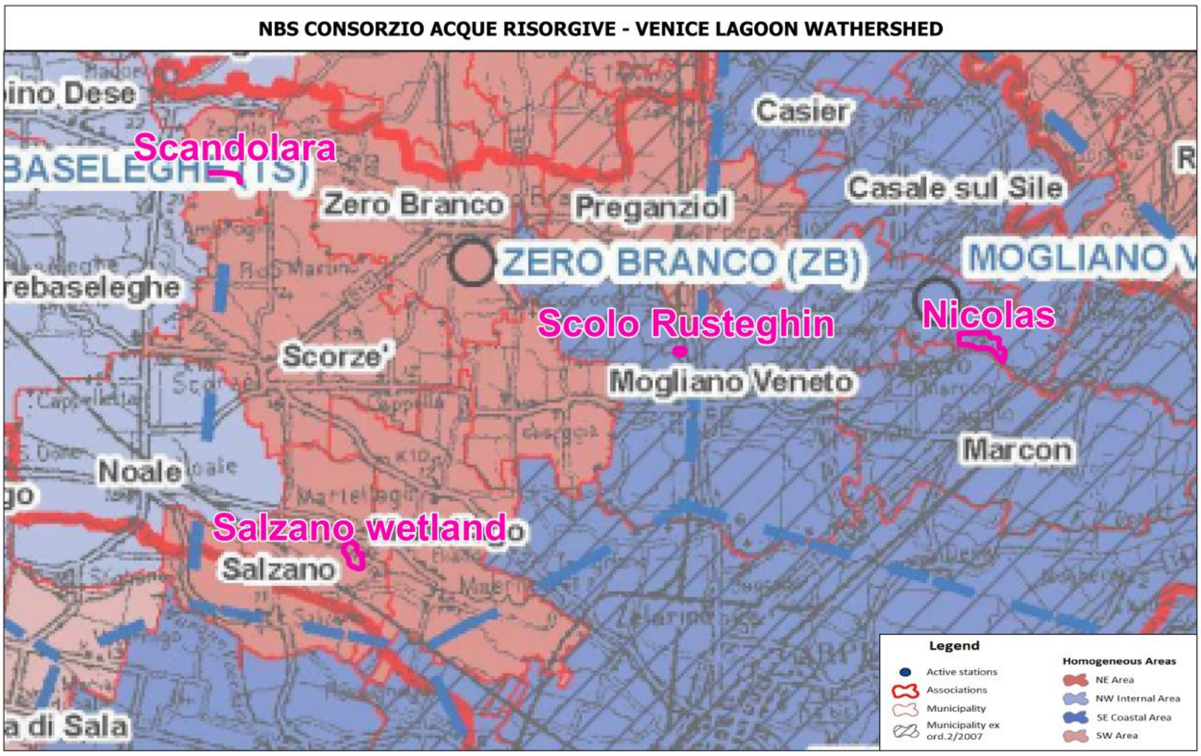


Figure 38. Position of the 4 NBS selected for this study in comparison to the hydrological homogeneous area defined by Veneto Region

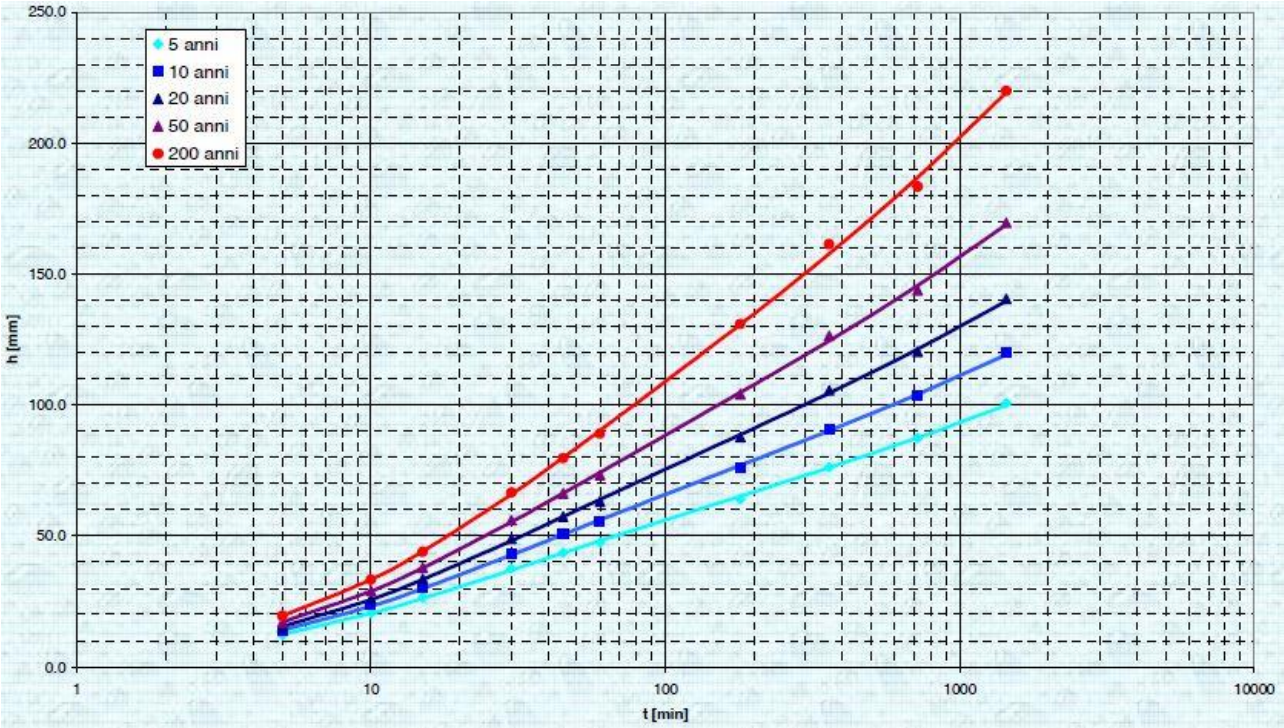


Figure 39. Rainfall depth-duration frequency curves function of different return times (5, 10, 20, 50, 200 years) for the homogeneous area South East coastal Area

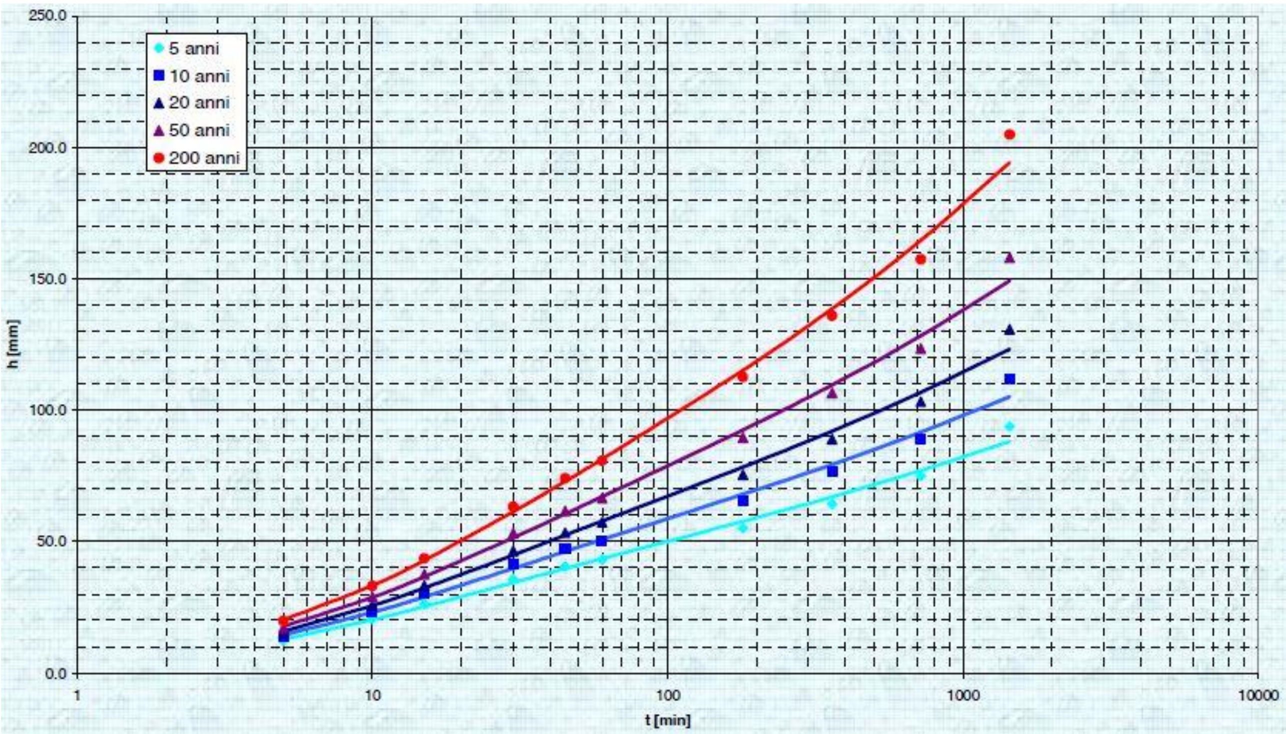


Figure 40. Rainfall depth-duration frequency curves function of different return times (5, 10, 20, 50, 200 years) for the homogeneous area North-East Area

Veneto Region guidelines proposes the following three parameter function to fit the curves

$$h = \frac{a}{(t+b)^c} t$$

where:

— *t* rainfall duration

— *a,b,c* fitting parameters, different for each return time and different homogeneous area

The fitting parameters for the two homogenous areas of interest are reported in **Table 58**, which lead to estimation of the rainfall depths for extreme rainfall events summarised in **Table 59.**

Table 58. Parameters of the rainfall depth-duration frequency curves for the two homogenous area of interest

	South-East – Coastal area			**North-East area**		
Return time *years*	**a** ***mm min^(c-1)***	**b** ***min***	**c** ***-***	**a** ***mm min^(c-1)***	**b** ***min***	**c** ***-***
2	20.3	12	0.821	20.3	12	0.821
5	27.2	13.5	0.82	27.2	13.5	0.82
10	31.4	14.4	0.816	31.4	14.4	0.816
20	35.2	15.3	0.809	35.2	15.3	0.809
30	37.2	15.8	0.805	37.2	15.8	0.805
50	39.7	16.4	0.8	39.7	16.4	0.8
100	42.8	17.3	0.791	42.8	17.3	0.791
200	45.6	18.2	0.783	45.6	18.2	0.783

