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

Lot 6: LDP in a Mediterranean environment

Feasibility Study

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Project Manager: Fabio Masi (IRIDRA)	***Data:*** September 2021
Team: Giulio Conte (IRIDRA) Riccardo Bresciani (IRIDRA) Anacleto Rizzo (IRIDRA) Alessandro De Carli Leonardo Borsacchi (PIN) Stefano Magaudda (U-SPACE) Flavio Camerata (U-SPACE)	***Contracting Entity technical referent:*** Alberto Pistocchi
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Authors

In alphabetical order

Leonardo Borsacchi

Riccardo Bresciani

Flavio Camerata

Giulio Conte

Alessandro de Carli

Fabio Masi

Stefano Magaudda

Anacleto Rizzo

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 *Agro Pontino* – once one of the largest European wilderness areas: 80.000 hectares of woods and wetlands lying from the *Albani* hills (south east of Rome) to the Mount Circeo – is the result of a heavy landscape transformation caused by the "Great Land Reclamation" of the 1920s. This transformation is continuing to this day, adding an intense industrial (1960s and 1970s) and then residential (1990s-2000) development to the environmental pressures due to crop and livestock farming, causing progressive pollution of surface and groundwater and a growing artificiality of the landscape, with important losses in terms of ecosystem services.

The water quality of most of the artificial and natural watercourses of the area is considered "poor" or "bad", according to the parameters established by the Water Framework Directive (WFD), and the most important pollution source are the intensive farming practices in the area.

In this context the *Life+ REWETLAND* project, coordinated by the Province of Latina, aimed at promoting NBSs to control diffuse pollution and improving the quality of the surface waters of the Agro Pontino.

The project led to the drafting of an *Integrated Environmental Restoration Program (ERP) of the Pontine Plain*, which identifies several NBS typologies that should be promoted on an area of about 700 km^2, entailing a network of 220 km of drainage canals.

Beside acting at large scale by developing the ERP, the *Life+ REWETLAND* project implemented four pilot projects aimed at demonstrating the effectiveness of constructed wetlands and buffer strips to control diffuse pollution.

The 4 NBS analysed

The wetland of Villa Fogliano: The area of Villa Fogliano covers a total surface of 5 ha (around 2 ha of wetlands) along the right bank of the Allacciante Canal. It is characterized by three basins (A, B and C) but only basin A has been considered by the present study. The wetland of Basin A covers an area of 0.85 ha, with a depth of 0.8 m. In this area, a surface flow system (FWS) treats the outflow from the Rio Martino – Foce Verde Canal (in summer) and from the Allacciante Canal (in winter).

The wetland in the Linear Park of Marina di Latina: The CW is a hybrid system: 1st stage, horizontal subsurface flow (HF) constructed wetland, with 2 beds in parallel; 2nd stage, 2 free water surface (FWS) basins in series. Overall, the constructed wetland system covers an area of about 0.4 ha. The wetland is fed by water coming from the Comata Canal; after the treatment, the water is discharged into the Mastro Pietro Canal.

The Allacciante Astura Buffer strip: The buffer strip (BS) is placed along the left bank of the Spaccasassi Ditch (Astura Allacciante Canal), in the stretch between the confluence with the Bottagone Ditch and the confluence with the Acqua Alta Canal. The buffer is 6 metres wide and includes both trees (willows – *Salix spp*.) and shrubs (dogwood – *Cornus sanguinea* – and hawthorn – *Crataegus monogyna*).

The Buffer strip and self-purification enhancement of Forcellata (Selcella Canal): along the Selcella Canal downstream of the Forecellata Idrovora, a buffer strip was placed with the same structure as the Allacciante Astura canal. Besides the buffer strip, to enhance the self-purification capacity of the Selcella canal, both emergent macrophites (*Phragmites australis*) and submerged hydrophytes *(Polygonum amphibium, Potamogeton crispus*) were planted in the canal section, to increase the roughness of the flow and therefore the retention time of the system.

The pollutant removal capacity of the NBSs

The pollutant removal capacity of the NBSs was estimated considering the available data and through an appropriate modelling exercise. The pollutant removal capacity of the wetlands ranges between:

- 2 and 20 g m^{-2} y^{-2} for nitrogen
- 0,2 and 1,1 g m^{-2} y^{-2} for phosphorus
- 0,1 and 4 m^{-2} y^{-2} for pesticides (Glyphosate)

The buffer strips show a better performance, even though the estimation method is affected by high uncertainty, with a removal rate of:

- 28,8 g m^{-2} y^{-2} for nitrogen
- 1,1 g m^{-2} y^{-2} for phosphorus
- 0,2 g m^{-2} y^{-2} for pesticides (Glyphosate)

The investment and O&M costs of the NBSs

The unit construction costs for the FWS Villa Fogliano - Basin A is equal to **4.54 €/m^2**. It is lower than the typical costs of free water surface (FWS) CWs, which are typically in the range of 20-60 €/m^2 because the wetland was constructed on an existing basin and did not require extensive excavation and subsequent embankment works. Considering the excavation (5.11 €/m^3) and embankment (4.09 €/m^3) costs for a depth of 0.8 m of the basin, the unit cost would become **11.9 €/m^2**, which is comparable with the literature values. The unit construction costs for the Linear Park of Marina di Latina is equal to **117.84 €/m^2**; the higher cost per square meter is due to the presence of a sub-surface flow stage, which typically costs 100-200 €/m^2.

The O&M costs for the wetlands range between **0.26** and **0.61 € m^{-2} y^{-1}.** These values are lower in comparison to those reported for CWs treating municipal wastewater.

The working cost for the Buffers of the Allacciante Canal and the Selcella Canal is about **11 €/m^2** (4 €/m) and **48 €/m^2** (10 €/m) respectively. They are comparable to similar buffer strips (5-10 €/m – CIRF[1]). O&M activities for the Buffers of the Allacciante Canal and the Selcella Canal are equal to **1.13 € m^{-1} y^{-1}** (€ 0.42 € m^{-2} y^{-1}) and **2 € m^{-1} y^{-1}** (€ 0.42 € m^{-2} y^{-1}). They are comparable with the values reported by CIRF in Italy, ranging from 1.8 to 3.9 €/m.

The social Analysis

The social analysis was carried out in two steps. A first phase of data collection concerned the REWETLAND project and was conducted between October 2019 and February 2020. The limitations and criticalities that emerged from the findings led to consider also the GREENCHANGE project that followed REWETLAND, thus carrying out a second phase of research activities in July 2021.

The first phase of the analysis revealed that, although the REWETLAND project had the characteristics to create a winning model as the result of a participatory process, in reality it showed a series of weaknesses that compromised its complete implementation and

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

above all its sustainability at the end of the project. Within REWETLAND, two important documents were produced, among others:

— The *Integrated Environmental Restoration Program* (ERP) *of the Pontine Plain*, a strategic policy document approved by the Province of Latina for the implementation of interventions to improve the quality of surface waters, including through the dissemination of NBSs and the application of good practices in agricultural activities;

— The Guidelines for watercourse management interventions, drawn up by the Consorzio di Bonifica.

At the conclusion of the REWETLAND project process, the Lazio Region accepted the *Integrated Environmental Restoration Program* as an implementation tool for the proceedings of the Regional *Water Protection Plan*. However, it does not provide for specific implementation rules or resources to carry out the interventions: the ERP has therefore remained inapplicable. The construction of NBSs in the Pontine plain therefore came to a halt with the end of REWETLAND.

Similarly, the Consorzio di Bonifica was unable to put into practice more ecological management methods: partly due to strong opposition from civil society and the media, but also due to the lack of a "mandate" by the Lazio Region. In fact, the Consorzio does not act autonomously but on the basis of a specification established by the Region, which determines its operating methods and resources.

Finally, in the REWETLAND project, farmers have always had a marginal, not direct role, having participated only as designated subjects. This factor is to be considered as one of the main reasons that undermined the success of the project.

The GREENCHANGE project was launched in 2018 with the aim of capitalizing on the REWETLAND experience: starting from the lessons learned to rethink a different model for the creation of NBSs for environmental restoration. The project envisages a different governance and stakeholder engagement model, also capable of being sustainable over time: the direct involvement of the agricultural world (Confagricoltura is a partner of GREENCHANGE while it did not participate in REWETLAND) indicates the different approach.

In a nutshell, the NBSs implementation and management model envisaged by GREENCHANGE is based on the enhancement of state-owned areas to be managed by farmers to create arboreal, shrubby and herbaceous hedges and rows, which can also function as buffer strips.

Identification and quantification of costs and benefits

The results of the social analysis show that, for several reasons, the REWETLAND project did not allow the development of NBS in the Pontinian plain; however the new approach developed through the GREENCHANGE project, could allow the diffusion of NBS, particularly of Buffer Strips.

Thus the assessment of costs and benefits was made envisaging the implementation of the approach proposed by GREENCHANGE at its "full capacity", estimating the possible impact on diffuse pollution together with the other environmental, social and economic benefits/costs. The first scenario analysed is therefore a simulation of the effects of the GREENCHANGE model when fully operational.

Since the GREENCHANGE approach is focused on the creation of linear NBSs only (hedgerows and tree lines acting as buffer strips), another scenario was analysed where, to the BSs created through the GREENCHANGE model, a few wetlands located in key sections of the hydrographic network are added, to treat pollutants not intercepted by the BSs. In this second scenario, both the capital and O&M costs are covered by the Region, as originally envisaged by the REWETLAND Project.

The analysis was based on the Rio Martino Basin: one of the most important of the whole Pontinian plain, where the city of Latina is located. The area of the Rio Martino basin is 411 km^2, of which 62% is for agriculture use. This basin includes an inner lowland, an area of clayey soil and, along the coast, a higher sandy soil area on the fossil dune.

The implementation of BSs on the Rio Martino basin (Scenario 1) would contribute to a marginal (7.4%) reduction of the total diffuse pollution load. In this scenario, only a few supplementary ecosystem services would be provided: recreational opportunities and new habitats supporting biodiversity (even though the more sensitive taxa – related to aquatic ecosystems – are not supported in this scenario). According to the value transfer analysis, the economic value of the NBSs implemented on the Rio Martino basin under scenario 1 could be estimated between 1,642,000 €/y and 1,900,000 €/y. Even though the forecasted benefits are not so huge, the business model proposed by the GREENCHANGE project allows to completely eliminate the public costs for the NBSs implementation and management. The implementation of the NBS under scenario 1 is therefore feasible and recommendable.

The simulation analysis of scenario 2 doesn't significantly increase the reduction of the total diffuse pollution load (3.6% more than scenario 1). Under scenario 2, more supplementary ecosystem services are provided (flood risk prevention and education, beside the ones provided under scenario 1) and the total economic value of the ES is more than 4 times higher than the one estimated for scenario 1 (between 4.2 and 8.5 million euro). On the other hand, the investment and O&M costs to implement the wetlands envisaged under scenario 2 are huge: over 80 million euros of capital costs and nearly 1.8 million euros/year of O&M costs, plus 0,5 million euros/year of farmland income loss.

Without further investigation allowing for a more detailed and trustable estimation showing better removal rates for the wetlands, the implementation of scenario 2 cannot be considered recommendable.

The "business model"

The background idea of the REWETLAND project was to implement some demonstration NBSs, showing to the local people that they could provide benefits, develop a program (the ERP) to replicate the NBSs on a larger scale, find the financial resources to implement NBSs on a large scale through the ordinary funding channels (River basin management plans, Flood risk management plans, funds supporting habitat and biodiversity). Thus, the business model mainly relied on public resources to be provided by ordinary water and biodiversity management sources.

However, the participatory model created through the REWETLAND Project went into decline in March 2015, when the national law 56/2014 deprived the Provinces of their authority, as well as of their financial resources. In addition, not all the demonstration sites implemented by the REWETLAND project showed evidence of providing benefits: the buffer strip located along the Allacciante Astura Canal was blamed to be one of the causes of the severe floods occurred in 2017 and 2018.

The Business Model envisaged by REWETLAND failed for two main reasons:

1. the lack of knowhow transfer and capacity building towards a key actor: the Consorzio di Bonifica Agro Pontino;
2. the lack of financial resources through ordinary channels to replicate the NBSs implementation on a larger scale.

The first reason deals with the poor technical skills of the Consorzio di Bonifica Agro Pontino for what concerns the design and management of multipurpose NBSs. Even though they fully agree with the new "NBS" approach, they were not able to correctly locate and design, at least one of the two buffer strips (but more generally speaking the design of the BSs was poor...), and they had to remove it to avoid flood risk problems. But the Consorzio di Bonifica Agro Pontino is not to blame: the technical approach of all Drainage Authorities in Italy has always been very far from the "green infrastructure" approach; their technical background lies in the conventional hydraulic engineering and land reclamation practices. Since the Consorzio plays a key role not only for the REWETLAND Project but also for the scaling up of the demonstrative experience to the whole Agro Pontino area, they should be equipped with a well-trained technical staff. Such condition, however, is not compatible with the time and financial constraints of the "Life+" program.

The second issue concerns the possible scaling up of the NBSs on the basin. Even though the ERP elaborated by REWETLAND has been acknowledged by the Lazio Region in its Water Quality Plan, none of the measures envisaged by the program has been financed by the Region nor by the River Basin Authority. That is a key point: the business model envisaged by REWETLAND must rely on a certain – even though small – dedicated annual budget.

A final remark concerning the business model deals with the process governance that mainly relies on the role of the Latina Province. When the Law 56/2014 deprived the Latina Province of its authority and financial resources, some other institutional actor should have taken the lead for the implementation of the ERP: presently neither the Lazio Region nor the Consorzio di Bonifica Agro Pontino appear to be able to play this role.