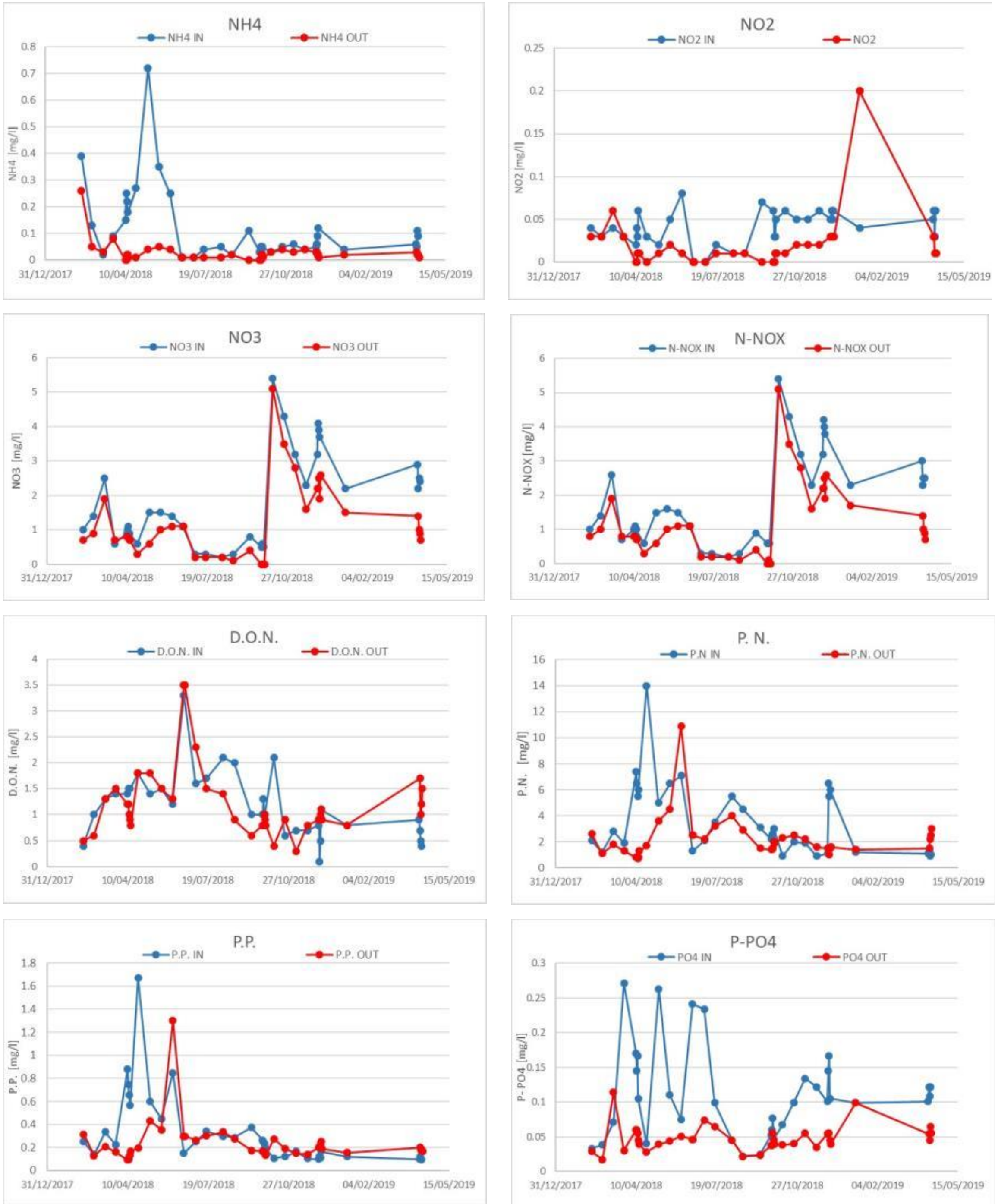
Table 59. Rainfall depths (in mm) for extreme event estimated from the rainfall depth-duration curves for the two homogenous area of interest.

South-East coastal area										
Tr	**Rainfall duration (min)**									
	5	**10**	**15**	**30**	**45**	**60**	**180**	**360**	**720**	**1440**
2	9.9	16.0	20.3	28.3	33.0	36.4	48.8	56.7	65.0	74.1
5	12.4	20.4	26.2	37.0	43.5	48.1	65.3	76.1	87.6	99.9
10	14.0	23.2	29.8	42.6	50.4	56.0	76.7	89.8	103.7	118.7
20	15.4	25.8	33.4	48.3	57.5	64.0	88.8	104.8	121.6	140.0
30	16.2	27.2	35.3	51.4	61.3	68.5	95.7	113.2	131.9	152.3
50	17.1	28.9	37.8	55.3	66.3	74.2	104.6	124.3	145.4	168.5
100	18.4	31.3	41.1	60.8	73.3	82.4	117.8	141.1	166.1	193.8
200	19.4	33.4	44.1	65.8	79.8	90.1	130.5	157.4	186.4	218.8
North-East area										
Tr	**Rainfall duration (min)**									
	5	**10**	**15**	**30**	**45**	**60**	**180**	**360**	**720**	**1440**
2	10.3	16.0	19.8	26.4	30.3	33.1	43.3	50.1	57.3	65.3
5	12.8	20.2	25.2	34.3	39.6	43.4	57.5	66.8	76.7	87.6
10	14.5	23.0	28.9	39.7	46.2	50.7	67.9	79.2	91.4	104.9
20	16.0	25.7	32.4	45.0	52.5	57.8	78.4	92.1	106.9	123.3
30	16.7	27.0	34.2	47.8	56.0	61.8	84.5	99.6	116.0	134.4
50	17.8	28.9	36.7	51.6	60.7	67.2	92.6	109.8	128.6	149.6
100	18.9	31.0	39.7	56.3	66.6	74.0	103.4	123.4	145.5	170.5
200	20.1	33.2	42.8	61.2	72.8	81.3	115.0	138.3	164.2	193.8

ANNEX 3: Detailed analysis of the two wetland performances

Rusteghin wetland

The temporal trends of the pollutant concentrations for the input and output section of the Rusteghin wetland are shown in **Figure 41**.



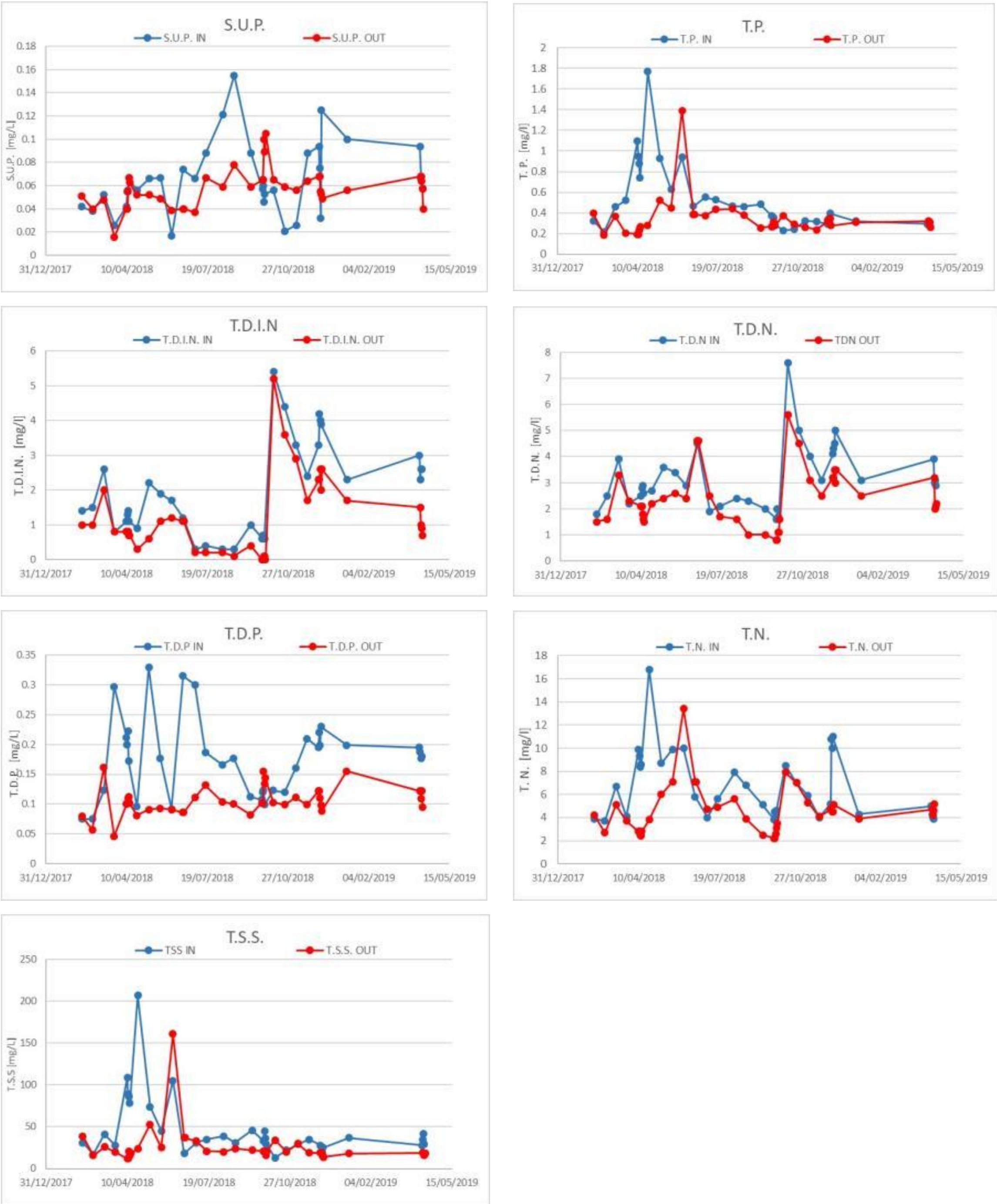
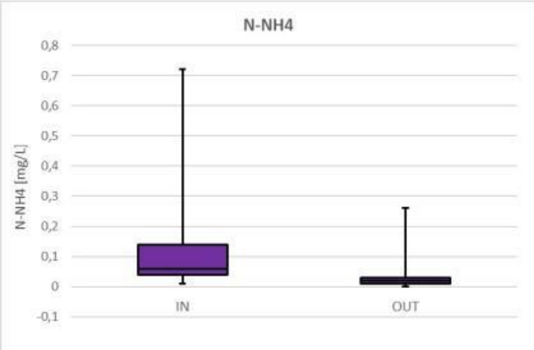
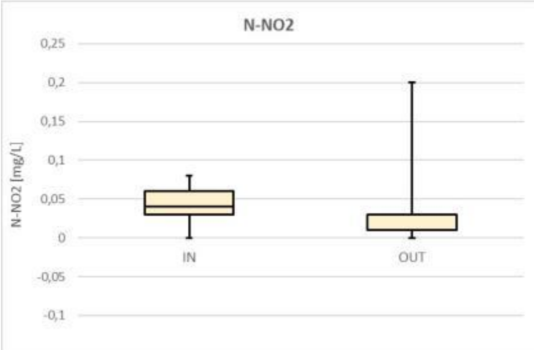
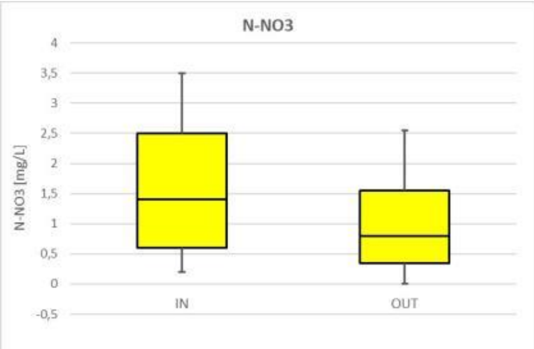


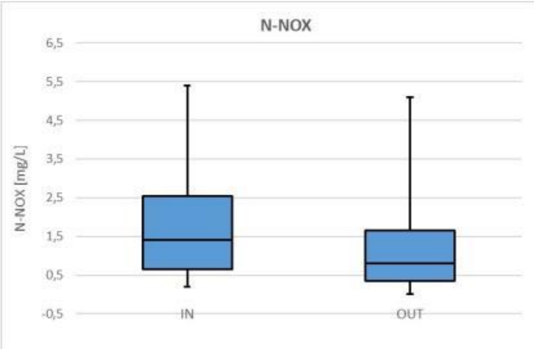
Figure 41. Influent and effluent pollutant concentration for the Rusteghin wetland

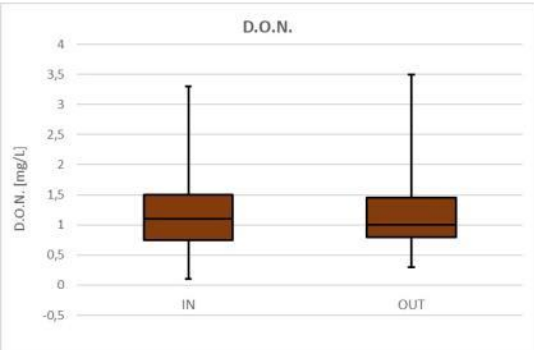
The results of the statistical analysis of the available dataset are reported in **Figure 42**.

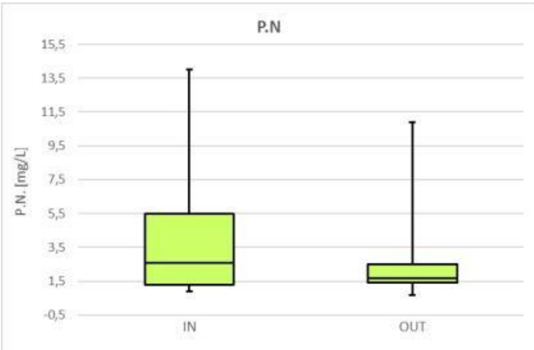

N-NH4
N-NH4 [mg/L]
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
-0,1
IN
OUT

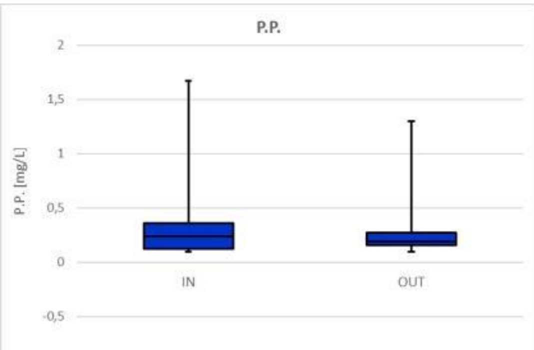

N-NO2
N-NO2 [mg/L]
0,25
0,2
0,15
0,1
0,05
0
-0,05
-0,1
IN
OUT

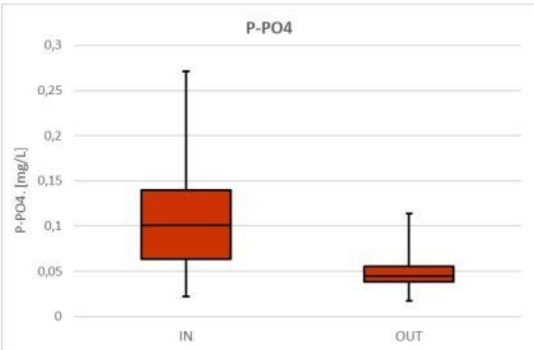

N-NO3
N-NO3 [mg/L]
4
3,5
3
2,5
2
1,5
1
0,5
0
-0,5
IN
OUT

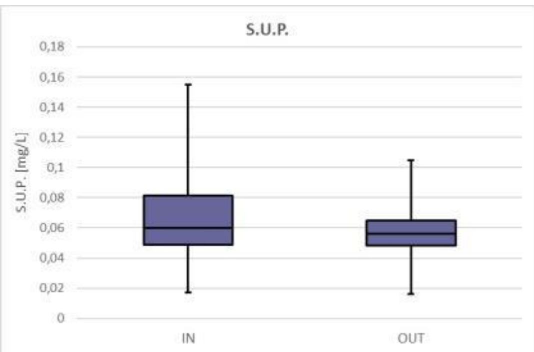

N-NOX
N-NOX [mg/L]
6,5
5,5
4,5
3,5
2,5
1,5
0,5
-0,5
IN
OUT

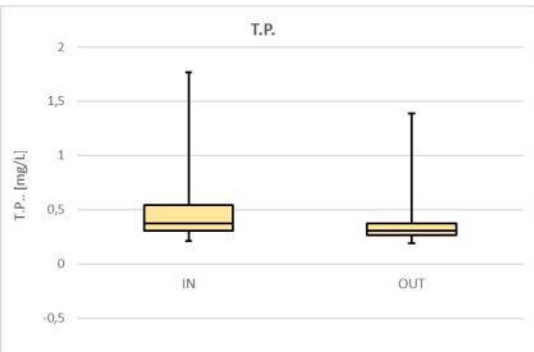

D.O.N.
D.O.N. [mg/L]
4
3,5
3
2,5
2
1,5
1
0,5
0
-0,5
IN
OUT


P.N
P.N. [mg/L]
15,5
13,5
11,5
9,5
7,5
5,5
3,5
1,5
-0,5
IN
OUT


P.P.
P.P. [mg/L]
2
1,5
1
0,5
0
-0,5
IN
OUT


P-PO4
P-PO4. [mg/L]
0,3
0,25
0,2
0,15
0,1
0,05
0
IN
OUT


S.U.P.
S.U.P. [mg/L]
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
IN
OUT


T.P.
T.P.. [mg/L]
2
1,5
1
0,5
0
-0,5
IN
OUT

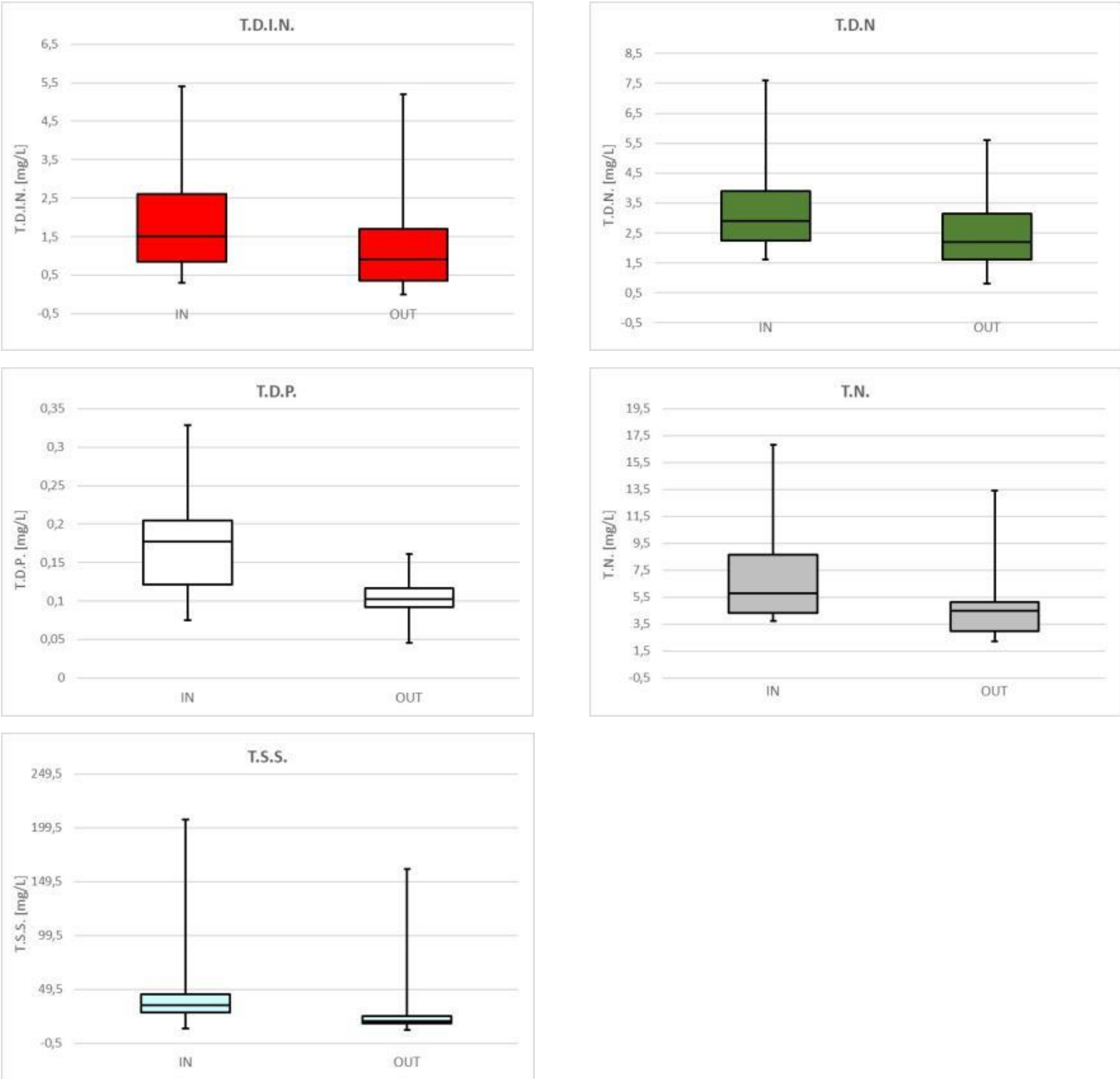


Figure 42. Pollutant box-whisker plots for the Rusteghin wetland.

An unpaired *t*-test with one-tail distribution was used to check the statistical significance of the difference between influent and effluent concentrations. The influent and effluent values resulted statistically significant for the following pollutants $N\text{-}NH_4$, $N\text{-}NO_2$,$N\text{-}NO_3$, N-NOX, T.D.I.N., T.D.N, P.N., T.N., $P\text{-}PO_4$, T.D.P., T.P., S.S.T. (*t*-test equal to 0.02%, 0.05%, 1.58%, 1.25%, 0.60%, 0.57%, 0.00%, 0.05%, 0.0002%, 0.00002%, 0.47%, 0.39% respectively). The value of the t-test is equal to 45.39%, 8.10% and 6.50% for the pollutants D.O.N., S.U.P. and P.P.

The removed mass load is given as the difference between the input and output mass load, and expressed as a percentage, assuming mean values for pollutant concentrations. The mass load removed per unit of area, for each single month, is defined considering the effective surface that participates in the treatment process, equal to 2.9 ha (floodplains at an altitude of 6.5 m and pound area at an altitude of 6 m).

The results are reported in the following table. Positive removal efficiencies have been observed for almost all the pollutants and all the monitored months. Only few negative values were observed for TN, TP, and TSS. Since negative performance were never observed for dissolved nutrients ($N\text{-}NO_3^-$ and $P\text{-}PO_4^{3-}$), these events are probably related to temporary diluted influent loads and small released of nutrients attached to TSS. Similar events can be expected in FWS for diffuse pollution control, but they do not compromise the capability of FWS to remove nutrients considering annual mass balance performance (Kadlec and Wallace, 2009).

Table 60. Monthly pollutant mass balances for the Rusteghin wetland.

N-NO3						
Month	**C_{ING} [mg/L]**	**M_{ING} [kg/m]**	**C_{OUT} [mg/L]**	**M_{OUT} [kg/m]**	**M_{REM} [%]**	**R_{mrem} [g/m^2/m]**
Jan	3.8*	138	0.8*	92	33%	1.6
Feb	3.8	156	0.8	105	32%	1.7
Mar	5.4	279	1.3	238	14%	1.4
Apr	10.6	100	0.7	74	26%	0.9
May	9.3	224	0.8	117	48%	3.7
Jun	7.9	271	1.1	234	15%	1.3
Jul	4.8	67	0.2	43	36%	0.8
Aug	7.4	51	0.2	30	43%	0.7
Sep	4.5	73	0.1	8	89%	2.2
Oct	7.8	761	4.3	675	11%	2.9
Nov	5.0	440	2.2	356	19%	2.9
Dec	9.3	414	2.2	240	42%	6.0

* January influent and effluent concentrations assumed equal to February for lack of direct measurement

TN						
Month	**C_{ING} [mg/L]**	**M_{ING} [kg/m]**	**C_{OUT} [mg/L]**	**M_{OUT} [kg/m]**	**M_{REM} [%]**	**R_{mrem} [g/m^2/m]**
Jan	3.8*	437	3.45*	397	9%	1.4
Feb	3.8	493	3.45	454	8%	1.4
Mar	5.4	972	4.40	806	17%	5.7
Apr	10.6	1181	2.85	308	74%	30.1
May	9.3	1389	6.55	955	31%	14.9
Jun	7.9	1714	9.20	1955	-12%	-8.3
Jul	4.8	1067	4.80	1043	4%	0.9
Aug	7.4	1508	4.75	947	38%	19.3
Sep	4.5	541	2.68	316	42%	7.8
Oct	7.8	1216	7.45	1170	4%	1.6
Nov	5.0	792	4.70	761	4%	1.1
Dec	9.3	1028	4.70	524	49%	17.4

* January influent and effluent concentrations assumed equal to February for lack of direct measurement

P-PO4						
Month	**C_{ING} [mg/L]**	**M_{ING} [kg/m]**	**C_{OUT} [mg/L]**	**M_{OUT} [kg/m]**	**M_{REM} [%]**	**R_{mrem} [g/m^2/m]**
Jan	0.04*	4.1	0.02*	2.6	35%	0.05
Feb	0.04	4.6	0.02	3.0	34%	0.05
Mar	0.17	30.8	0.07	13.2	57%	0.61
Apr	0.13	14.0	0.05	5.2	63%	0.30
May	0.19	27.9	0.04	6.1	78%	0.75
Jun	0.16	34.3	0.05	10.1	70%	0.83
Jul	0.17	37.0	0.07	15.1	59%	0.76
Aug	0.03	6.9	0.03	6.7	3%	0.01
Sep	0.05	6.3	0.04	4.6	26%	0.06
Oct	0.08	13.0	0.04	6.1	53%	0.24
Nov	0.13	20.5	0.05	7.3	64%	0.45
Dec	0.13	14.4	0.05	5.5	62%	0.31

* January influent and effluent concentrations assumed equal to February for lack of direct measurement