The GREENCHANGE business model is based on entrusting farms with state-owned areas bordering waterways for the construction and management of NBSs (typically linear arboreal/shrub formations or wetlands) whose primary objective is to support biodiversity, but which also perform a function of reducing diffuse pollution.

The model proposed by GREENCHANGE is advantageous for the farm because the state-owned areas entrusted to the company through land stewardship agreements (administratively a loan agreement) are recognized as Ecological Focus Areas (EFAs). This allows them to take advantage of the CAP incentives without having to subtract part of their land from agricultural production, thus obtaining immediate benefits.

There is also an interest on the part of farmers in the Pontinian plain to manage the state-owned areas where the old eucalyptus windbreaks are planted because the plants are too tall and old (they are now about a hundred years old) and no longer serve as windbreaks.

Finally, there is also an advantage for the public body (the Lazio Region in particular), which no longer has to guarantee the maintenance of state-owned areas entrusted to farmers in custody.

The surveys carried out by Confagricoltura show a growing interest in the project by medium-large farms (greater than 15 hectares), which increasingly look to their business from a multifunctional perspective: not only production of agri-food goods (primary function) but also provision of secondary services useful to the community (tourism and accommodation capacities). In addition to the immediate benefits described above, the creation of NBSs allows the creation of paths that facilitate access to the farms for the urban population and tourists.

Confagricoltura estimates that, if the conditions for direct payments remain advantageous (as it would seem from the provisions of the new CAP 2021-2027, see paragraph 7.2.1), about 70% of the state-owned areas of the Agro Pontino could be allocated to NBSs and entrusted to farms in the near future.

Conclusions

The analysed case study provides several useful hints, even though it does not always allow clear answers to all the questions that are the objective of the present study.

The pollutant removal capacity of the NBSs was estimated through specific models and the removal rates are in the expected range according to scientific literature, but lower than the most performing existing case studies.

Investment and O&M costs of the NBSs implemented in the present case study are in line with similar systems implemented in other Italian sites.

To assess direct and indirect costs and benefits of the implementation of NBS at basin scale, two scenarios were developed on the Rio Martino basin: scenario 1 envisages only the implementation of buffer strips by the farmers – at their own costs but on public land entrusted to them through land stewardship agreements; scenario 2 envisages supplementary wetland NBSs, to be implemented and managed by the Consorzio di Bonifica making use of public (Regional) funds. Both scenarios do not excel in term of diffuse pollution reduction: pollutant removal of nitrogen and phosphorus range between 7.4% and 12% of the total load. Such a weak performance depends on several factors.

The buffer strips network envisaged is too coarse to intercept the important pollutants load due to intensive farming activity: even though their areal removal rate is in line with the best performance of similar NBSs according to the available scientific literature (Zhang et al 2010), their contribute in reducing the pollutant load is not sufficient.

For what concerns the wetlands envisaged under scenario 2, their areal removal rate is very low, compared to the international literature: the areal removal rate of N estimated for the NBSs of the present case study is 14 g/m^3/year while the average for wetlands (Kadlec 2012) is 70. Such low areal removal rate depends on the low concentration of pollutant that emerges from the available data, provided by studies carried out by the Latina Province. According to these data, the $N\text{-}NO_3$ concentration is always lower than 2 mg/L, while in similar intensive agriculture European sites the N concentration is 3 to 5 times higher. If this low concentration is not due to some bias in the monitoring campaigns carried out by the Latina Province, it may depend on the dilution by groundwater. If this is the case, in this specific local context the use of wetlands to reduce diffuse pollution shows to be poorly effective and is not recommendable.

The results of the MCA and the monetization of the ES provided by the NBSs under the two scenarios developed, confirm the significant value of the ES provided by the NBSs, ranging between 1,5-2 million €/year for scenario 1 and 5-8 million €/year for scenario 2. However, while scenario 1 shows a clear economic feasibility, providing valuable ES – even though not satisfactory in terms of diffuse pollution removal – without any public cost, scenario 2 is much less "profitable", presenting high capital, (80 million euros) O&M (1,7 million euros/year) and opportunity (0,5 million euros/year of lost farming income) costs. The annual value of the ES provided by the NBSs under scenario 2 is at least double of the annual running costs (O&M plus lost income) of the new NBSs, but the payback time of the investment costs would be very long (around 40 years) compared to similar NBSs located in more appropriate geographic contexts.

Finally, for what concerns the business model, the approach proposed by REWETLAND – to implement some demonstration NBSs, show to the local people that they could provide benefits, develop a program to replicate the NBSs on a larger scale, find the financial resources to implement NBSs on a large scale through the ordinary funding channels (River basin management plans, Flood risk management plans, funds supporting habitat and biodiversity) – clearly failed. The GREENCHANGE project developed a completely different "win-win" approach, involving the farmers and entrusting them to manage public areas to implement NBSs (buffer strips). These areas are recognised as "ecological Focus Areas", allowing farmers to access to the direct payment of the "CAP greening" without withdrawing part of their farming land from production. The condition for this business model to be replicable is the availability of public land properly located to allow the implementation of effective NBSs for diffuse pollution removal. Such condition occurs on the pontinian plain as a heritage of the land reclamation occurred 100 years ago, that created stripes of public land along the draining ditches, used for windbreaks plantation. It is certainly a very peculiar "land property pattern", probably not very common – and therefore with scarce replication opportunity – however a similar pattern could exist in other European geographical contexts subject to land reclamation in the past.

1 INTRODUCTION

1.1 Objectives of the feasibility study

The present study analyses how Nature-based solutions (NBSs) 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 NBSs?
- What are the benefits they deploy?
- What are the technical, capacity, governance, management and financial constraints hampering their take-up?

To answer these questions, this study focuses on the "Agro Pontino" (Latina Province), an intensive farming and livestock area located in Central Italy where a few NBS for diffuse pollution control have recently been implemented through a *Life+* project (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 in removing diffuse pollutants due to farming practices is analysed, relying as much as possible on real monitored data (chapter 3).

Investment, operation and maintenance costs of the examined NBSs 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 social analysis has been conducted by interviewing the key stakeholders (chapter 5).

A quantification of the direct and indirect benefits (recreation, flood protection, biodiversity, etc.) together with possible negative effects (Loss of farmland income, nuisances due to farming practice) and their valuation through appropriate value transfer methods was carried out. Benefits and Drawbacks were estimated for the 4 studied NBSs and scaled up to the whole basin (chapter 6).

Finally (chapter 7), the governance and financial scheme that allows the implementation of the NBSs was analysed and discussed to delineate a possible "business model" that could be proposed for broader implementation of diffuse pollution NBS in agricultural landscapes.

1.2 Overview of the project area

Until the end of the XIX century the project area was one of the largest European wilderness areas: 80.000 hectares of woods and wetlands lying from the hills *Colli Albani* (south east of Rome) to the Mount Circeo. The Pontina plain has a peculiar morphology: the highest altitudes are closest to the coast, where a thick series of Pleistocene marine terraces is covered in places by Aeolian sand. A discontinuous cordon of low dunes, formed during the terminal Pleistocene and the Holocene, runs parallel to the coast just behind the present day beach. The lowest part of the graven is actually situated farther inland, at the base of the Lepini and Ausoni mountains, where it is filled with a complex series of Holocene peats and clays, overlying thick Pleistocene deposits (**Figure 1**).

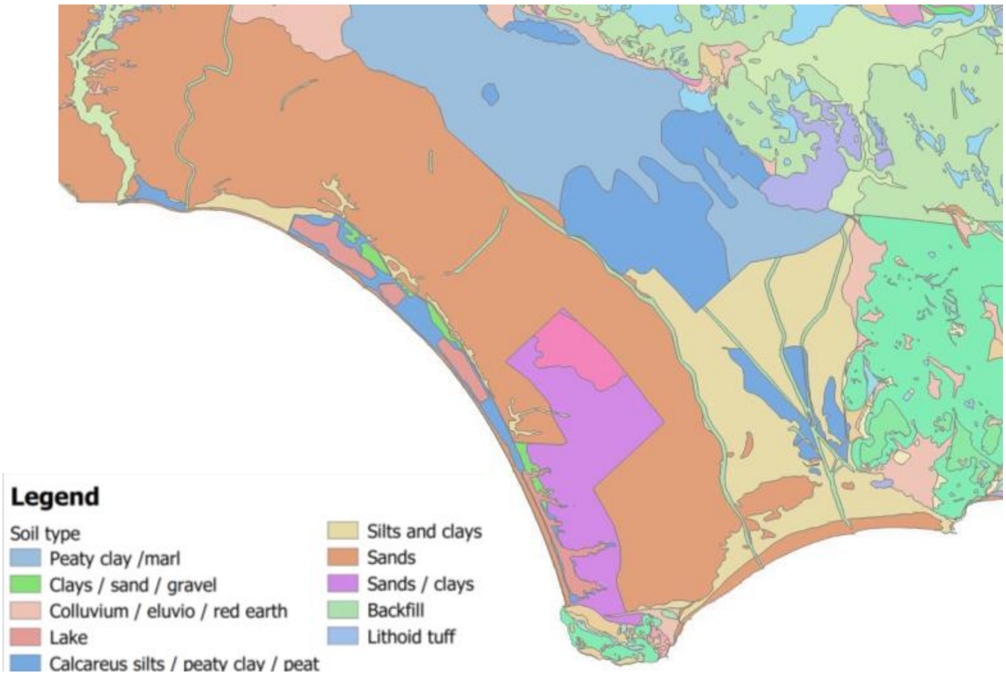

Figure 1. Soil type map of the agropontino area. Source: Regional soil type map[2]

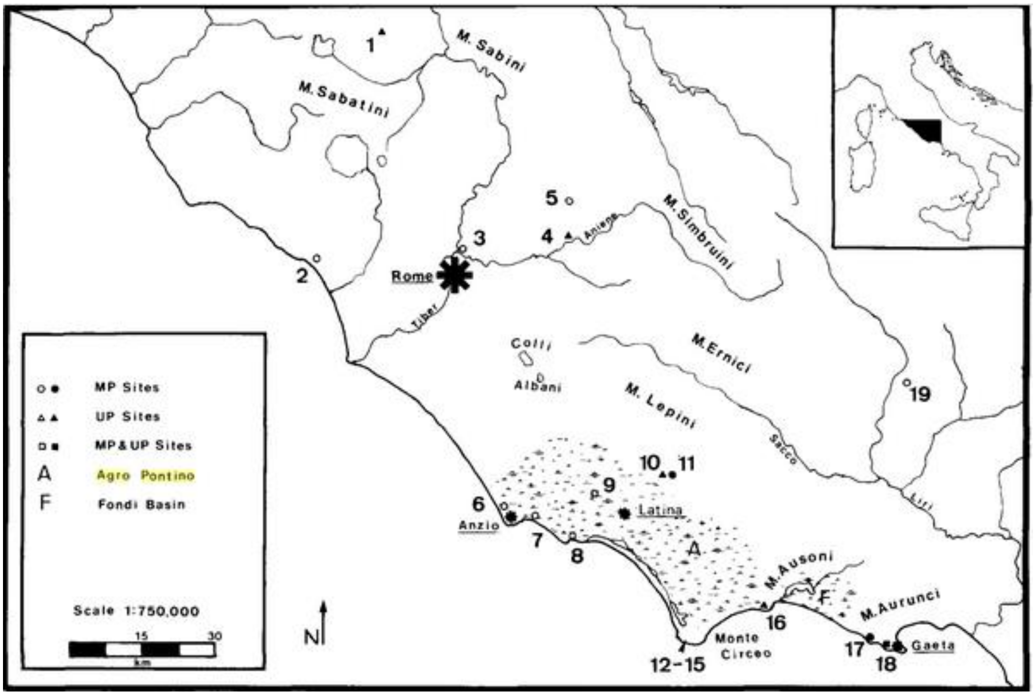

Figure 2. Map of the ancient Pontinian Plain (Kuhn 2014)

[2]https://geoportale.regione.lazio.it/geoportale/web/guest/catalogo?p_p_id=GNet_WAR_GNetportlet&p_p_lifecycle=0&_GNet_WAR_GNetportlet_lifportrend=carta%20geologica

This peculiar morphological feature has favoured the ecological conditions for the formation of a series of wetlands, ponds and woods: a hostile environment for human beings that has prevented human settlements in the area for millennia, until the end of the XIX century when the first reclamation works started. It was at the beginning of the XX century, during the Italian Fascism, that Mussolini decided to completely reclaim the area to provide farming land to feed the growing population of Rome, and reshaped the wild Pontine plain into the *Agro Pontino*.

The *Agro Pontino* is the result of a heavy landscape transformation caused by the "Great Land Reclamation" of the 1920s. This transformation is continuing to this day, adding an intense industrial (1960s and 1970s) and then residential (1990s-2000) development to the environmental pressures due to crop and livestock farming. The result has been a progressive pollution of surface and ground water and a growing artificiality of the landscape with important losses in terms of ecosystem services.

The water quality of most of the artificial and natural watercourses of the area is considered "poor" or "bad", according to the parameters established by the Water Framework Directive (WFD), and the most important pollution source is the intensive farming practices in the area.

In this context the *Life+ REWETLAND* project, coordinated by the Province of Latina, aimed to spread NBSs to control diffuse pollution, and thus improve the quality of the surface waters of the Agro Pontino.