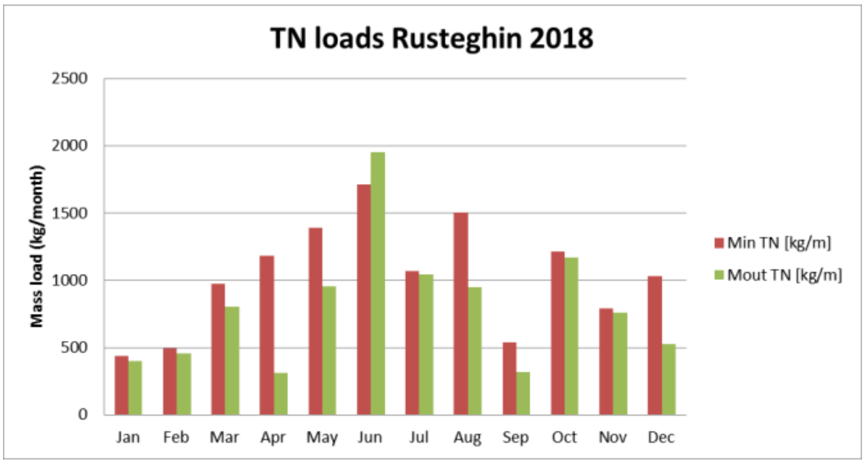
TP						
Month	**C_{ING} [mg/L]**	**M_{ING} [kg/m]**	**C_{OUT} [mg/L]**	**M_{OUT} [kg/m]**	**M_{REM} [%]**	**R_{mrem} [g/m²/m]**
Jan	0.27*	31	0.29*	34	-8%	-0.09
Feb	0.27	35	0.29	38	-9%	-0.11
Mar	0.49	88	0.29	53	40%	1.22
Apr	1.08	121	0.24	25	79%	3.29
May	0.78	116	0.48	71	39%	1.57
Jun	0.70	152	0.72	153	0%	-0.02
Jul	0.54	120	0.40	88	27%	1.11
Aug	0.46	95	0.41	81	15%	0.48
Sep	0.38	46	0.28	33	29%	0.45
Oct	0.24	37	0.33	52	-41%	-0.52
Nov	0.32	51	0.25	40	21%	0.37
Dec	0.34	37	0.32	36	4%	0.05

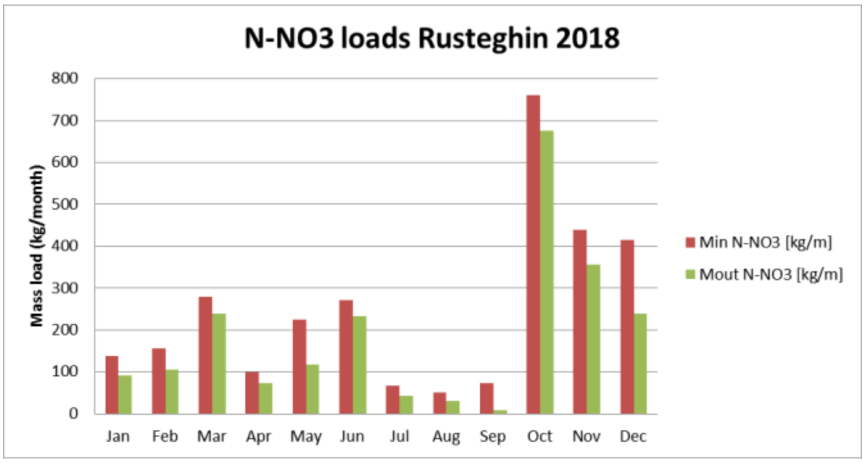
* January influent and effluent concentrations assumed equal to February for lack of direct measurement

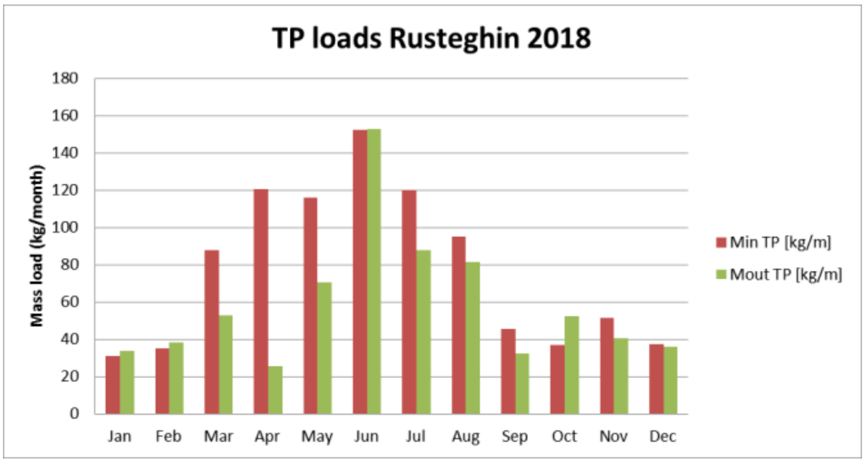
TSS						
Month	**C_{ING} [mg/L]**	**M_{ING} [kg/m]**	**C_{OUT} [mg/L]**	**M_{OUT} [kg/m]**	**M_{REM} [%]**	**R_{mrem} [g/m²/m]**
Jan	24.0*	2759	27.5*	3165	-15%	-14.0
Feb	24.0	3117	27.5	3619	-16%	-17.3
Mar	34.5	6207	23.0	4211	32%	68.8
Apr	113.8	12681	17.0	1836	86%	373.7
May	59.5	8885	39.0	5688	36%	110.2
Jun	61.5	13346	78.3	16650	-25%	-113.9
Jul	33.0	7339	27.0	5865	20%	50.8
Aug	35.0	7179	22.0	4386	39%	96.2
Sep	37.8	4585	20.0	2352	49%	76.9
Oct	17.5	2745	27.0	4241	-54%	-51.5
Nov	32.0	5120	24.5	3969	22%	39.7
Dec	23.0	2557	16.6	1850	28%	24.4

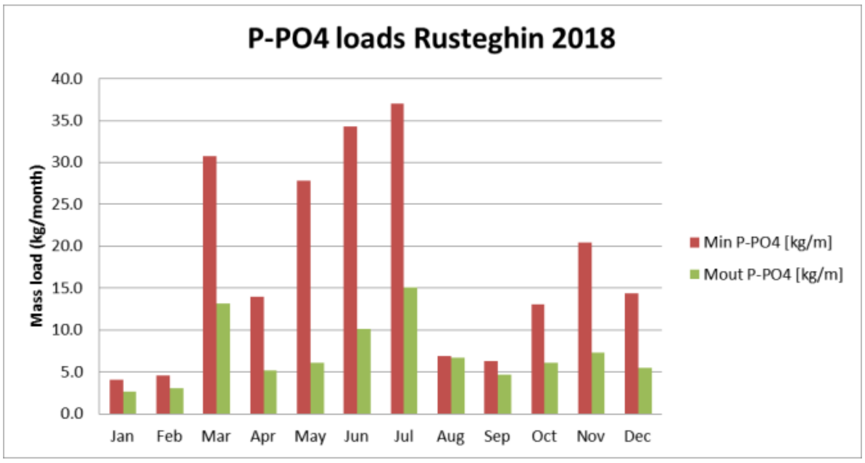
* January influent and effluent concentrations assumed equal to February for lack of direct measurement

Pollutant mass loads are reported in **Figure 43**. The average percentage of pollutants removal, for the year 2018, is shown in **Table 7** in the main text.


TN loads Rusteghin 2018
Mass load (kg/month)
2500
2000
1500
1000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Min TN [kg/m]
Mout TN [kg/m]


N-NO3 loads Rusteghin 2018
Mass load (kg/month)
800
700
600
500
400
300
200
100
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Min N-NO3 [kg/m]
Mout N-NO3 [kg/m]


TP loads Rusteghin 2018
Mass load (kg/month)
180
160
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Min TP [kg/m]
Mout TP [kg/m]


P-PO4 loads Rusteghin 2018
Mass load (kg/month)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Min P-PO4 [kg/m]
Mout P-PO4 [kg/m]

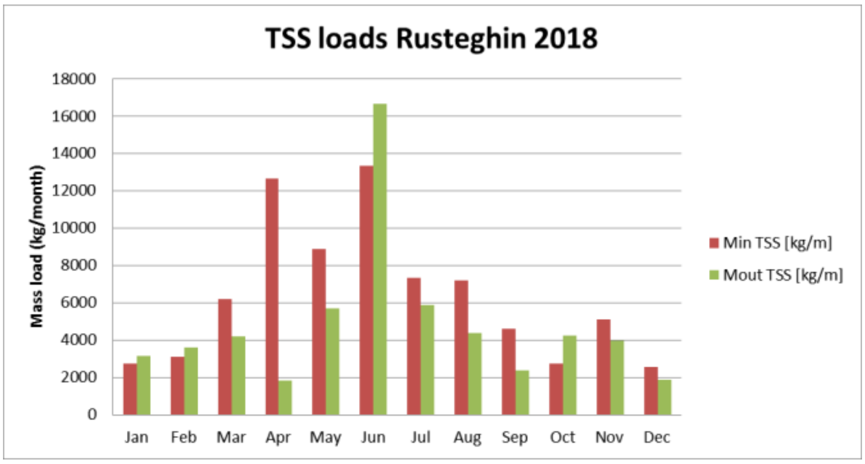


Figure 43. Pollutant mass load for Rusteghin wetland in 2018

Salzano wetland

The routine monitoring conducted from June 2009 to June 2010 by the University of Padova[22], made it possible to acquire the temporal trend of the concentrations of TN, TP and TSS, for the input and output section of the Salzano wetland (see following figures).

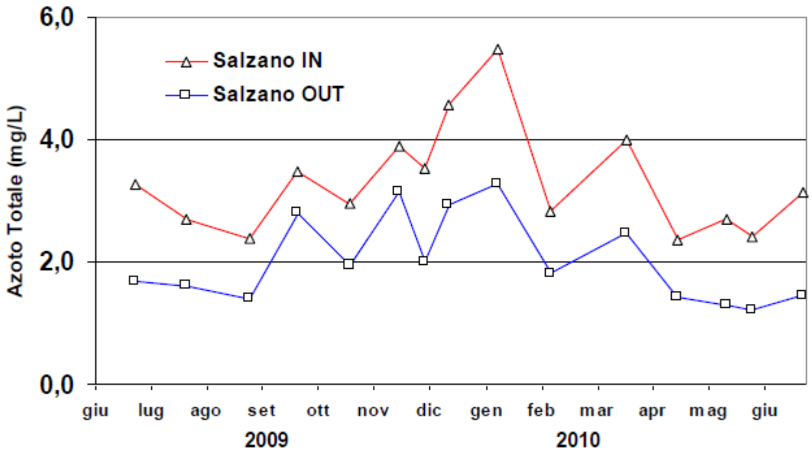


Figure 44. TN concentration for the 2009-2010 monitoring campaign for the Salzano wetland.

[22] Università degli Studi di Padova Facoltà di Ingegneria Dipartimento di Processi Chimici dell'Ingegneria Laboratorio Analisi dei Sistemi Ambientali; *MONITORAGGIO DELLE CAVE DI SALZANO 2009 – 2010*

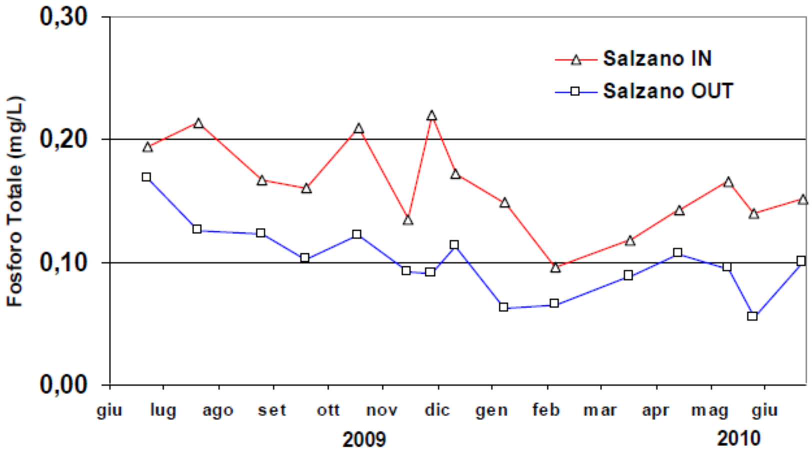


Figure 45. TP concentration for the 2009-2010 monitoring campaign for the Salzano wetland.

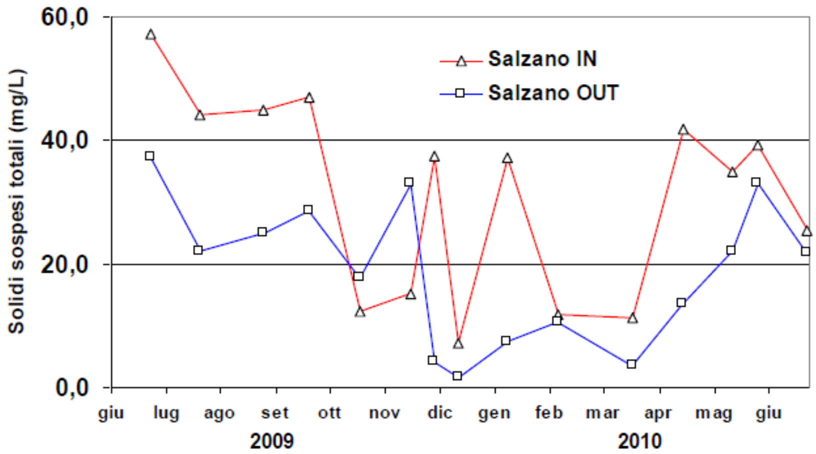


Figure 46. Influent and effluent TSS concentration for the Salzano wetland.

The results of the statistical analysis of the available dataset are reported in **Figure 47**. An unpaired *t*-test with one-tail distribution was used to check the statistically significance of the influent and effluent concentrations. The influent and effluent values resulted statistically significant for all the pollutant parameters (*t*-test equal to 0.01%, 0.001%, and 1.37% for TN, TP, and TSS, respectively).

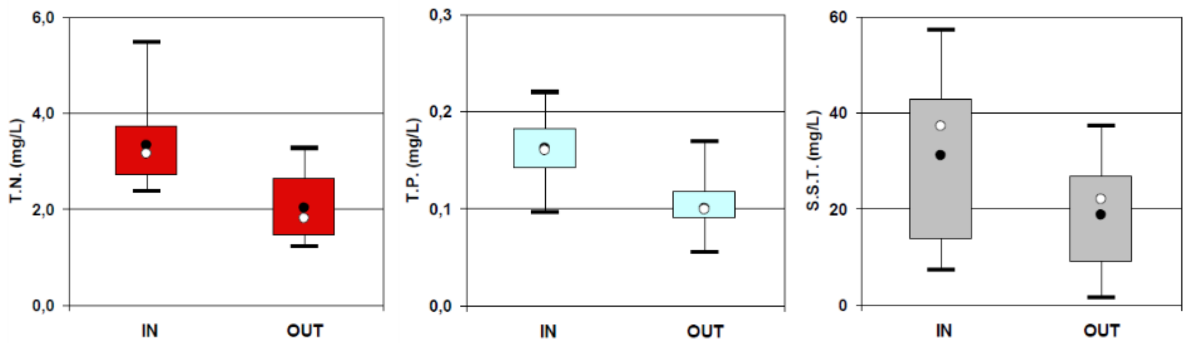


Figure 47. TN, TP, TSS box-whisker plots for the Salzano wetland.

ANNEX 4: Value Transfer methodology

List of acronyms

NBS	Nature Based Solution
MA	Millennium Ecosystem Assessment
TEEB	The Economics of Ecosystems and Biodiversity
VT	Value Transfer
GDP	Gross Domestic Product
PPP	Purchasing Power Parity
ES	Ecosystem Service
WTP	Willingness to Pay

Value Transfer: general approach

Value transfer (VT) is an economic valuation method which can be applied to ecosystems, or goods and services from an ecosystem. VT provides empirical estimates of the subject of interest, when time, funding or other constraints prevent the use of primary research to generate these estimates. Indeed, it allows extrapolating research results of pre-existing primary studies at one or more *study sites* so that to estimate, indirectly, the value of some characteristics of similar unstudied *policy sites* (Rolfe *et al.*, 2015).

The estimate transferred is usually expressed as a value per unit. Whether to choose one set of units or another depends on the nature of the available information from case studies, which is a partial consequence of the nature of the ecosystem service (ES) valuated. For example, recreation values may be expressed per person rather than per unit of ecosystem area. On the other hand, services as carbon sequestration cannot be straightforwardly expressed in per-beneficiary terms while per unit area measurements result more adequate. The selection of appropriate units in which to transfer values also depends on the available information for the policy site on which the value is transferred (Brander, 2013).

The process of value transfer analysis follows a number of common steps, described in the table below.

Table 61. Value Transfer phases (Brander, 2013)

Step 1 Policy site	**a**	Describe policy, investment or project
	b	Identify impacted ES
	c	Describe baseline level of provision
	d	Describe change in provision
	e	Describe the population of beneficiaries
Step 2 Study site	**a**	Collect existing information
	b	Assess relevance and quality

Step 3 **Transfer values**	a	Select appropriate units
	b	Select transfer method
	c	Estimate policy site unit values
	d	Aggregate across policy site population and change in ecosystem service provision
	e	Assess uncertainties
Step 4 **Results**	a	Report results
	b	Communicate uncertainties

These steps are common to any VT exercise, irrespectively of the method chosen; indeed, VT can be applied with four different techniques (Barton, 2017). The scheme is selected depending on the availability of study site value data, the similarity of available study sites and policy sites, and the number and variety of policy sites to be assessed (Brander, 2013). The four methodologies of VT are:

- **Unit Value Transfer:** Unit value transfer is preferred when study and policy sites are closely similar; indeed, even one, highly comparable, study site is sufficient to carry out the measurement. This methodology implies that values from the study site are multiplied by the number of units of the policy site without any form of adjustment and the resulting value estimates are assumed to be correct "on average".

- **Adjusted Unit Value Transfer**. The method is similar to Unit Value Transfer but the estimates are transferred with simple adjustments; typically, they aim at reducing differences between study and policy site, with respect to income and purchasing power, for example. The use of unit values or a simple value function estimate (third technique) potentially produces lower transfer errors in cases where highly similar sites are available (Brander et al., 2013).

- **Value Function Transfer.** Through the input of the policy site information on each of the explanatory variables in the value function – estimated through a regression analysis - an estimate of the dependent variable at the policy site (i.e. the unit value) is obtained. Value function transfer and meta-analytic function transfer (fourth technique) are preferred when there are important differences between study sites and policy sites.

- **Meta-analytic Function Transfer**. They are close to value function transfer, but the value function is generated from a meta-analysis of many valuation study sites collected into a database.

Over the past two decades the literature on VT has been in large part focused on the validity and accuracy of the method (Rolfe et al., 2015). Indeed, transferred values can significantly differ from the real value of the ecosystem service under consideration. Uncertainties occurring in the process of VT may arise both from inaccuracies from the original primary studies - denoted *measurement errors*- and generating from the transfer process itself -*generalization errors* (Rolfe et a., 2015). The latter occurs when values are transferred to policy sites that are different without carefully accounting for the above mention differences (Brander et al., 2013).

Boyle and Bergstrom (1992) were among the first to recommend ideal criteria to guarantee the more reliable transfer of value as possible, as highlighted by Rolfe et al. (2015). The authors report the key requirements, suggested by Bennett in 2006, to reduce uncertainty:

- the biophysical conditions of the selected study site must be similar to those in the policy site
- the scale of environmental change occurred in the study site, as a consequence of policy action, must approximate that of the policy site
- the socioeconomic characteristics of the population impacted by the change must be comparable between the study and policy sites;
- the source study needs to be reliable.

The degree to which all these characteristics are met determines what is called correspondence, which is essential in approving the accuracy of a VT (Plummer, 2009).

Exceptions to this principle are often noted. Virtually, all transfers violate these ideal criteria to some degree (Rolfe et al., 2015). What is important is the maximum possible reduction of detected differences between the context of implementation and the source case/cases.

In the table below are summarized the main adjustments applied in VT exercises.

Table 62. Methods of value adjustments (Brander, 2013)

Adjustments	**Differences**	**Method**	**Formula**
Income	Demand for most goods and services, changes with income; it is necessary, when transferring values for ecosystem services across populations with different incomes, to account for this effect.	Using information on the responsiveness of willingness-to-pay (WTP) for the ecosystem service in question with respect to income. In cases where this is not available, Gross Domestic Product (GDP) per capita can be used.	$WTP_P = WTP_S (Y_P/Y_S)^E$ $_P$ =Policy site $_S$ =Study site Y= income per capita ^{E} = income elasticity to WTP
Year / **Price Level**	Value estimates are reported at price levels for a particular year. As inflation causes general price levels in a country to rise over time, any given amount of money is worth less and less, in terms of the goods and services that it can purchase.	All values can be adjusted using available domestic price indices or GDP deflator that measure the annual rate of price change in an economy - available from the World Bank World Development Indicators.	$WTP_P = WTP_S (D_P/D_S)$ D= GDP deflator index for the reference year
PPP / **Currency**	A dollar worth less in a country with a high general price level than in a country with a low price level (Purchasing Power differences); the same amount of money may represent a different quantity of goods and services (and therefore utility) in different places.	To transfer values between countries involves using purchasing power parity adjusted exchange rates - available for all countries in the World Bank World Development Indicators.	$WTP_P = WTP_S \times E$ WTP expressed in original E= PPP adjusted exchange rate
Time	When ecosystem services provided in future time periods are considered, it is necessary to account for the determinants of values in each future year.	Projections of how national incomes and populations are likely to change; discounting future costs and benefits to reflect their present values	PV = FV / (1+r) PV= present value FV= future value r= discount rate

		n= years in which the cost/benefit occurs
Culture / Preferences	Different people and cultures have different perceptions, preferences and values for ecosystem services.	Cultural considerations should be reflected in the selection of relevant primary valuation studies from which values are transferred.
Scarcity / Substitutes / Complements	The local scarcity or abundance of an ecosystem service is a determinant of its value; differences in the availability of substitute or complementary resources should be controlled.	Controlling for such factors in a value transfer application is challenging. Meta-analytic value functions that include explanatory variables for scarcity, substitutes and complements provide a means to account for these factors.

An adequate characterization of the context is a problematic task investigated in several analyses of ecosystem service values (De Groot *et al.*, 2012). Through the literature review different approaches to standardisation have been identified; Brenner (2007) in his value transfer exercise standardizes ecosystem service values to average 2004 U.S. dollar per hectare, per year; he harmonizes values from different years using annual Consumer Price Index variation for Catalonia (INE 2006b) and converts the Euro to U.S. dollar using the fix exchange rate ($ 1 = 133.94 Pesetas and 166.38 Pesetas = 1 Euro) set in 1994 by the Bank of Spain.

In the database, specifically designed to support the application of value transfer exercises and meta-analysis, De Groot (2012), explains that the values were standardized into the common metric of 2007 International dollars per hectare per year and converted into the official local currency, if necessary. They were then adjusted to 2007 values using the GDP deflators of each country and converted to international dollars using Purchasing Power Parity (PPP) conversion factors of 2007 (based on World Bank, 2009). In addition, WTP per person or household per year were converted to per hectare per year values - given information on the case study area and population size.

Ghemardi (2010) standardized values used for meta-analysis to US$ per hectare per year. WTP per person or household were converted in per hectare per year values. Discount rate and time period given in the primary studies were used to capitalize value estimates. Values referring to different years were deflated using appropriate factors from the World Bank Millennium Development Indicators (2006), while differences in purchasing power among the countries were accounted for by the PPP index provided by the Penn World Table.

Alternatively, there are different ways to communicate uncertainties in value transfer, when adjustments are not enough to reduce differences between study and policy sites (Brander, 2013):

- In cases where is not possible to select a preferable value among multiple primary value estimates, a **range of values** can be presented to explicit the variability of the estimates.
- Information on the **distribution of value** estimates (average, median and standard error of the average value) can be presented.
- **Confidence intervals** can be displayed; they are usually expressed as a range of values within which the actual value lies with a given confidence level or probability.
- **Sensitivity analysis** might be carried out.
- **Transfer errors** can be computed.

Value Transfer: literature review

It is broadly recognised that Nature Based Solutions (NBS) are multifunctional. As stated by the European Commission indeed, NBS provide economic, social, and environmental benefits (EU, 2015). The capacity to produce several services, simultaneously and at the same locality, is one of their most important attributes in comparison to grey infrastructures (Somarakis et al., 2019).