The project led to the drafting of an *Integrated Environmental Restoration Program* (ERP) *of the Pontine Plain*, that identifies several NBS typologies that should be promoted on an area of about 700 km^2, entailing a network of 220 km of drainage canals. The ERP has been recently acknowledged by the Lazio Region and the River Basin Authority as a tool to locally implement the policy measures envisaged by the River Basin Management Plan and the subordinate Regional Water Quality plan.

Beside acting at large scale by developing the ERP, *Life+ REWETLAND* project implemented four pilot projects aimed at demonstrating the effectiveness of constructed wetlands and buffer strips to control diffuse pollution.

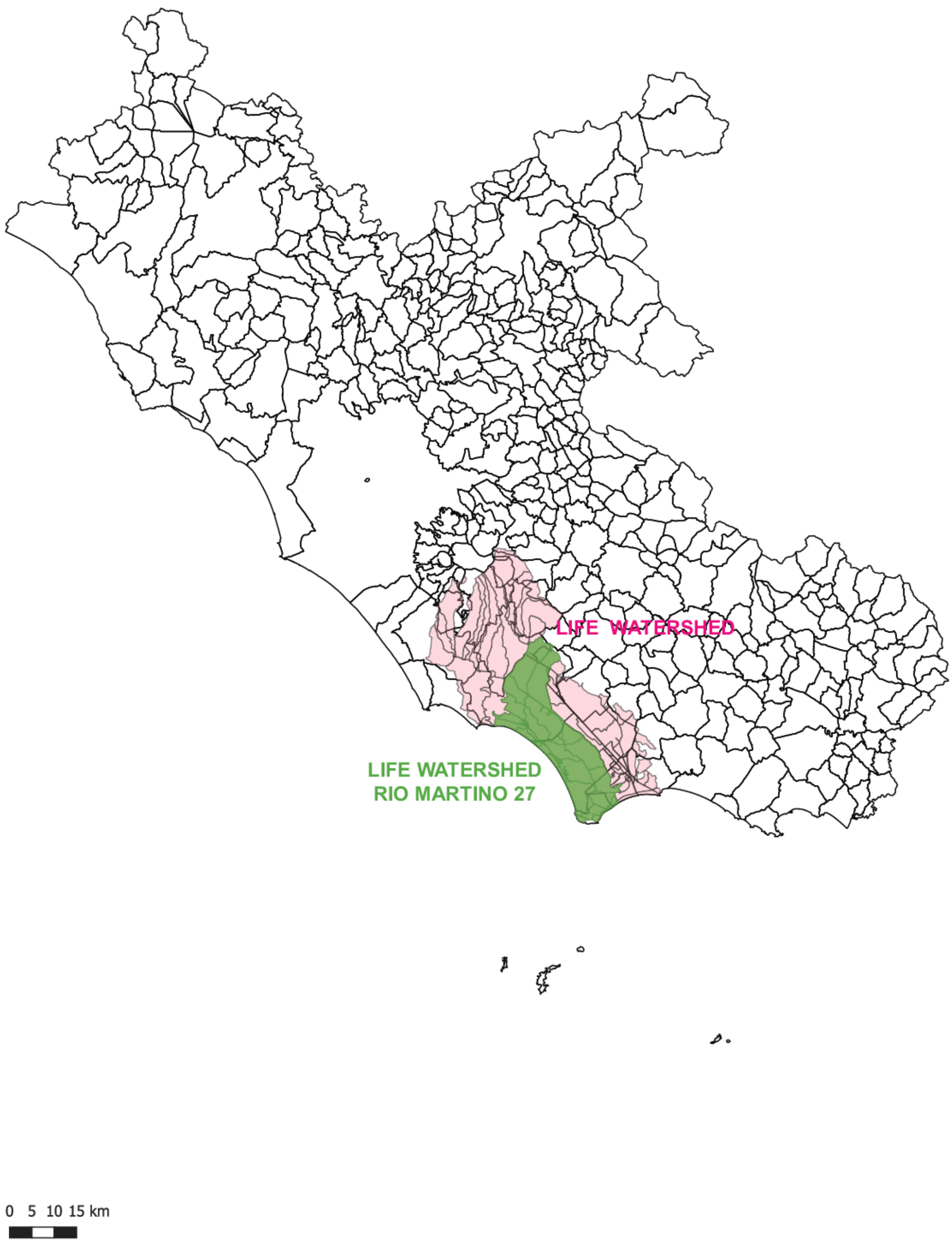

Figure 3. Geographical localization of the watershed of interest of the LIFE+ REWETLAND

Figure 4. The drainage network of the studied watershed and the positioning of the investigated NBSs

2 CHARACTERIZATION of the NBSs

2.1 NBSs design

The REWETLAND pilot projects (PPs) considered by the present study are the following:

- PP1 – **n°1 constructed wetland** fed by a small flow diverted from the Rio Martino stream before it discharges into the Fogliano lake (Pantano Cicerchia);
- PP2 – 4000 m^2 of **constructed wetlands (CWs)** for the treatment of water from the Colmata stream, in the Linear Park of Marina di Latina;
- PP3 – Buffer strips along the reclamation canals in two different locations
  - The Canale Allacciante Astura valley;
  - The drainage canal of the Forcellata dewatering pump.

2.1.1 PP1: Constructed wetlands in Villa Fogliano

The intervention area of interest in Pilot Project 1 (PP1) is identified as Area 2 in the REWETLAND project (**Figure 5**), i.e. the wetland of Villa Fogliano (**Figure 6**).

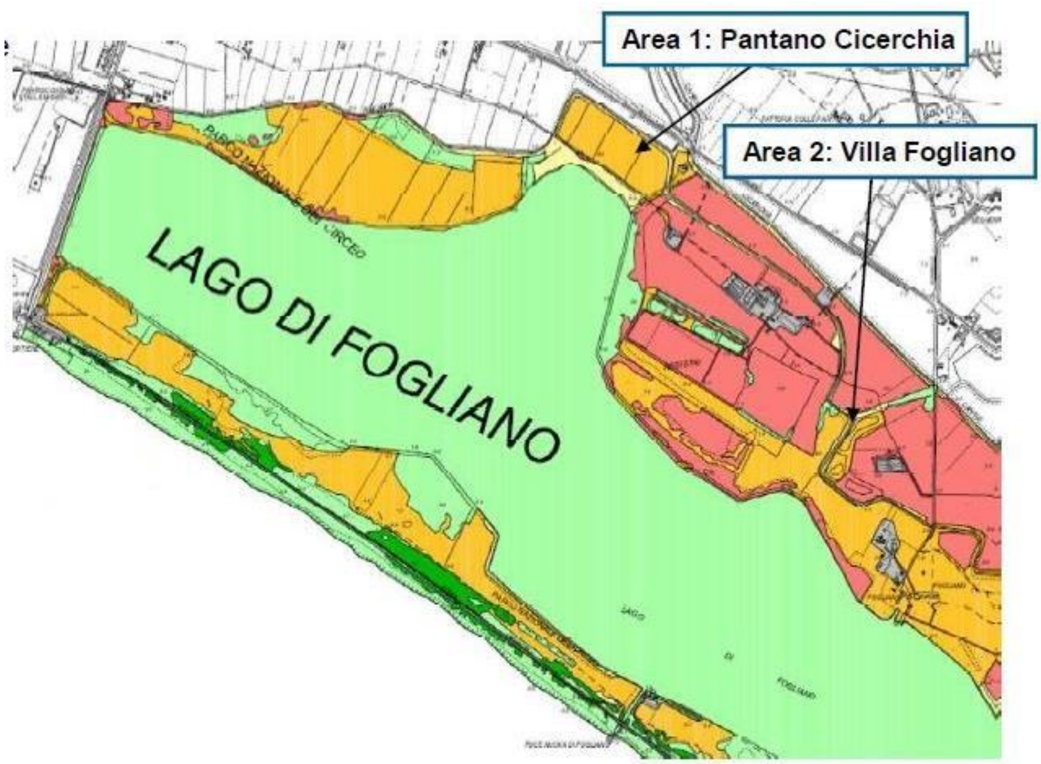

Figure 5. Intervention areas in Pilot Project 1 (Source: LIFE+ REWETLAND)

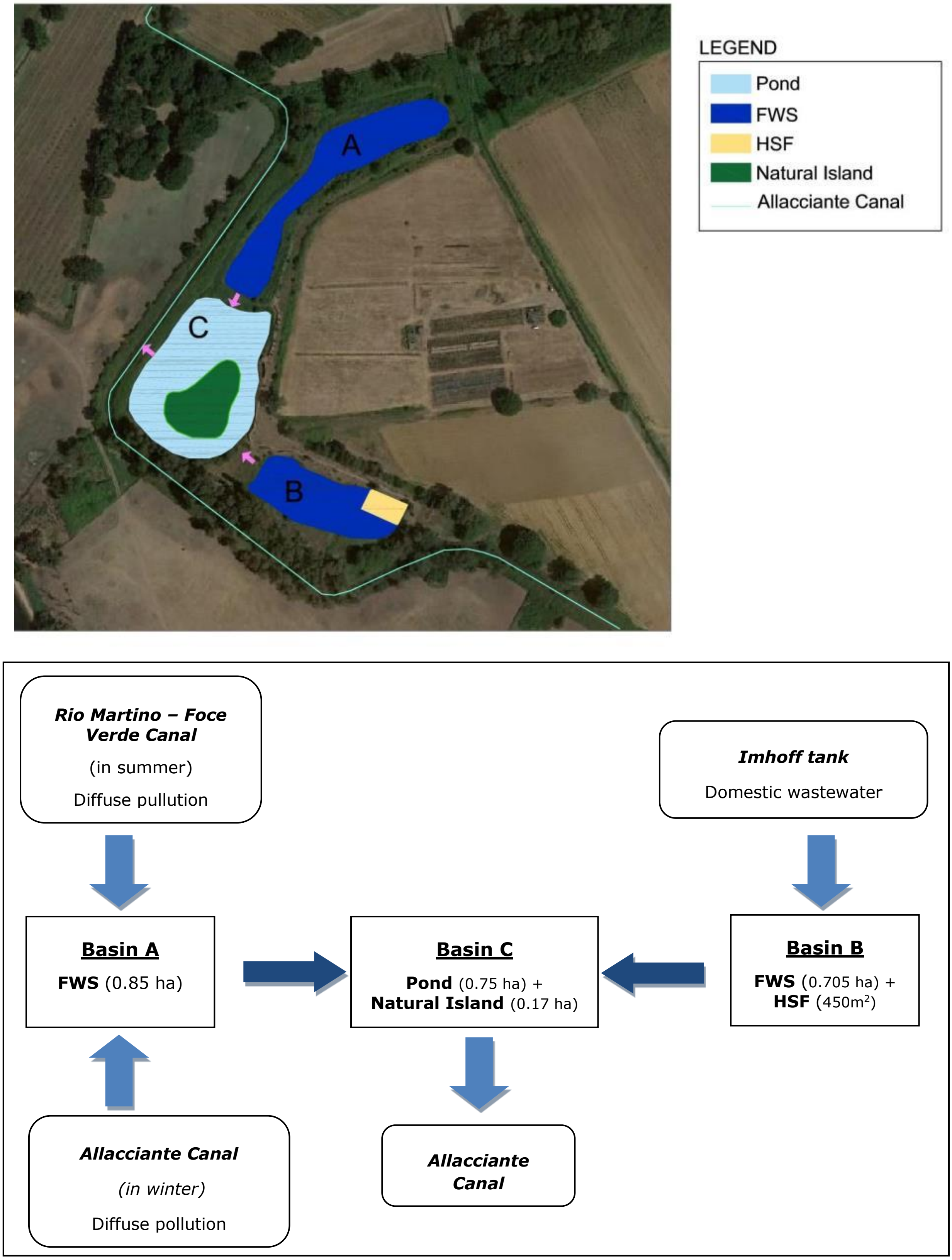

Figure 6. Functional scheme of the Villa Fogliano Constructed wetlands

The area of Villa Fogliano under examination covers a total surface of 5 ha (around 2 ha of wetlands) along the right bank of the Allacciante Canal. It is characterized by three basins. **Figure 6** shows the location of the basins, indicated with the letters A, B and C; **Figure 7** shows an aerial picture of the area.

Figure 7. Aerial view of Villa Fogliano area (Source: LIFE+ REWETLAND)

Basin A (**Figure 8**) covers an area of 0.85 ha, with a depth of 0.8 m. In this area, a surface flow system (FWS) treats the outflow from the Rio Martino – Foce Verde Canal (in summer) and from the Allacciante Canal (in winter). The discharge from basin A to basin C takes place by means of a pipe of 400 mm in diameter.

Figure 8. Basin A (Source: LIFE+ REWETLAND)

Basin B (**Figure 9**) has an area equal to 0.75 ha and a depth of 0.80 m. This CW includes a small (450 m^2) horizontal sub-surface system (HF) for the secondary treatment of the waste water of the Villa Fogliano village and a surface flow system (FWS) of 0.705 ha for the tertiary treatment of the waste water. The primary waste water treatment is performed upstream by means of an Imhoff tank.

Figure 9. Basin B (Source: LIFE+ REWETLAND)

The sub-surface system is made up of a rectangular basin (W= 18 M; L= 25 m), with a depth of 0.8 m and a bottom slope equal to 2%. To regularize the bottom tank, there is a 10 cm layer of sand. The bottom is covered with a bentonite geosynthetic barrier, reinforced with a dry thickness of 6 mm. The system has a gravel layer (G=D10/D60=4), with a porosity of about 30% and a thickness equal to 60 cm. The inlet and outlet of the tank are characterized by large pieces of stone (100 mm in diameter). The type of aquatic plants used are: *Phgramites australis, Typha latifolia L.* and *Iris pseudacorus L.*

Basin C (**Figure 10**) has a rounded shape, covering a surface of 0.52 ha. In the centre there is an island of about 0.17 ha. It receives the outflow coming from basin A and basin C. The surface waters are conveyed into the Allacciante Canal by means of a 250 mm diameter pipe.

Figure 10. Basin C (Source: LIFE+ REWETLAND)

Considering that the aim of the present study is to analyse the role of CWs in reducing water pollution by retaining and processing diffuse pollutants generated by farming practices, and that the basin B CW treats domestic sewage and basin C receives the effluents of both basin A and basin B, the material flow analysis for this system (see chapter 3) will be focused only on the basin A CW.

2.1.2 PP2: Constructed wetlands in the Linear Park of Marina di Latina

The CW is a hybrid system: 1st stage, horizontal subsurface flow (HF) constructed wetland, with 2 beds in parallel; 2nd stage, 2 free water surface (FWS) basins in series. Overall, the constructed wetland system covers an area of about 0.4 ha. The functional scheme of the system is shown in the following figure.

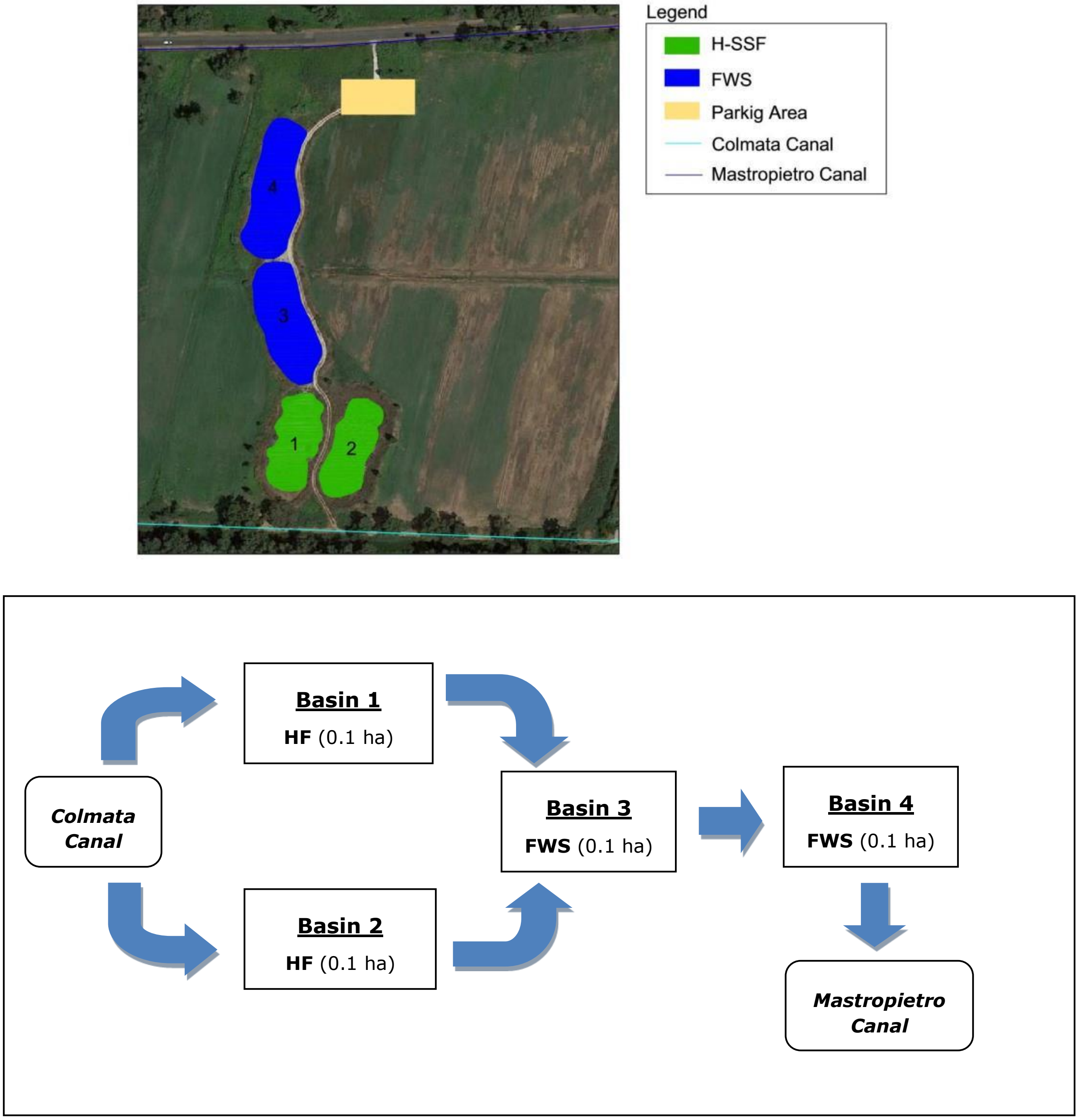

Figure 11. Functional scheme of the Linear Park of Marina di Latina

The wetland is fed by the water coming from the Colmata Canal through a completely underground system, characterized by a pair of submerged pumps; after the treatment, the water is discharged into the Mastro Pietro Canal, by means of a pumping system.

Figure 12. HF (Source: Photo opening event of PP2 - LIFE+ REWETLAND)

The second and third basins are FWSs, which cover an area of approximately 0.1 ha each (L=66.5 M; W=15 m). They are characterized by a double crossed layer of non-woven of 200 g/m^2, a waterproof clay layer with $k<10^{-7}$ cm/s and thickness equal to 10 cm. They have a free flowing water level of 40 cm.

The original design of both FW systems envisaged to introduce in the wetlands floating macrophytes (*Eichornia crassipes; Lemna minor*), but then the water Hyacinth (Eichornia c.) was excluded and the basins were spontaneously colonized by local vegetation (emergent and floating).

Figure 13. FWS (Source: Photo opening event of PP2 - LIFE+ REWETLAND)

2.1.3 PP3: Buffer strips

The Pilot Project 3 involves the creation of Vegetated Buffer Strips along two stretches of the canals network managed by the *Consorzio di Bonifica Agro Pontino* (CBAP).

The first intervention concerns the 3.7 km stretch along the Allacciante Astura Canal between the Bottagone ditch tributary and the entry of the Acque Alte Canal (Area 1 in **Figure 14**); the second one concerns the Selcella Canal, downstream of the Forcellata pumping station, for a length of 1.40 km (Area 2).

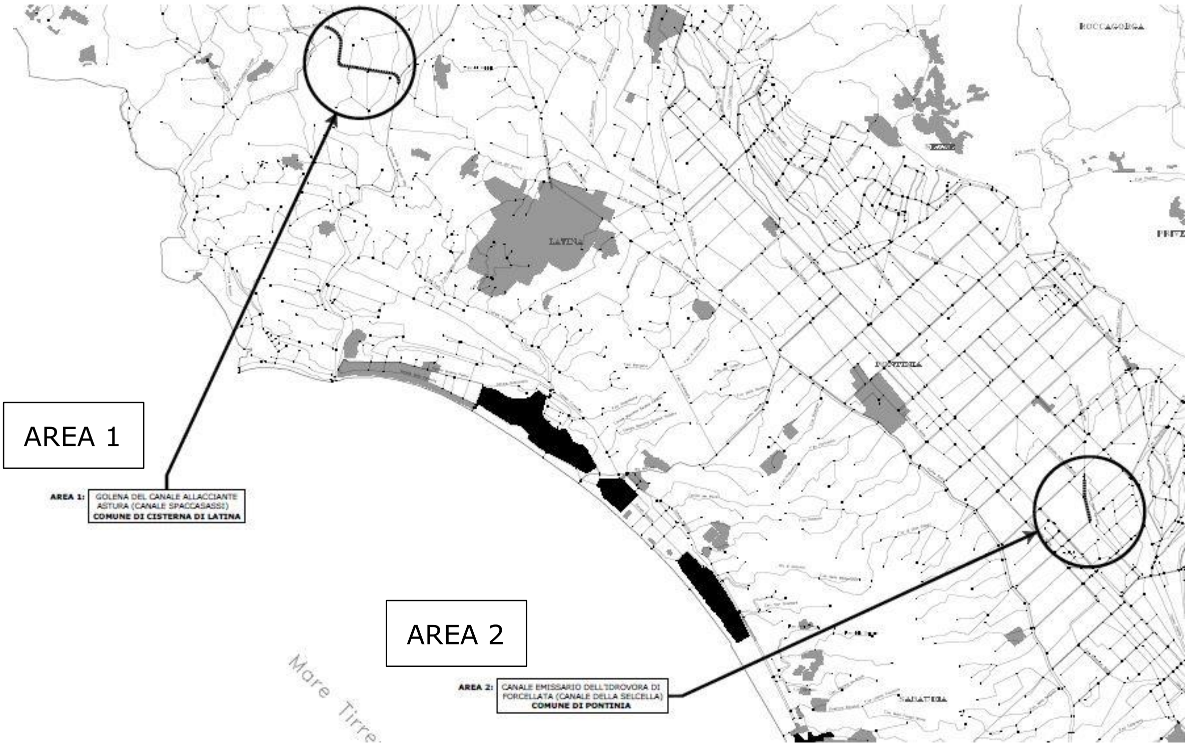

Figure 14. The two sites of the buffer strips

2.1.3.1 PP3 – Area1: Buffer strip along the Allacciante Astura Canal

The BS in Area 1 was placed along the left bank of the Spaccasassi Ditch (Astura Allacciante Canal CAA), in the stretch between the confluence of the Bottagone Ditch and the confluence of the CAA in the Acqua Alta Canal (**Figure 15**).

Figure 15. Buffer Strip (in orange) of the Allacciante Astura Canal (in light blue)

The buffer is 6 metres wide and includes both trees (willows) and shrubs (dogwood and hawthorn) disposed as shown in **Figure 16**. The buffer strip was designed and implemented with a slope of about 5%.

Tratto di riferimento: MODULO lungh. ml. 6 - largh. ml. 6-8	n°30
Specie arboree secondarie	
Salis caprea	1
Salis triandra	1
Specie arbustiva	
Cornus sanguinea	2
Crataugus monogyna	1

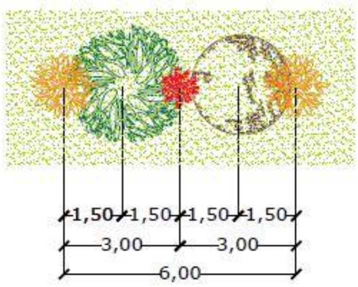

Figure 16. Buffer strip structure PP1 (taken from REWETLAND detailed design). Design specifications of interest (translated from Italian): width 6 m; Schrubs: *Comus sanguinea, Crataugus monogyna*; Trees: *Salis caprea*, *Salis triandra*.

2.1.3.2 PP3 Area 2: Buffer strip and Forcellata (Selcella Canal)

In Area 2, along the Selcella Canal, downstream of the Forcellata dewatering pump (**Figure 17**), a buffer strip was implemented.

Figure 17. Buffer Strip and self-purification enhancement of the Selcella Canal

The project includes the creation of buffer strips in the right bank of Selcella Canal, with the insertion in linear sequence of II size trees (willows) and shrubs (dogwood and hawthorn) and a width of 6 m, i.e. the same implementation scheme used for the Allacciante canal (see **Figure 16**). The only design difference compared to the Allacciante canal is the slope, equal to about 25%.

2.1.2.1 The fate of the Buffer strips

Both the buffer strips created along the Allacciante Astura canal and the Selcella canal were implemented without reshaping the canal section. This technical solution is acceptable for BSs along small ditches or streams that are not subject to rapid flow fluctuations. For canals or streams with rapid flow fluctuations, the presence of the BS – increasing the roughness of the section and consequently reducing the water flow velocity – could locally increase the flood risk. To avoid such a problem in other areas (e.g. the Consorzio Acque Risorgive near Venice) BSs along these kind of water bodies are implemented widening the canal section, in order to preserve the required conveyance for floods, while allowing vegetation to grow.

In 2017 and 2018 the area of Agro Pontino was affected by important floods causing several damages to the local agricultural activity. After the floods, the local farmers protested against the Consorzio di Bonifica Agro Pontino, blaming it for not taking care of the vegetation along the canals and thus not fulfilling its task of ensuring the maintenance of the water network. To answer to the request of maintenance of the local farmers the Consorzio di Bonifica Agro Pontino cut down most of the trees, bushes and aquatic vegetation along the canals affected by high flows.

Figure 18. The banks of the Allacciante Astura canal: the Buffer strips have almost completely disappeared (picture taken in January 2020)

Figure 19. The right banks of the Selcella canal (left in the picture): only the shrubs of the original Buffer strip are still visible (picture taken in January 2020)

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 - http://dati.lazio.it/catalog/it/dataset/carta-tecnica-regionale-1991)
- Soil type: Regional soil type map (https://geoportale.regione.lazio.it/geoportale/web/guest/catalogo?p_p_id=GNet_WAR_GNetportlet&p_p_lifecycle=0&_GNet_WAR_GNetportlet_lifportrend=carta%20geologica)
- Flood and risk maps (Bacini Regionali Lazio) (http://www.regione.lazio.it/prl_ambiente/?vw=contenutidettaglio&id=211)
- Hydrogeological map (https://www.idrogeologiaquantitativa.it/?p=2022&lang=it)

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

2.2.2 Climatic and hydrological framework

Climatic framework was developed consulting the following sources of data and information:

- precipitation and potential evapotranspiration estimated from temperature data registered in the nearest weather station of Sabaudia[3]
- rainfall depth-duration frequency curves for the hydrological framework from the Regional Functional Center[4]
- agricultural runoff model elaborated from the hydrological and hydraulic analysis of the hydrographic basins of Province of Latina[5]

The data was used for the mass balance analysis of Chapter 3.