Benefits from wetland and buffer strips

The aim of the literature review was to collect aggregate researches, such as value transfer studies, meta-analysis or narrative reviews, highlighting the most common benefits (Ecosystem Services) deriving from wetland and buffer strips implementation. Drawing on web-based (Google Scholar) sources, the assortment had followed a keyword process with different combinations of the terms "Wetlands", "Buffer Strips", "Benefits", "Nature-Based Solutions", "Multiple functions", "Multiple Benefits", "Meta-analysis", "Review". The studies considered in this phase do not attempt to give a monetary evaluation of benefits but they do identify the ES potentially evaluable – even though some of them reported market values for single benefits or for the aggregate NBS.

24 studies were selected, with the oldest dating to 1993 and the most recent one to 2019 (see References – Benefits Identification). The geographic focus has been on Italy, Europe and North America, even though in this first phase other advanced economies and global reviews were allowed. Through this phase, 19 ES were identified.

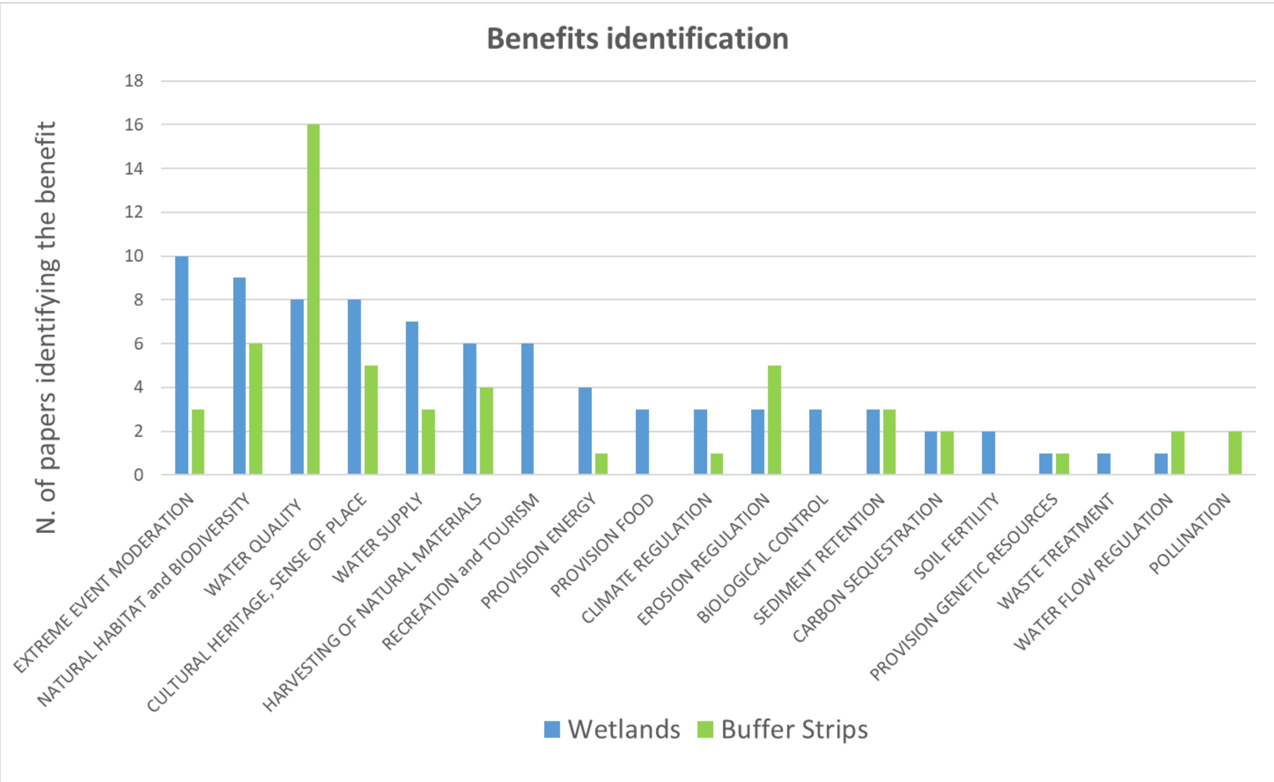


Figure 48. Identification of benefits from Wetlands and Buffer Strips implementation, through literature review.

One problem which immediately rose is the use of different ES classification systems. Among the researches adopting a classification, Millennium Ecosystem Assessment (MA) was the most used, followed by the Economics of Ecosystem and Biodiversity (TEEB). Instead, we decided to categorize the benefits according to the Common International Classification of Ecosystem

Services (CICES) 4.3 because it builds on the previews two and it introduce a detailed hierarchical structure (Potschin & Haines-Young, 2016). Another reason is that it is the only classification including a specific category for nuisance (Code: 2.1.2.3) - which is of our interest.

As displayed in **Figure 48**, some benefits associated with Wetlands or Buffer Strips implementation, were described by many studies while other were identified just by one or two researchers.

Selected benefits

The 19 benefits identified have been filtered out to select the most appropriate ones in the context of analysed case study. The selection has been carried out through expert judgment and it is based on the results of the analysis done in the main report. The ES are shown in table below, associated with a brief description of the physical measurement of the service and the expected effects.

Table 63. Identified NBS benefits and their main features

Category	Benefit	CICES 4.3	Example indicators	Effect
ENVIRONMENT	WATER SUPPLY	1.1.2.1; 1.2.2.1	Increase in surface/ground water quantity (m3/ha/yr): flow, retention, storage of fresh water	↑
	NATURAL HABITAT and BIODIVERSITY SUPPORT	2.3.1.2	Increase in the number of resident species of plants and animals (including rare and endangered species); improvements in habitat diversity and integrity; maintenance of minimum critical surface area, etc.	↑
	WATER QUALITY	2.3.4.1	Removal of nutrients: Nitrogen, Phosphorus, (Pesticides) (kg/ha/yr)	↑
SOCIAL	CARBON SEQUESTRATION	2.3.5.1	Quantity of GHG potentially abated: sequestration / storage capacity per hectare (tonsCo2/ha)	↑
	FLOOD RISK	2.2.2.2	Increased water storage (buffer) capacity in m3; reduced peak flows; ecosystem structure characteristics; Reduction of flood danger and prevented damage to infrastructure	↑

Category	Benefit	CICES 4.3	Example indicators	Effect
	NUISANCE (ODOURS, RUMORS, OBSTACLES TO COMMON FARMING PRACTICES)	2.1.2.3	Reduction in market good price caused by external cost; real estate value	↓
	RECREATION and TOURISM	3.1.1.1; 3.1.1.2	Presence of landscape & wildlife features suitable for recreational activities: entrance fee/visitor per year, WTP/person/year for protection interventions; actual or potential use	↑
	VISUAL IMPACT/AMENITY and AESTHETIC	3.1.2.5	Presence of landscape features of aesthetic appreciation; number of houses bordering natural areas; real estate values; number of users of scenic routes	↑ ↓
	AWARENESS/ EDUCATION	3.1.2.2	Number of education trips/classes visiting; Presence of features with special educational and scientific value/interest; number of scientific studies, etc.	↑

Collection of study sites economic values

As anticipated, through the literature review economic assessments of ES were not collected; thus, only for those selected environmental and social benefits we carried out a research on existing economic valuation so that to proceed with the Value Transfer.

Among the techniques explained above we estimate the economic value of NBS benefits through Adjusted Unit Value Transfer. The unit value may come from one or few relevant study sites.

It follows from the constraints applied in this phase that only few empirical studies have been chosen as candidates, in comparison with the required procedure for Meta-Analytic Function Transfers. Indeed, a set of decision rules has been applied in the selection of valuation studies.

Detailed steps involved in **Adjusted Unit Value Transfer**

i. From the selected study site, obtain or compute the value per unit (e.g. USD per household, USD per hectare). The unit value **may be from a single study site valuation or the average unit value from multiple study sites, if more than one study site is found to be relevant**.

ii. Where necessary and feasible, **adjust the study site unit value to reflect any identified differences between the study site and the policy site**. Common variations are incomes or price levels. Later in the chapter will be presented potentially important adjustments and resolution methods to solve the more common differences.

iii. For the policy site, **quantify the ecosystem service in the units** in which the transfer is being made (e.g. visits, hectares).

iv. Multiply the unit value by the change units at the policy site to **estimate the aggregate value** in ecosystem service value.

Source: Brander (2013)

They need to:

- be located in regions sharing similar socio-economic characteristics with Italy (IT, EU, North America) and located at similar latitudes;
- the environmental goods and services valued need to be relevant for the purpose of the benefits of the policy sites, thus economic valuations of ecosystem services deriving from the implementation of Nature Based Solution have been preferred, despite this may exclude a number of ES valuation not related to Wetland and Buffer Strips. Some exceptions were allowed for those benefits which would report comparable values also in case of general ES valuations (as for Water Quality) and other exceptions were allowed for those benefits of our interest which had not been widely assessed in preview NBS studies (i.e. Nuisance and Awareness/Education).

Overall, the valuation studies used are of four types:

- online databases and collections of values [23]
- summary studies as meta-analyses or value transfers of primary valuation literature using either conventional and non-conventional environmental valuation techniques
- primary empirical analyses that use conventional techniques to determine individual preferences on environmental services
- non peer-reviewed publications (master and doctoral thesis, technical reports and proceedings).

A total of 83 benefit values have been found. The number of articles observed is lower, as a paper could focus on more than one NBS benefit (see References – Collection of values). In particular, Brenner (2007) focuses on wetlands in the region of Catalonia, in Spain, valuing 10

[23] Two databases were used as sources of values:

1. Van der Ploeg, S. and R.S. de Groot (2010) The TEEB Valuation Database – a searchable database of 1310 estimates of monetary values of ecosystem services. Foundation for Sustainable Development, Wageningen, The Netherlands.
2. Appendix to: De Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., ... & Hussain, S. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem services, 1(1), 50-61.

benefits in our sample. He is followed by Anielski & Wilson (2005), although their geographical focus, Canada, is less interesting for our purpose. Instead, buffer strips benefits are mainly enhanced by Everard & Jevons (2010) and Rein (1999) reporting vales, respectively, from United Kingdom and United States.

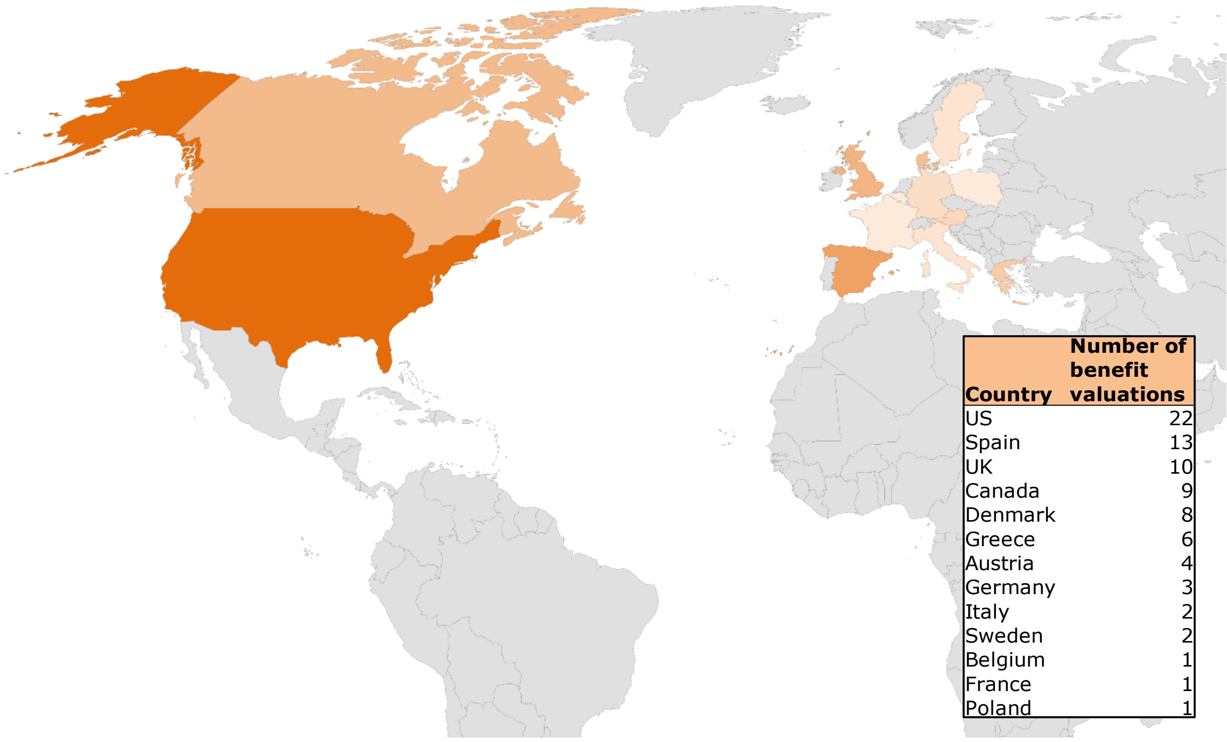
During this screening, has emerged a great disparity between studies focusing on one or the other NBS of our interest. 61 records refer to wetland benefits while just 19 values are attributed to buffer strips benefits, with 3 extra values in common (i.e. Nuisance and Awareness/Education).