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

[3] http://www.arsial.it/portalearsial/agrometeo/C1.asp
[4] http://www.idrografico.regione.lazio.it/std_page.aspx-Page=curve_pp.htm
[5] Origine dei carichi inquinanti e stato di eutrofizzazione delle acque interne della Provincia di Latina – Atlante dei Bacini Idrografici. Tecnostudi Ambiente S.r.l., May 2009 (www.provincia.latina.it)

3 MATERIAL FLOW ANALYSIS

3.1 Source of data and assumptions

The REWETLAND project included a complete Monitoring Program assigned to two companies: the SIBA s.p.a. (group leader) and BIOPROGRAMM s.c.[6]. The material flow analysis here proposed is based on the four sampling campaigns carried out from 2014 to 2015 (first from January to May 2014; second from December 2014 to September 2015).

The monitoring program included several pollutant parameters, as detailed in Annex 3.

Data were collected from 29 sampling points, which covered all the NBSs implemented in the REWETLAND project.

Despite the big monitoring efforts of the REWETLAND Project, the monitoring protocol does not fit with the aims of the present study. Indeed, the sampling points were located within the drainage canals, instead of being at the influent and effluent points of the NBSs. Although this sampling campaign evidenced a potential benefit of the installed NBSs (see Annex 3), the high uncertainty due to the low number of samples per NBS did not allow to effectively estimate the proper pollutant removal promoted by the NBS. In fact, the effluent point can be strongly disturbed by other canal tributaries, located upstream of the NBS site. As an example, the sampling points of the Linear Park of Marina di Latina are shown in **Figure 20**.

Figure 20. Sampling points for the linear park of Marina di Latina, took as an example of not suitable sampling points for a mass balance analysis of NBS performance

In order to fulfil the aim of the chapter and to provide suitable data for the watershed analysis of chapter 6, a theoretical estimation of the treatment performance of the REWETLAND NBS sites was proposed. The general methodology is described in the next sections.

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[6] ATI SIBA s.p.a. and BIOPROGRAMM s.c. "Progetto Life + Rewetland - Widespread introduction of constructed wetlands for a decentralised waste water treatment – Monitoraggio Ambientale dei progetti pilota – Provincia di Latina"

3.1.1 Constructed wetland mass balances

3.1.1.1 Hydraulic balance

According to Kadlec and Wallace (2009) and neglecting the infiltration at the bottom of the wetland bed, the **monthly hydraulic balance of a constructed wetland** can be defined as

$$V_{OUT} = V_{IN} + (P - ET) \cdot A_{CW}$$

with:

- V_{OUT} monthly effluent volume from the wetland [m^3/month]
- V_{IN} monthly influent volume in the wetland [m^3/month]
- P monthly precipitation over of the wetland surface [m/month]
- ET monthly evapotranspiration from the wetland surface [m/month]
- A_{CW} wetland area

Precipitation values were taken according to climatic data from the nearest weather station (Sabaudia – See Annex 2).

Evapotranspiration was calculated as follows

$$ET = k_{CW} \cdot ET_0$$

with:

- k_{CW} crop coefficient for wetland ecosystems, assumed equal to 1.6 according to Kadlec and Wallace (2009)
- ET_0 monthly reference evapotranspiration, calculated with Thornthwaite method from temperature data of the nearest weather station (Sabaudia – See Annex 2)

The Influent volume was calculated as follows

$$V_{IN} = V_{IN,MAX,CW} \qquad V_{IN,R} \geq V_{IN,MAX,CW}$$

$$V_{IN} = V_{IN,R} \qquad V_{IN,R} < V_{IN,MAX,CW}$$

with:

- $V_{IN,MAX,CW}$ maximum monthly influent volume to be treated according to design values
- $V_{IN,R}$ monthly runoff volume generated by the drained agricultural catchment

In other words, it was assumed that the wetland can receive, monthly, either the maximum designed volume (i.e. the maximum volume that can be pumped from the agricultural ditches) or the maximum volume that the agricultural catchment generates according to the monthly precipitation.

The monthly runoff volume from the agricultural catchment was calculated with the rational method as follows

$$V_{IN,R} = c_R \cdot P \cdot A_{CATCHMENT}$$

with:

- $A_{CATCHMENT}$ area of the drained agricultural catchment

— c_R runoff coefficient, function of precipitation [in mm/month] and of the drained sub-basin (see Annex 2 for details)

- MOS-RMA-100 $c_R = 0.034\,P - 0.0022$
- MOS-RMA-110 $c_R = 0.005\,P + 0.0612$
- MOS-790 $c_R = 0.0017\,P + 0.0092$

3.1.1.2 Nutrient removal efficiencies

The pollutant removal of the constructed wetlands was estimated with the **P-k-C* model** proposed by Kadlec and Wallace (2009), i.e. the most recent and complete design tool given by the Scientific Community of CWs (Dotro et al., 2017). The P-k-C* model simulates the CW as a tank in series reactor, i.e. with the following formulation:

$$\left(\frac{C_{out} - C^*}{C_{in} - C^*}\right) = \frac{1}{\left(1 + \frac{k_A}{Pq}\right)^P}$$

where:

— P apparent number in tanks-in-series, equal to 1 for BOD_5

— C_{in} influent concentration

— C_{out} effluent concentration out

— C^* background concentration, equal to 10 mg/l for BOD_5

— k_A First-order areal rate coefficient

— q hydraulic loading rate (HLR)

Kadlec and Wallace (2009) estimate the k_A for TN and TP as a function of temperature as follows

$$k_{A(T)} = k_{A(20)}\theta^{(T-20)}$$

where:

— T temperature

— $k_{A(T)}$ First-order areal rate coefficient at temperature T

— $k_{A(20)}$ First-order areal rate coefficient at temperature 20°C

— θ temperature coefficient

Contrarily to classical deterministic design approaches for CWs (e.g. the Reed's method – 1995), for which one CW area provides only one effluent concentration value (i.e. only one rate coefficient), Kadlec and Wallace (2009) proposed for the P-k-C* model a probabilistic distribution of rate coefficients for different pollutant parameters and different CW solutions; statistical analyses of the rate coefficients are done on the basis of a vast dataset of observed CW removal efficiencies. To consider this variability, the removal efficiencies was estimated for different pollutants considering three different k values:

— <u>Conservative</u>: 50^{th} percentile

— <u>Moderately Conservative</u>: 70^{th} percentile

— <u>Optimistic</u>: 90^{th} percentile

In this way, a range of potential effluent concentrations was provided, representing both more conservative and more optimistic estimations.

P, k, C* parameters for the analysed pollutants and for horizontal subsurface flow (HF) and free water surface (FWS) constructed wetlands are reported in the **Table 1**.

Table 1. P-k-C* kinetics from Kadlec and Wallace (2009)

		HF	FWS	
		TN	TN	TP
$k_{A(20)}$ – 50th perc	[m/yr]	8.4	12.6	10
$k_{A(20)}$ – 70th perc	[m/yr]	14.2	24.2	13.1
$k_{A(20)}$ – 90th perc	[m/yr]	30.5	39.2	60
C^*	[mg/l]	1	1.5	0.002
P	[-]	6	3	3
θ	[-]	N/A	1.056	1.005 (Warm climate)

Since Kadlec and Wallace (2009) do not provide P-k-C* kinetic parameters for TP removal in HF wetlands, the **loading rate chart** provided by the same authors was used to verify potential phosphorous retention in HF systems (**Figure 21**).

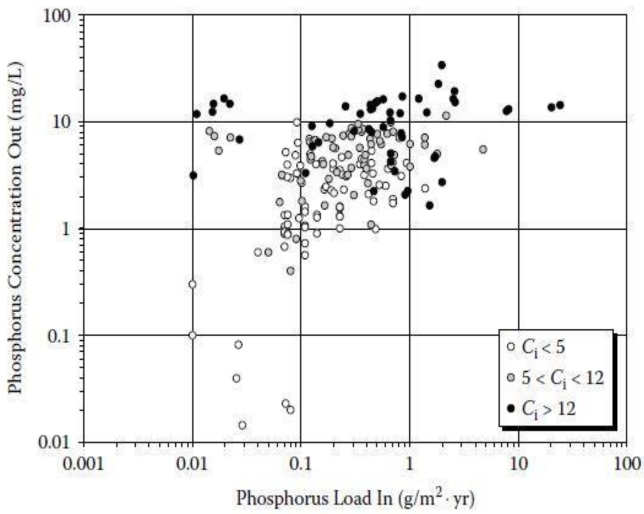


Figure 21. Outlet TP concentration versus TP loading for HF from Kadlec and Wallace (2009); data from 193 HF wetlands

3.1.1.3 Mass load removal

The **wetlands mass load removal** is calculated as follows

$$M_{rem,W} = M_{IN,W} - M_{OUT,W}$$

with:

— $M_{IN,W} = C_{IN} \cdot V_{IN}$ influent pollutant load,

— $M_{OUT,W} = C_{OUT} \cdot V_{OUT}$ effluent pollutant load

where:

— C_{IN} is the influent concentration, assumed equal to the mean values from the monitoring campaign of REWETLAND

— C_{OUT} is the effluent concentration estimated with the P-k-C* model

The **wetlands areal load removal** (g/m^2/y) is estimated as

$$areal\ load\ removal = \frac{M_{rem,W}}{A_W}$$

3.1.2 Buffer strips mass balance

Despite 20 years of experience in installing and monitoring buffer strips worldwide, clear and largely accepted simplified design models to estimate the removal efficiencies of buffer strips have not yet emerged. What is now clear in literature, though, is that buffer strips can be divided into two groups (Vidon et al., 2019):

— buffer strips targeting the interception of pollutant load driven by sediments conveyed by surface runoff (BS-R)

— buffer strips targeting the interception of pollutant load driven by subsurface groundwater (BS-G)

As evidenced in section 2, the implementation of buffer strips in the REWETLAND project faced some issues and the real effect in water pollution control during the monitoring period in 2014 remained highly uncertain. However, this chapter investigates the potential beneficial effect of the installed buffer according to available literature evidence. Not having enough information on groundwater flow and the potential of the buffer to intercept the subsurface pollution load, this analysis is limited to estimating the expected load interception of the buffer in terms of runoff surface interception.

3.1.2.1 Nutrient removal efficiencies

To this aim the TN and TP removal efficiency of the REWETLAND buffer strips was calculated with the regression **model proposed by Zhang (2010)**, that analysed the effect of the buffer strip width, slope, vegetation and soil on the pollutant removal efficiency of surface runoff. In the literature reviewed by Zhang, buffer slope varied from 2% to as high as 16%, and it was found that the optimum buffer slope is between 8.14 and 11.72%, with the sediment removal efficacy increasing from 0% to 10% and decreasing with slopes > 10%.

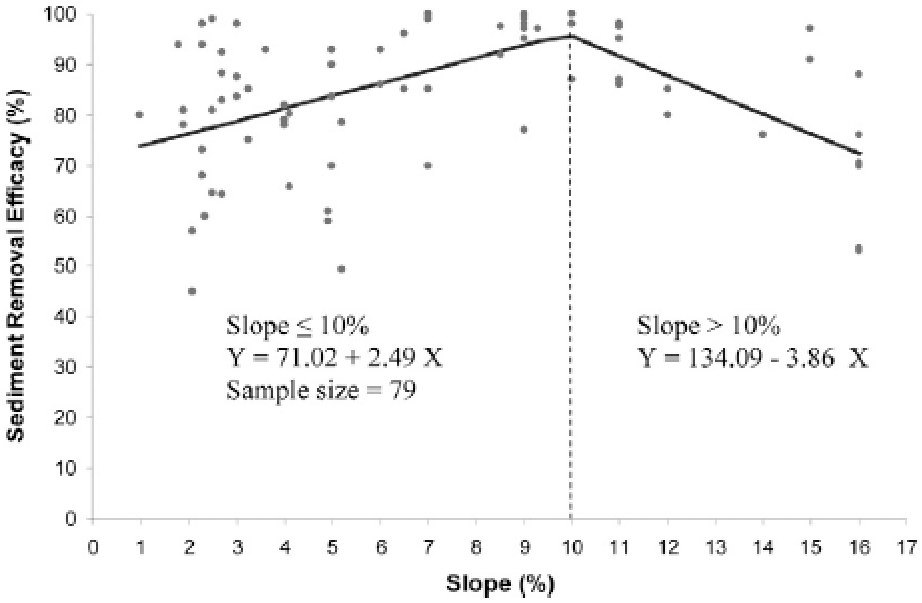


Figure 22. Correlation between sediment removal efficacy and buffer slope (Zhang et al., 2010)

The Allacciante canal buffer strip was constructed with an average slope of 5%, while the Selcella canal buffer strip has an average slope of 38%, way higher than the range considered by Zhang et al. (2010). Therefore, it was decided not to analyse the removal efficacy of the Selcella canal buffer strip, as TN and TP are mainly removed through sediment removal in buffer strips.

The **removal of nitrogen (TN)** of buffer strips vegetated with mixed grasses and trees/grasses is calculated with the following formulation:

$$\eta_{B,TN} = 10.2 + 91.4 * (1 - e^{-0.11*x})$$

Where:

— $\eta_{B,TN}$ is the mass removal efficiency expressed in percentage (%)

— x is the buffer width (m)

The **removal of phosphorous (TP)** of buffer strips vegetated with mixed grasses and trees/grasses is calculated with the following formulation:

$$\eta_{B,TP} = 30.5 + 147 * (1 - e^{-0.03*x})$$

Where:

— $\eta_{B,TN}$ is the mass removal efficiency expressed in percentage (%)

— x is the buffer width (m)

3.1.2.1 Mass load removal

Buffer strips for runoff interception (BS-R) aim to intercept the pollutant loads generated by sediments conveyed by agricultural runoff before the pollutant load enters the network of agricultural drainage ditches. Therefore, the **mass load removal of the buffer strips** is calculated as follows

$$M_{rem,B} = \eta_B \cdot M_{IN,B}$$

with:

— $M_{IN,B}$ influent diffuse pollutant load conveyed by agricultural runoff

— η_B mass removal efficiency from the Zhang et al. (2010) model

The influent diffuse pollutant load is calculated as follows

$$M_{IN,B} = areal\ diffuse\ pollutant\ load\ \cdot\ A_{CATCHMENT,B}$$

where $A_{CATCHMENT,B}$ is the area of the agricultural catchment drained towards the buffer strips and the $areal\ diffuse\ pollutant\ load$ is assumed equal to the agricultural diffused load estimated by the Ecology and Environment Sector of the Province of Latina for each hydrographic basin[7].

The **buffer strips areal load removal** (g/m^2/y) is estimated as

$$areal\ load\ removal = \frac{M_{rem,B}}{A_B}$$

3.2 Wetlands mass balances

3.2.1 PP1, wetland of Villa Fogliano

For the Villa Fogliano wetland, the sub-basins of interest are MOS-RMA-100 and MOS-RMA-110. The MOS-RMA-100 sub-basin surface is equal to 1270 ha, of which about 251 ha drained to the Villa Fogliano wetland, while the MOS-RMA-110 sub-basin surface is equal to 60 ha, of which a drainage area equal to half of the total area was estimated, about 30 ha.

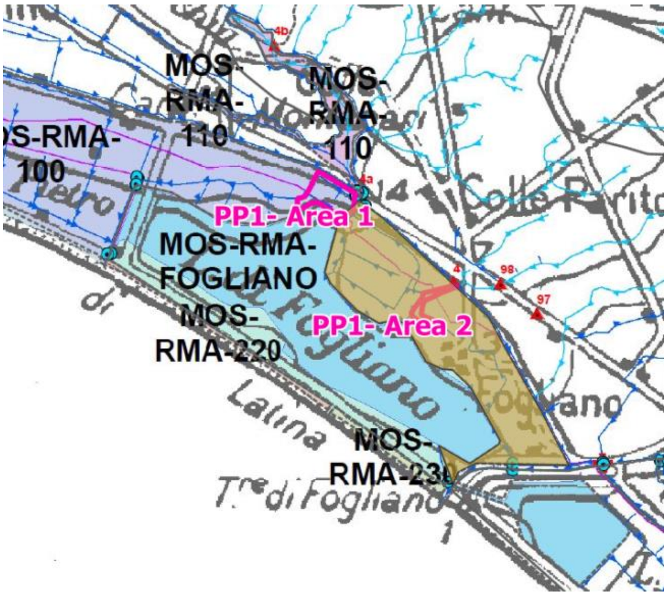


Figure 23. Close-up of the sub-basin map with the agricultural catchment area drained by the ditch of interest of the Villa Fogliano wetland: half of the MOS-RMA 110 (Rio Martino Foce Verde) and the yellow area for MOS-RMA 100 (Allacciante canal)

[7] Origine dei carichi inquinanti e stato di eutrofizzazione delle acque interne della Provincia di Latina – Atlante dei Bacini Idrografici. Tecnostudi Ambiente S.r.l., May 2009 (www.provincia.latina.it)

For the inflow into the wetland, a maximum withdrawal is allowed, managed by the Rio Martino Foce Verde and Allacciante canals, equal to 10 L/s for 24 hours/day between April and September and 19 L/s for 8 hours/day between October and March. Therefore, the inlet flow was considered equal to the maximum that could be withdrawn when the calculated flow was greater than the maximum, otherwise, it was considered equal to the calculated one.

The results of the hydraulic balance for the year of 2014 are shown in **Table 2**.

Table 2. Monthly hydraulic balance for the Villa Fogliano wetland for the year 2014

PP1 - 2014 FWS Villa Fogliano	**P**	**ET**	**Q_1 MOS-RMA-100**	**Q_2 MOS-RMA-110**	**Q_{1+2}**	**Q_{IN}**	**V_{IN}**	**V_{OUT}**
Month	**mm/m**	**mm/m**	**l/s**	**l/s**	**l/s**	**l/s**	**m^3/m**	**m^3/m**
Jan	145.30	22.6	159.8	30.57	190.4	19.0	7114	7113.6
Feb	71.50	27.6	45.5	9.45	55.0	19.0	6019	6019.2
Mar	113.90	35.3	141.7	27.71	169.4	19.0	4925	4924.8
Apr	45.40	58.0	25.1	5.68	30.8	10.0	6912	6478.9
May	34.10	85.9	28.2	6.86	35.1	10.0	3456	2533.6
Jun	76.40	130.1	114.4	23.51	137.9	10.0	4320	3133.7
Jul	60.80	142.5	51.7	11.01	62.7	10.0	6048	4554.3
Aug	3.60	143.5	0.5	0.50	1.0	1.0	176	0
Sep	88.20	107.4	254.5	51.27	305.7	10.0	2592	1826.5
Oct	3.60	79.4	1.1	0.99	2.0	2.0	59	0
Nov	173.90	48.9	270.8	51.09	321.9	19.0	6019	6019.2
Dec	218.70	25.1	428.6	79.71	508.3	19.0	6019	6019.2

The sampling points for the pollutants concentrations in the Villa Fogliano CW are shown in **Figure 24**.

Figure 24. Sampling points of the REWETLAND monitoring plan for the wetland of Villa Fogliano in 2014.

The sampling stations chosen for the CW are PP1-A2-1 (located along the Allacciante Canal), PP1-A2-8 (located along the Irrigation Canal feeding the system) and PP1-A2-5 (located at the discharging point into basin C). (**Figure 25**).

Figure 25. Station PP1-A2-1 located along the Allacciante Canal (upper photo); Station PP1-A2-8 along the Irrigation Canal (left); Station PP1-A2-5 upstream of the Basin A discharge section (right)

The averages of the concentrations recorded during the monitoring campaign in the PP1-A2-1 and PP1-A2-8 stations were assumed as the inlet concentrations, and the P-k-C* model proposed by Kadlec and Wallace (2009) was used to calculate the outlet concentrations and the removal efficiency considering a FWS surface area of 8500 m^2. The results of the modelled effluent concentrations where then compared with the Outlet concentrations recorded during the monitoring campaign in the PP1-A2-8 (inlet) and PP1-A2-5 (outlet) stations.

The removed mass load is given by the difference between the input and output mass load, and is then divided by the wetland surface to obtain the areal removal ($g/m^2/y$). The results of the analysis are given in **Table 3**, **Table 4**, and

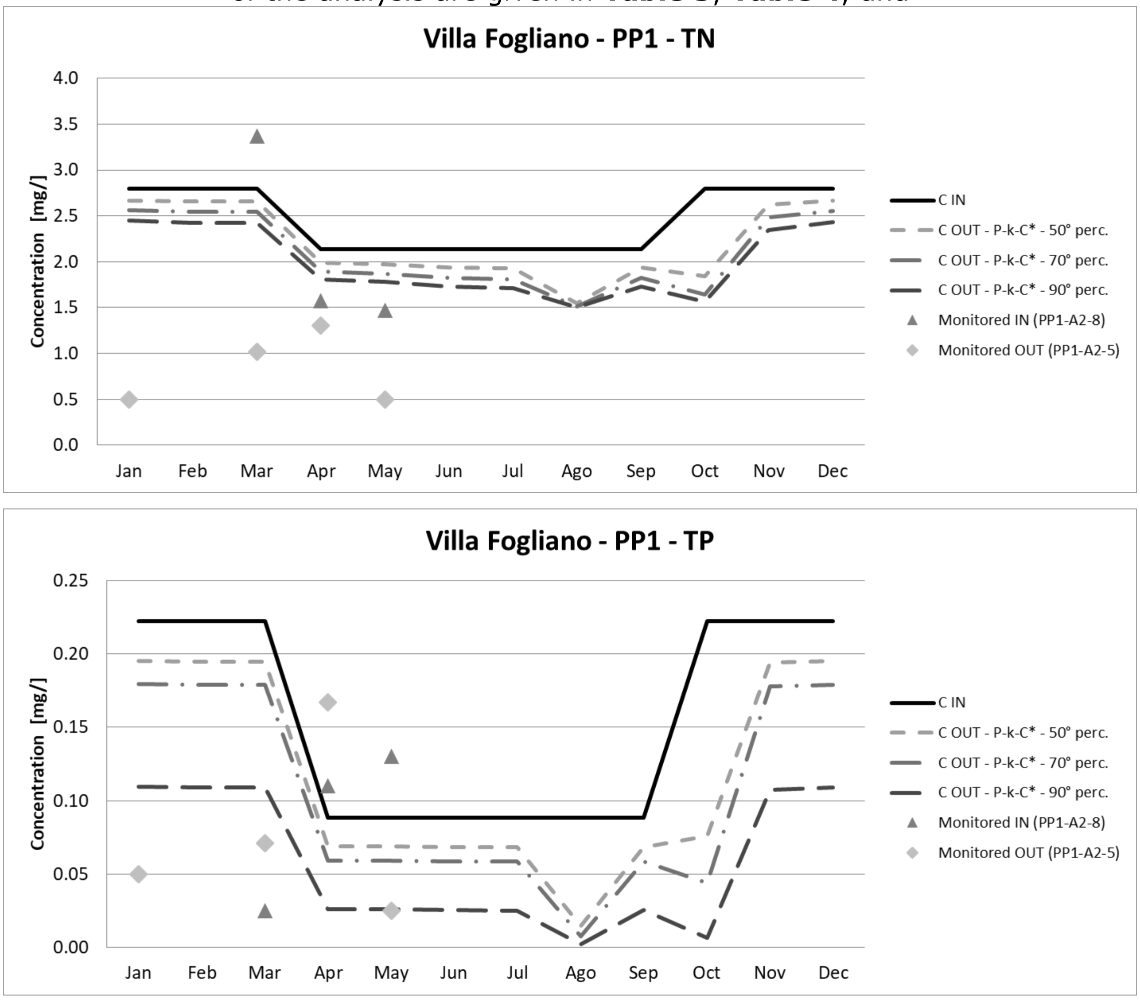


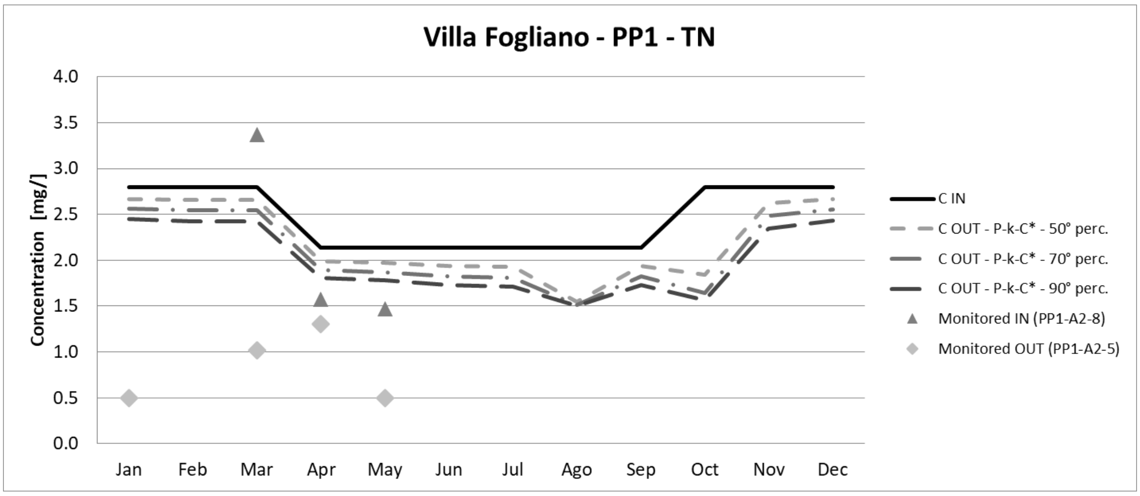
Figure 26.