We have included the monetization into a dataset (reported at the end of this ANNEX), containing details on some interesting features, useful to select the most appropriate study site. They are explained in the following paragraphs.

The benefit valuations have been originally computed in the period from 1980 to 2018. However, not all the values have been extracted from the original research computing them. Indeed, it was not always possible to track down the original study; many values are reported from a more recent research, referencing the original one. In addition, as some values had already been updated in online databases and collections of values, we have preferred to keep this latest adjustment in our dataset.

The values collected represent 13 countries (Austria, Belgium, Canada, Denmark, France, Germany, Greece, Italy, Poland, Spain, Sweden, United Kingdom and United States). Map below (**Figure 49**) highlights the distribution of benefits economic values in the regions of our focus, showing as the most represented country United States, with 22 NBS benefits valuated, followed by Spain.

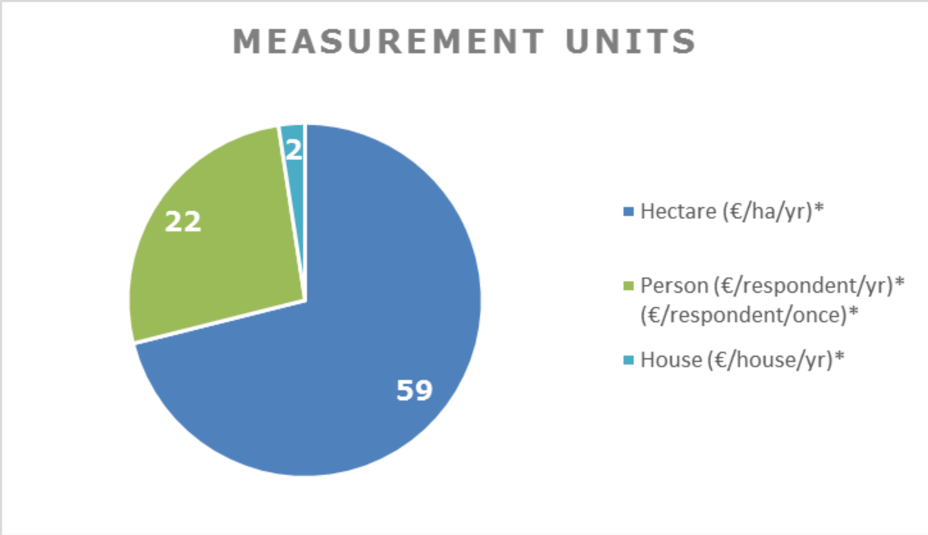
ECONOMIC VALUATION OF BENEFITS, PER COUNTRY



Country	Number of benefit valuations
US	22
Spain	13
UK	10
Canada	9
Denmark	8
Greece	6
Austria	4
Germany	3
Italy	2
Sweden	2
Belgium	1
France	1
Poland	1

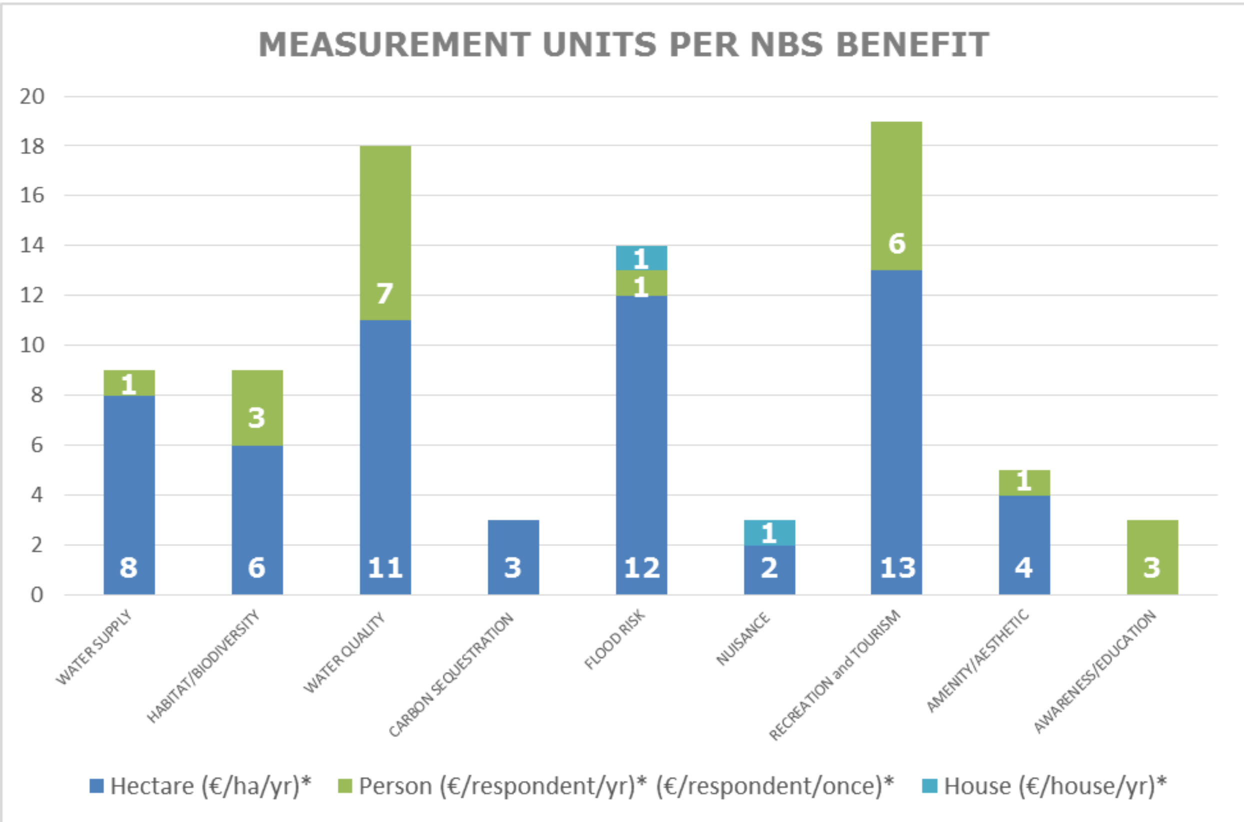
Figure 49. Distribution of benefits economic values per country.

The economic values collection also to identify the measurement units used in study sites candidates and allowed to associate the best, for each benefit. Across the sample, the most used is per unit of ecosystem area measurement (currency/ha/year). Just one benefit shows a prevalence of per-beneficiary terms, as the literature suggests (Brander, 2013), a social benefit, Awareness/Education. So that not to increase the possibility of error in the final transfer we did not transformed the base units to a common measure; the conversion to hectare units would raise uncertainty in the transfer as number of people involved in the valuation and/or population density and/or direct/indirect users number must be taken into account but we are not provided with these information.



*€ or any currency used in the study site economic valuations.

Figure 50. Most common measurement units in study sites economic valuations.



*€ or any currency used in the study site economic valuations.

Figure 51. Most common measurement units in study sites economic valuations, per NBS benefit.

The only correction made at this phase, for few cases, has been to homogenize them to our dataset (for example values expressed in per acre/year have been converted to per hectare/year).

A specific set of information on the study site context has been collected to better understand the biophysical characteristics of the study sites candidates in addition to information on the indicator used to quantify the magnitude of ES for each case. These ecological, biophysical or other appropriate indicators however vary depending on the context as each decision-making situation is unique, in space and time (De Groot et al., 2006). Results confirm that there is no study using the same exact method of another one (we tried to report all of them, in the table located at the end of this ANNEX).This is a great obstacle to value transfer exercise as the comparison and selection of a study site among many values based on different indicators lead to high uncertainty. Despite this, through literature review (De Groot et al., 2006; Russi, et al., 2012) and the integration with our sample, we have created a list of example indicators suitable for determining provision of NBS benefits, listed in **Table 63**.

Valuation techniques used to associate economic values to physical measurements differ greatly too (De Groot, et al., 2002; De Groot, et al., 2006). Even though different methods allow capturing different component of Total Economic Value ES[24], this variety further increase the uncertainty in the transfer. As we will explain later, we based the choice of our study site for each benefit also on this feature. In the pie chart below are depicted the most common monetary valuation techniques used to value ES in our sample.

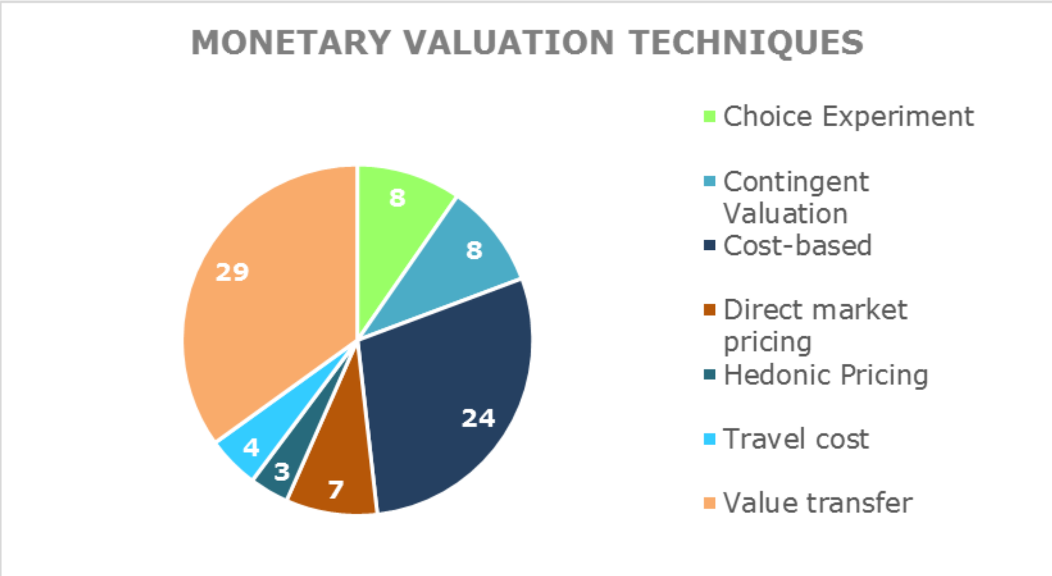


Figure 52. Most common monetary valuation techniques in study sites economic valuations.

Cost-based approach (which comprises damage costs avoided, replacement costs and substitution costs methods) is the second most used method while value transfer is the first. This is not at our advantage as estimates obtained through Value Transfer method are endowed with transfer errors themselves. Often, we do not have much information about neither the original monetary valuation technique involved in the VT exercise nor the indicator used to quantify the ES - indeed, the only information collected in this category is on the ES on which the values has been transferred.

The latest characteristics described above increase the basket of measurement errors involved in our transfer. We try to reduce these sources of error through the choice of the most appropriate study sites (section *Selection of one or more study sites*) but first we carry out a

[24] Revealed preference methods (Market price, Cost-based, Hedonic pricing and Travel cost) capture use value (direct and indirect) and the affected population of users while Stated preferences methods (Contingent valuation and Choice experiment) capture both use value and non use-value and the affected population of users and non-users (Plan Bleu, 2014)

series of adjustments to decrease the potential generalization errors explained in the first paragraph of this ANNEX.