Table 3. Nitrogen mass balance for the wetland of Villa Fogliano (PP1) for the year 2014

TN PP1 - 2014 FWS Villa Fogliano	T_air (°C) - 2014	Q IN (m^3/d)	HRT (d)	HLR (cm/d)	C IN (mg/L)	Load - tot FWS (g/m^2 y)	C OUT – Cons. - perc 0.5 (mg/l)	C OUT – Mod. cons. - perc 0.7 (mg/l)	C OUT – Opt. - perc 0.9 (mg/l)	M OUT – Cons. - perc 0.5 (kg/m)	M OUT – Mod. cons. - perc 0.7 (kg/m)	M OUT – Opt. - perc 0.9 (kg/m)	M rem – Cons. - perc 0.5 (kg/m)	M rem – Mod. cons. - perc 0.7 (kg/m)	M rem – Opt. - perc 0.9 (kg/m)
Jan	10.7	1641.6	4.1	19.3	2.8	197.4	2.67	2.56	2.45	19.0	18.2	17.40	0.9	1.7	2.5
Feb	12.0	1641.6	4.1	19.3	2.8	197.4	2.66	2.55	2.43	16.0	15.3	14.60	0.8	1.5	2.3
Mar	12.2	1641.6	4.1	19.3	2.8	197.4	2.66	2.55	2.42	13.1	12.5	11.93	0.7	1.2	1.9
Apr	15.5	864.0	7.9	10.2	2.1	79.3	1.99	1.90	1.81	12.9	12.3	11.71	1.9	2.5	3.1
May	18.1	864.0	7.9	10.2	2.1	79.3	1.98	1.87	1.78	5.0	4.7	4.51	2.4	2.6	2.9
Jun	22.8	864.0	7.9	10.2	2.1	79.3	1.94	1.82	1.73	6.1	5.7	5.41	3.2	3.5	3.8
Jul	23.9	864.0	7.9	10.2	2.1	79.3	1.93	1.81	1.72	8.8	8.3	7.81	4.1	4.7	5.1
Ago	24.9	88.2	77.1	1.0	2.1	8.1	1.54	1.51	1.50	0.0	0.0	0.00	0.4	0.4	0.4
Sep	22.8	864.0	7.9	10.2	2.1	79.3	1.94	1.82	1.73	3.5	3.3	3.15	2.0	2.2	2.4
Oct	20.1	176.3	38.6	2.1	2.8	21.2	1.84	1.65	1.56	0.0	0.0	0.00	0.2	0.2	0.2
Nov	16.7	1641.6	4.1	19.3	2.8	197.4	2.62	2.49	2.34	15.8	15.0	14.11	1.1	1.9	2.7
Dec	11.6	1641.6	4.1	19.3	2.8	197.4	2.66	2.55	2.43	16.0	15.4	14.64	0.8	1.5	2.2
mean			**14.6**	**12.5**	**2.5**	**117.7**	**2.20**	**2.09**	**1.99**						
std			**21.9**	**6.7**		**74.1**	**0.42**	**0.41**	**0.38**						
mean rem. eff.							**11%**	**15%**	**19%**						
sum													**18.4**	**23.8**	**29.4**
												areal removal (g/m^2/y)	**2.2**	**2.8**	**3.5**

Table 4. Phosporous mass balance for the wetland of Villa Fogliano (PP1) for the year 2014

TP PP1 - 2014 FWS Villa Fogliano	T_air (°C) - 2014	Q IN (m^3/d)	HRT (d)	HLR (cm/d)	C IN (mg/L)	Load - tot FWS (g/m^2 y)	C OUT – Cons. - perc 0.5 (mg/l)	C OUT – Mod. cons. - perc 0.7 (mg/l)	C OUT – Opt. - perc 0.9 (mg/l)	M OUT – Cons. - perc 0.5 (kg/m)	M OUT – Mod. cons. - perc 0.7 (kg/m)	M OUT – Opt. - perc 0.9 (kg/m)	M rem – Cons. - perc 0.5 (kg/m)	M rem – Mod. cons. - perc 0.7 (kg/m)	M rem – Opt. - perc 0.9 (kg/m)
Jan	10.7	1641.6	4.1	19.3	0.22	15.7	0.20	0.18	0.11	1.4	1.3	0.78	0.2	0.3	0.8
Feb	12.0	1641.6	4.1	19.3	0.22	15.7	0.19	0.18	0.11	1.2	1.1	0.66	0.2	0.3	0.7
Mar	12.2	1641.6	4.1	19.3	0.22	15.7	0.19	0.18	0.11	1.0	0.9	0.54	0.1	0.2	0.6
Apr	15.5	864.0	7.9	10.2	0.09	3.3	0.07	0.06	0.03	0.4	0.4	0.17	0.2	0.2	0.4
May	18.1	864.0	7.9	10.2	0.09	3.3	0.07	0.06	0.03	0.2	0.1	0.07	0.1	0.2	0.2
Jun	22.8	864.0	7.9	10.2	0.09	3.3	0.07	0.06	0.03	0.2	0.2	0.08	0.2	0.2	0.3
Jul	23.9	864.0	7.9	10.2	0.09	3.3	0.07	0.06	0.03	0.3	0.3	0.11	0.2	0.3	0.4
Ago	24.9	88.2	77.1	1.0	0.09	0.3	0.01	0.01	0.00	0.0	0.0	0.00	0.0	0.0	0.0
Sep	22.8	864.0	7.9	10.2	0.09	3.3	0.07	0.06	0.03	0.1	0.1	0.05	0.1	0.1	0.2
Oct	20.1	176.3	38.6	2.1	0.22	1.7	0.08	0.04	0.01	0.0	0.0	0.00	0.0	0.0	0.0
Nov	16.7	1641.6	4.1	19.3	0.22	15.7	0.19	0.18	0.11	1.2	1.1	0.65	0.2	0.3	0.7
Dec	11.6	1641.6	4.1	19.3	0.22	15.7	0.20	0.18	0.11	1.2	1.1	0.66	0.2	0.3	0.7
mean			**14.6**	**12.5**	**0.16**	**8.1**	**0.12**	**0.10**	**0.06**						
std			**21.9**	**6.7**		**6.8**	**0.07**	**0.07**	**0.05**						
mean rem. eff.							**25%**	**34%**	**63%**						
sum													**1.65**	**2.31**	**5.04**
												areal removal (g/m^2/y)	**0.19**	**0.27**	**0.59**



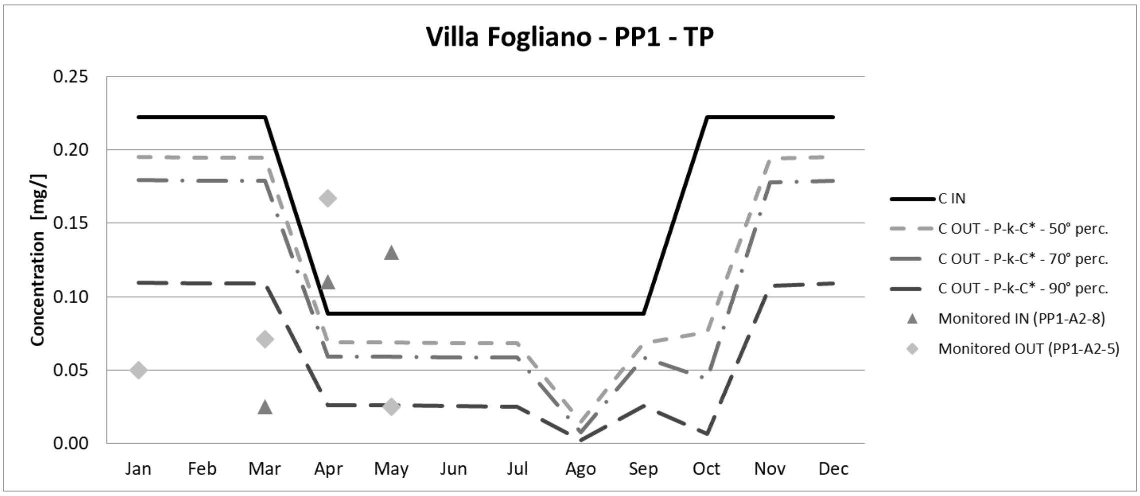
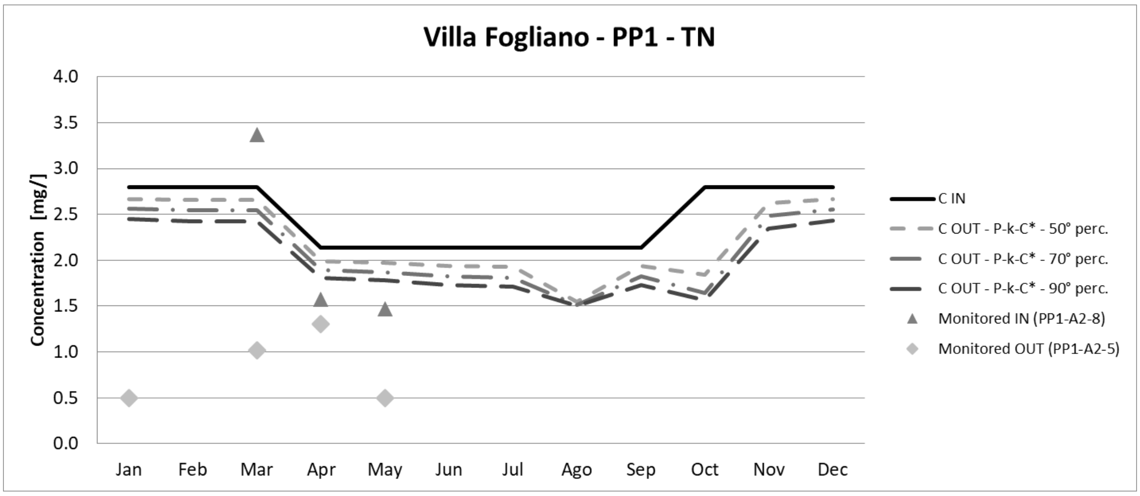


Figure 26. Influent and effluent concentrations for the FWS of Villa Fogliano (PP1) simulated and monitored in 2014.

As can be noted from



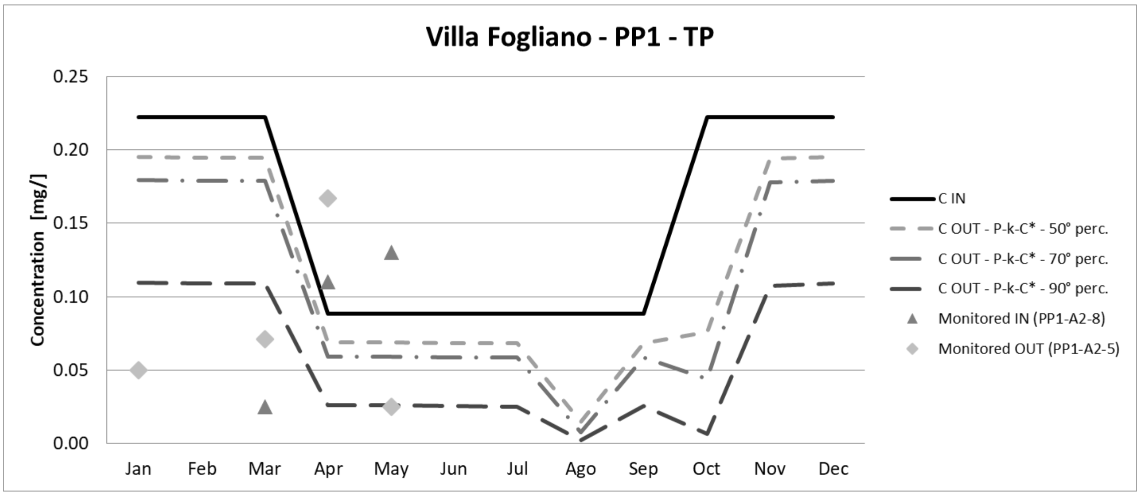


Figure 26, the monitored outlet TN concentrations are too low even with the most optimistic assumption on kinetic removal, especially considering that background TN concentration of FWSs is estimated equal to 1.5 mg/l by Kadlec and Wallace (2009), i.e. higher than the monitored effluent concentrations. On the other hand, monitored outlet TP concentrations seem in line with moderately optimistic kinetic assumption for TP removal (70^{th} percentile). It is interesting to note that a peak in removal efficiency was simulated for both TN and TP in August. This is due to the very low estimated influent load (1 l/s instead of the targeted 10-19 l/s), driven by low mean precipitation in August 2014. In this month the expected hydraulic retention time (HRT) is so high (greater than 1 month) within the wetland that the percentage of removal rises to 30% for TN and almost 100% for TP in more optimistic kinetic conditions (90^{th} percentile). Apart from the doubt about the treatment performance at such high and low HRTs experienced in literature, it is important to remind that a high HRT also means very low loads, therefore very low intercepted and removed loads. This is confirmed by the negligible annual mass load removed in August in comparison to other months (**Table 3** and **Table 4**). Hence, this theoretical analysis rises the importance of considering loads rather than percentage removal in the analysis of wetlands (and NBSs in general) for diffuse pollution control, where is much more important to reduce polluting loads rather than just respecting a threshold value for the discharge outflow, common practice in centralised sanitation schemes.

3.2.2 PP2, wetland of Marina di Latina

For the Marina di Latina wetland, the sub-basin of interest is the MOS-RMA-100. The MOS-RMA-100 sub-basin surface is equal to 1270 ha, of which about 297 ha drained to the Marina di Latina wetland **Figure 27**.

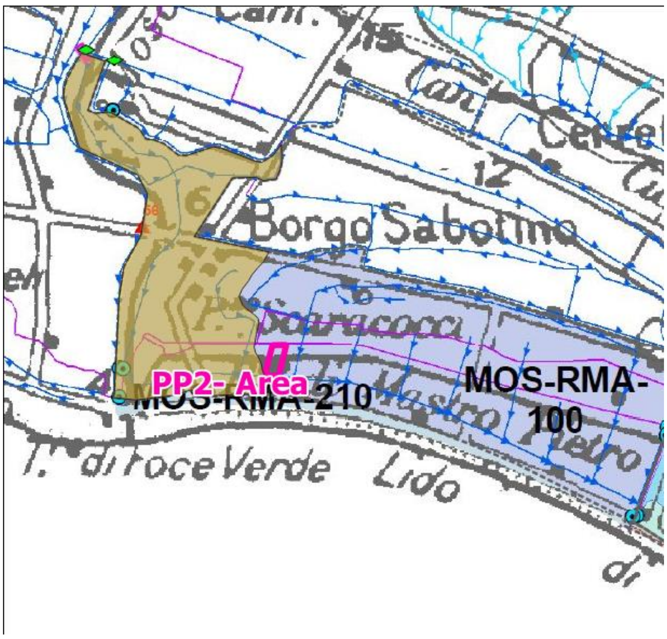


Figure 27. Close-up of the sub-basin map with the agricultural catchment area drained by the ditch of interest of the Marina di Latina wetland MOS-RMA 100.