Adjustments to policy site

As explained by Brander (2013), adjustments are required to transfer values from study site to the policy site. Different authors apply different methods of adjustments. In this paragraph are described the ones we applied:

	Adjustments:	$\boldsymbol{OriginalValue\,}^{SS}_{c\,y}$
i	To account for inflation, values have been adjusted to the general price level of the same year. To compare ecosystem service values computed in different years they have been harmonized using annual Consumer Price Index (OECD, 2020), with 2015 as the base year, transforming values in latest available "original" currency, which correspond to year 2018.	↓ $\boldsymbol{Value\,}^{SS}_{c\,2018}$ ↓
ii	To control for differences in price levels, values have been transformed into US$ 2018, using 2018 exchange rates (OECD, 2018) so that to proceed with the next step (which implies using a monetary measure expressed in USD).	$\boldsymbol{Value\,}^{SS}_{USD\,2018}$ ↓
iii	To control for the effect of income on the demand and value of ecosystem services, estimates have been adjusted for the differences in Gross Domestic Product per capita based on Purchasing Power Parity (PPP) (WB, 2020) between study and policy site.	$\boldsymbol{Value\,}^{PS}_{USD\,2018}$ ↓
iv	Values have finally been transformed into euro$_{2018}$, using exchange rates (OECD, 2018).	$\boldsymbol{Value\,}^{PS}_{€\,2018}$

SS=study site; PC=policy site; c= currency used in the latest update of the value; y=year of latest update of the value

Selection of one or more study site

From the list of comparable values, candidate for the transfer, we selected the most suitable.

The choice consists on several criteria, aiming at excluding the study sites whose degree of correspondence with policy site is the lowest:

- First of all, values expressed in *per hectare per year* have been preferred; this is because benefits computed through the monetary valuation techniques based on stated preference method (i.e. Contingent Valuation and Choice Experiment) are based on subjective measure and represent more demand of ES (involving preferences) rather than supply (Schmidt et al., 2016).

  Differently, in the case of Awareness/Education the most appropriate unit, *per beneficiary* terms has uniquely been considered and for Recreation and tourism benefit the unit *per beneficiary* terms has been pulled together with *per hectare per year*; in the case of Nuisance the unit €/house/year has been additionally kept.

- Study site characteristics such as the type of wetland, the surrounding environment and the threats to ecosystem stability have been weighted. Through expert judgement each study site context has been assigned a value, on a scale from 1 to 5 where the highest extreme corresponds to a great fitness to policy site. We tried not to select study sites with low *policy-site-fit* values.

- In the choice, also the year when the value was calculated assumed great importance. Since calculation methods vary over time, and people and preferences too, recent studies have been preferred to the oldest ones.

We have selected one or maximum two economic valuations (composed by a single value or a range), for each benefit, for each NBS. The values in the final sample do not come from the same study site but, among all, Brenner (2007) has been one of the most preferred. The selection is reported in the main text, at **Table 49**, after confidence level is applied.

Confidence interval

As stated by Schmidt *et al.* (2016), *assigning a monetary value on nature is not considered to be absolute, rather it is an indication in a particular area, over a given time period, for a specific beneficiary group, depending on valuation context and use*. Adjustments may be not enough to remove transfer errors so, consistent with Brander (2013) guidelines, an additional correction factor, has been applied to all of them; it is a measure of monetization reliability, inspired by CIRIA Benefits Evaluation of SuDS Tool (B£ST). This last step allows to communicate economic transferred values as confidence intervals: the maximum value of the range is represented by the adjusted economic value before confidence level is applied (the highest value is opted for in case more than one suitable study site was selected); the minimum value of the range corresponds to the economic value after the confidence level is applied (in case of more than one study site has been selected the lowest value have been chosen). Indeed, we made a conservative choice by proceeding with an underestimation of the original value.

Actually, the selected criteria have already been explained in preview phases of our Adjusted Value Transfer exercise but, in order to identify confidence levels, we associate them to scores, as reported below.

Table 64. Criteria and associated scores for confidence level selection

	Criteria	Score	
i	Evaluation of the study site characteristics, which have been associated to a measure of fitness to policy site context, as explained above.	**Score: 1-5**	1=weak fitness 5=great fitness
ii	Monetary valuation technique used for economic value calculation*.	**Score: 0-1**	**0**=Value Transfer **1**=Cost-based/direct market pricing if *per hectare* terms; Contingent Valuation/Choice experiment if *per beneficiary* terms
iii	Indicator used to quantify the magnitude of benefits -	**Score: 0-1**	**0**=low reliability

ecological, biophysical or other appropriate indicators as ES in the case of VT**.**	**1**=high reliability

**** As suggested by De Groot et al. (2006) introducing a rank ordering on monetary valuation techniques allows to better compare different studies, guiding the valuation process.***

As the possible scores range from 1 to 7, we applied the following confidence levels:

Table 65. Scores and associated confidence levels for monetization reliability application

Score 7	→	**100%**	Confidence level
Score 6	→	**90%**	Confidence level
Score 5	→	**80%**	Confidence level
Score 4	→	**70%**	Confidence level
Scores 3-2-1	→	**50%**	Confidence level

Final values, transferred on policy site, are reported those reported in the main text, at **Table 49**.

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Original Reference	Year of value calculation	Where (socio-economic context)	Fitness to policy site (1 min – 5 max)	Monetary valuation technique	Economic value (latest availbale)	Units	Year of lastest available update of the value
WETLAND – NATURAL HABITAT and BIODIVERSITY SUPPORT							
Thibodeau & Ostro (1981)	1980	US	3	Cost-based	146	USD/ha/yr	2007
Folke (1991)	1990	Sweden	4	Cost-based	39	USD/ha/yr	2007
Posford Duvivier Environment (1999)	1998	UK	4	Cost-based	9369	USD/ha/yr	2007
Ragkos et al. (2006)	2005	Greece	2	Contingent Valuation	43	€/respondent/yr	2005
Alfranca et al. (2011)	2006	Spain	3	Direct market pricing	19719-49275	€/ha/yr	2006
Brenner (2007)	2007	Spain	5	Value transfer	3815	USD/ha/yr	2004
Grygoruk et al. (2013)	2013	Poland	3	Cost-based	3116 - 9512	€/ha/yr	2013
WETLAND – WATER QUALITY							
Thibodeau, F.R. and Ostro, B.D. (1981)	1980	US	3	Cost-based	41909	USD/ha/yr	1980
Gren et al. (1995)	1994	Austria	4	Cost-based	256	USD/ha/yr	2000
Dubgaard et al. (2002)	2000	Denmark	4	Direct market pricing	480	DKK/ha/yr	2000
Dubgaard et al. (2002)	2000	Denmark	4	Direct market pricing	1750	DKK/ha/yr	2000
Meyerhoff and Dehnhardt, A. (2004). Environment, 17(1), 18-36.	2001	Germany	5	Cost-based	2089-6188	€/ha/yr	2001
Dehnhardt (2002)	2000	Germany	5	Cost-based	386-1146	GBP/ha/yr	2000
Anielski and Wilson (2005)	2004	Canada	2	Value Transfer	354	CAD/ha/yr	2002
Ragkos et al. (2006)	2005	Greece	2	Contingent Valuation	42	€/respondent/yr	2005
Brouwer et al. (2010)	2006	Spain	5	Choice experiment	123-212	EUR/household/year	2006
Brenner (2007)	2007	Spain	5	Value transfer	2071	USD/ha/yr	2004
Kataria et al. (2012)	2008	Denmark	4	Value transfer	192-586	DKK/respondent/yr	2008
Jenkins et al. (2010)	2008	US	2	Direct market pricing	1248	USD/ha/yr	2008
Dias and Belcher (2015)	2011	Canada	3	Choice experiment	105	CAD/household/one-off payment	2011
Ibrahim and Amir-Faryar, B. (2018)	2017	US	2	Cost-based	580000	USD/ha/yr	2017
WETLAND – FLOOD RISK							
Thibodeau, F.R. and Ostro, B.D. (1981)	1980	US	3	Cost-based	82459	USD/ha/yr	1980
Leschine et al. (1997)	1996	US	4	Cost-based	8484	USD/ha/yr	2007
Costanza et al. (1997)	1996	US	3	Cost-based	4436	USD/ha/yr	2007
Posford Duvivier Environment (1999)	1998	UK	4	Cost-based	8331	USD/ha/yr	2003
Posford Duvivier Environment (2000)	1999	UK	4	Cost-based	150	USD/ha/yr	2003
Dubgaard et al. (2002)	2000	Denmark	4	Cost-based	1000	DKK/house/yr	2000
Anielski and Wilson (2005)	2004	Canada	2	Value transfer	571	CAD/ha/yr	2001
Anielski and Wilson (2005)	2004	Canada	2	Value transfer	926	CAD/ha/yr	2001
Ragkos et al. (2006)	2005	Greece	2	Contingent Valuation	44	€/respondent/yr	2005
Brenner (2007)	2007	Spain	5	Value transfer	7378	USD/ha/yr	2004
Brenner Guillermo (2007)	2007	Spain	5	Value transfer	9037	USD/ha/yr	2004
Watson et al. (2016)	2014	US	3	Cost-based	496-3861	USD/ha/yr	2014
WETLAND - RECREATION and TOURISM							
Thibodeau and Ostro (1981)	1980	US	3	Value transfer	50200	USD/ha/yr	1980
Creel & Loomis (1992)	1991	US	4	Travel cost type	128-173	USD/respondent/yr	1989
Gren & Söderqvist (1994)	1993	Austria	3	Value transfer	133	USD/ha/yr	1993
Kosz (1996)	1993	Austria	3	Value transfer	5565	ATS/ha/yr	1993
Kosz (1996)	1993	Austria	3	Value transfer	80	ATS/respondednt/visit	1993

Original Reference	Year of value calculation	Where (socio-economic context)	Fitness to policy site (1 min – 5 max)	Monetary valuation technique	Economic value (latest availbale)	Units	Year of lastest available update of the value
Oglethorpe & Miliadou (2000)	1997	Greece	3	Contingent Valuation	9144	USD/ha/yr	2003
Dubgaard et al. (2002)	2000	Denmark	4	Value transfer	40	DKK/person/visit	2000
Scherrer (2003)	2002	France	4	Contingent Valuation	687	USD/ha/yr	2003
Brenner Guillermo (2007)	2004	Spain	5	Value transfer	3474	USD/ha/yr	2004
Ghermandi & Fichtman (2015)	2015	Italy, Cave di Noale	5	Value transfer	373	€/ha/yr	2013
Ghermandi & Fichtman (2015)	2105	Italy, Ca di Mezzo	5	Value transfer	191	€/ha/yr	2013
Alfranca et al. (2011)	2007	Spain	3	Travel Cost	3	€/person/visit	2007
Jenkins et al. (2010)	2008	US	2	Value transfer	16	USD/ha/yr	2008
WETLAND - AWARENESS/EDUCATION							
Cable et al (1984)	1983	Canada	2	Travel cost	6,00-17,00	USD/person/visit	1983
Birol et al. (2006)	2005	Greece	4	Choice Experiment	9–13	€/respondent/one-off payment	2003
Hutcheson et a. (2018)	2017	US, NY	2	Travel cost	3,00-6,00	USD/student/trip	2017
BUFFER STRIPS – NATURAL HABITAT and BIODIVERSITY SUPPORT							
Everard and Jevons (2010)	2009	UK	4	Cost-based	14	USD/ha/yr	2007
BUFFER STRIPS – WATER QUALITY							
Lant and Roberts (1990)	1987	US	4	Contingent Valuation	36-49	USD/respondent/yr	1987
Rein (1999)	1998	US	1	Cost-based	77	USD/ha/yr	1998
Dias & Belcher (2015)	2011	Canada	3	Choice experiment	65	CAD/household/one-off payment	2011
Uggeldahl & Olsen (2019)	2018	Denmark	5	Choice Experiment	1899-2099	DKK/household/yr	2018
BUFFER STRIPS – FLOOD RISK							
Rein (1999)	1998	US	1	Cost-based	14	USD/ha/yr	1998
Brenner-Guillermo (2004)	2007	Spain	5	Value transfer	217	USD/ha/yr	2004
BUFFER STRIPS - RECREATION and TOURISM							
Lant and Roberts (1990)	1987	US	4	Contingent Valuation	43-54	USD/respondent/yr	1987
Rein (1999)	1998	US	1	Cost-based	55-66	USD/ha/yr	1998
Brenner-Guillermo (2007)	2007	Spain	5	Value transfer	3385	USD/ha/yr	2004
Everard and Jevons (2010)	2009	UK	4	Direct market pricing	7176	USD/ha/yr	2007
Everard and Jevons (2010)	2009	UK	4	Value transfer	18608	USD/ha/yr	2007
Uggeldahl & Olsen (2019)	2018	Denmark	5	Choice Experiment	140-281	DKK/household/yr	2018
BUFFER STRIPS - AWARENESS/EDUCATION							
Cable et al. (1984)	1983	Canada	2	Travel cost	6,00-17,00	USD/person/visit	2017
Hutcheson et al. (2018)	2017	US, NY	2	Travel cost	3,00-6,00	USD/student/trip	2017