For the inflow into the wetland, a maximum withdrawal is allowed, equal to 10 L/s for 24 hours/day. Therefore, the inlet flow was considered equal to the maximum that could be withdrawn when the calculated flow was greater than the maximum, otherwise, it was considered equal to the calculated one.

The results of the hydraulic balance for the year of 2014 are shown in **Table 5**.

Table 5. Monthly hydraulic balance for the Marina di Latina wetland for the year 2014

PP1 - 2014 FWS Villa Fogliano	**P**	**ET**	**Q MOS-RMA-100**	**Q_{IN}**	**V_{IN}**	**V_{OUT}**
Month	**mm/m**	**mm/m**	**l/s**	**l/s**	**m^3/m**	**m^3/m**
Jan	145.30	22.6	188.8	10.0	11232	11232.0
Feb	71.50	27.6	53.8	10.0	9504	9504.0
Mar	113.90	35.3	167.4	10.0	7776	7776.0
Apr	45.40	58.0	29.7	10.0	6912	6861.0
May	34.10	85.9	33.3	10.0	3456	3347.5
Jun	76.40	130.1	135.2	10.0	4320	4180.4
Jul	60.80	142.5	61.0	10.0	6048	5872.3
Aug	3.60	143.5	0.6	0.6	107	
Sep	88.20	107.4	300.6	10.0	2592	2501.9
Oct	3.60	79.4	1.2	1.2	107	
Nov	173.90	48.9	319.9	10.0	9504	9504.0
Dec	218.70	25.1	506.3	10.0	9504	9504.0

The sampling points for the pollutants concentrations in the Marina di Latina CW are shown in **Figure 28**.

Figure 28. Sampling points of the REWETLAND monitoring plan for the wetland of Marina di Latina in 2014.

The sampling stations chosen for the CW are PP2-SMS2-PP2-2 (located at the inlet of the wetland system) and PP2-SMS2-PP2-1 (located at the outlet of the wetland system). (**Figure 29**).

Figure 29. Station PP2-SMS2-PP2-1 at the outlet of the wetland system (left); Station PP2-SMS2-PP2-2 at the inlet of the wetland system (right)

The average of the concentrations recorded during the monitoring campaign in the PP2-SMS2-PP2-2 station was assumed as the inlet concentration, and the P-k-C* model proposed by Kadlec and Wallace (2009) was used to calculate the outlet concentrations and the removal efficiency, considering the treatment train of the implemented system (see **Figure 11**): 1st stage, 2 parallel horizontal subsurface flow wetlands (HF, Basin 1-2, each one equal to 1000 m^2); 2nd stage, free water surface (FWS, Basin 3 of 1000 m^2); 3rd stage, free water surface (FWS, Basin 4 of 1000 m^2). The results where then compared with the inlet and outlet concentrations recorded during the monitoring campaign in the PP2-SMS2-PP2-1 (inlet) and PP2-SMS2-PP2-2 (outlet) stations.

The removed mass load is given by the difference between the input and output mass load, and is then divided by the wetland surface to obtain the areal removal ($g/m^2/y$). The results of the analysis are given in **Table 6**, **Table 7**, and **Figure 31**.

As can be noted from **Figure 31**, the monitored outlet TN and TP concentrations are not in line with theoretical estimations, confirming the correctness of basing the mass balance on theoretical estimations rather than the uncertain sampled data of the REWETLAND monitoring campaign of 2014. Considerations similar to those already discussed for the mass balances of PP1 (section 3.2.1) can be done on the simulated peaks of low effluent concentration (**Figure 31**), related to the low influent low rate (higher hydraulic retention times) but negligible in terms of mass removal.

The analysis of the Marina di Latina wetland also allows to do some considerations on the use of hybrid wetlands, i.e. using both subsurface and surface wetlands, for the treatment of the agricultural runoff. This scheme is very rare in literature, and only tested in some small scale systems, while the prevalent wetland solution for agricultural diffuse pollution control is that of free water surface (Ioannidou and Stefanakis, 2020). This is reasonable, due to the high solid load of agricultural runoff, which could compromise the hydraulic conductivity of the filling media and lead to clogging issues. Apart from the rarity of seeing a HF as first step for agricultural runoff treatment, it must be noted that the hydraulic retention times (HRTs) of the HF beds were extremely short: 0.2 days (**Table 26**), leading to a phosphorous loading rate of 27.8 g m^{-2} y^{-1} which is extremely high in comparison to those usually encountered in HF systems (**Figure 30**); therefore, the TP removal rates of the HF was considered negligible. Contrarily, the FWS stages phosphorous loading rate of basins 3 and 4 of 31.8 g m^{-2} y^{-1}, corresponding to a HRT of about 1 day, was realistic in accordance to literature evidence (**Figure 30**), confirming the fact that FWSs are mostly used for water rich in nutrients as those from agricultural pollution and that the simulated results of the P-k-C* can be considered more reliable. Similar considerations can also be done for the TN removal by the HF, which is quite negligible.

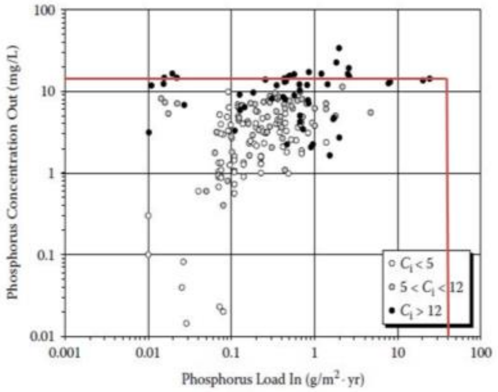
Table 6. Nitrogen mass balance for the wetland of Marina di Latina (PP2) for the year 2014

			Basin 1 – 2 (in parallel) HF							Basin 3 – 4 (in series) FWS												
TN PP2 - 2014 wetland Marina di Latina	**T_air (°C) - 2014**	**C IN (mg/L)**	**Q IN 1-2 (m³/d)**	**HRT 1-2 (d)**	**HLR 1-2 (cm/d)**	**Load - tot 1 – 2 (g/m² y)**	**C OUT 1-2 – Cons. - perc 0.5 (mg/l)**	**C OUT 1-2 – Mod. cons. - perc 0.7 (mg/l)**	**C OUT 1-2 – Opt. - perc 0.9 (mg/l)**	**Q IN 3-4 (m³/d)**	**HRT 3-4 (d)**	**HLR 3-4 (cm/d)**	**Load - tot 3 – 4 (g/m² y)**	**C OUT 3-4 – Cons. - perc 0.5 (mg/l)**	**C OUT 3-4 – Mod. cons. - perc 0.7 (mg/l)**	**C OUT 3-4 – Opt. - perc 0.9 (mg/l)**	**M OUT – Cons. - perc 0.5 (kg/m)**	**M OUT – Mod. cons. - perc 0.7 (kg/m)**	**M OUT – Opt. - perc 0.9 (kg/m)**	**M rem – Cons. - perc 0.5 (kg/m)**	**M rem – Mod. cons. - perc 0.7 (kg/m)**	**M rem – Opt. - perc 0.9 (kg/m)**
Jan	10.7	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.65	4.39	3.93	52.2	49.3	44.1	4.1	7.0	12.2
Feb	12.0	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.64	4.37	3.90	44.1	41.6	37.1	3.5	6.1	10.5
Mar	12.2	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.64	4.37	3.90	36.1	34.0	30.3	2.9	5.0	8.7
Apr	15.5	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.61	4.31	3.83	31.6	29.6	26.2	3.0	5.0	8.4
May	18.1	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.58	4.26	3.76	15.3	14.3	12.6	2.0	3.0	4.7
Jun	22.8	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.51	4.16	3.62	18.9	17.4	15.1	2.8	4.3	6.5
Jul	23.9	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.50	4.13	3.59	26.4	24.2	21.1	3.9	6.1	9.3
Ago	24.9	5.0	27	3.9	2.7	49.1	2.80	2.09	1.33	54	15.0	2.7	49.1	1.80	1.54	1.50	0.0	0.0	0.00	0.5	0.5	0.5
Sep	22.8	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.51	4.16	3.62	11.3	10.4	9.1	1.7	2.6	3.9
Oct	20.1	5.0	54	2.0	5.4	98.1	3.65	3.02	2.00	107	7.4	5.4	98.1	2.66	1.99	1.59	0.0	0.0	0.0	0.5	0.5	0.5
Nov	16.7	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.59	4.29	3.80	43.7	40.8	36.1	4.0	6.8	11.6
Dec	11.6	5.0	432	0.2	43.2	790.4	4.81	4.67	4.32	864	1.0	43.2	790.4	4.64	4.38	3.91	44.1	41.6	37.2	3.5	6.0	10.5
mean		**5.0**		**0.7**	**36.7**	**670.9**	**4.54**	**4.32**	**3.87**		**2.6**	**36.7**	**670.9**	**4.19**	**3.86**	**3.41**						
std				**1.9**	**15.3**	**279.2**	**0.64**	**0.85**	**1.04**		**4.2**	**15.3**	**279.2**	**0.94**	**0.99**	**0.88**						
mean rem. eff.							**9%**	**14%**	**23%**					**16%**	**23%**	**32%**						
sum																				**32.54**	**53.04**	**87.27**
																			areal removal (g/m2/y)	**8.1**	**13.3**	**21.8**

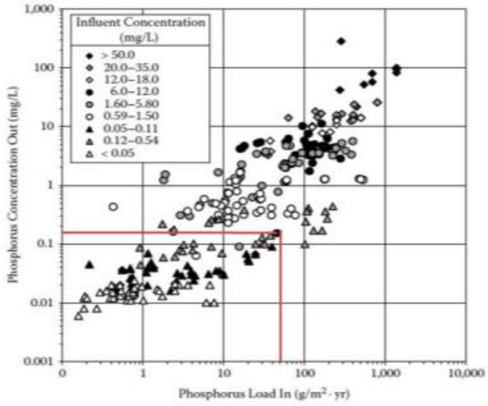
Table 7. Phosporous mass balance for the wetland of Marina di Latina (PP2) for the year 2014

			Basin 1 – 2 (in parallel) HF							Basin 3 – 4 (in series) FWS												
TP PP2 - 2014 wetland Marina di Latina	**T_air (°C) - 2014**	**C IN (mg/L)**	**Q IN 1-2 (m³/d)**	**HRT 1-2 (d)**	**HLR 1-2 (cm/d)**	**Load - tot 1 – 2 (g/m² y)**	**C OUT* 1-2 – Cons. - perc 0.5 (mg/l)**	**C OUT* 1-2 – Mod. cons. - perc 0.7 (mg/l)**	**C OUT* 1-2 – Opt. - perc 0.9 (mg/l)**	**Q IN 3-4 (m³/d)**	**HRT 3-4 (d)**	**HLR 3-4 (cm/d)**	**Load - tot 3 – 4 (g/m² y)**	**C OUT 3-4 – Cons. - perc 0.5 (mg/l)**	**C OUT 3-4 – Mod. cons. - perc 0.7 (mg/l)**	**C OUT 3-4 – Opt. - perc 0.9 (mg/l)**	**M OUT – Cons. - perc 0.5 (kg/m)**	**M OUT – Mod. cons. - perc 0.7 (kg/m)**	**M OUT – Opt. - perc 0.9 (kg/m)**	**M rem – Cons. - perc 0.5 (kg/m)**	**M rem – Mod. cons. - perc 0.7 (kg/m)**	**M rem – Opt. - perc 0.9 (kg/m)**
Jan	10.7	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.9	0.20	0.19	0.15	2.2	2.1	1.6	0.14	0.22	0.69
Feb	12.0	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.8	0.20	0.19	0.15	1.9	1.8	1.4	0.12	0.19	0.58
Mar	12.2	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.8	0.20	0.19	0.15	1.5	1.5	1.1	0.09	0.15	0.48
Apr	15.5	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.7	0.20	0.19	0.15	1.3	1.3	1.0	0.10	0.15	0.44
May	18.1	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.5	0.20	0.19	0.14	0.7	0.6	0.5	0.06	0.09	0.23
Jun	22.8	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.3	0.20	0.19	0.14	0.8	0.8	0.6	0.08	0.12	0.30
Jul	23.9	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.2	0.20	0.19	0.14	1.1	1.1	0.8	0.11	0.16	0.42
Ago	24.9	0.2	27	3.9	2.7	2.0	-	-	-	54	15.0	2.7	1.4	0.08	0.05	0.00	0.0	0.0	0.0	0.02	0.02	0.02
Sep	22.8	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.3	0.20	0.19	0.14	0.5	0.5	0.4	0.05	0.07	0.18
Oct	20.1	0.2	54	2.0	5.4	4.1	-	-	-	107	7.4	5.4	3.2	0.13	0.09	0.02	0.0	0.0	0.0	0.02	0.02	0.02
Nov	16.7	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.6	0.20	0.19	0.15	1.9	1.8	1.4	0.12	0.19	0.60
Dec	11.6	0.2	432	0.2	43.2	32.8	-	-	-	864	1.0	43.2	31.9	0.20	0.19	0.15	1.9	1.8	1.4	0.11	0.19	0.58
mean		**0.2**		**0.7**	**36.7**	**27.8**					**2.6**	**36.7**	**26.7**	**0.18**	**0.17**	**0.12**						
std				**1.9**	**15.3**	**11.6**					**4.2**	**15.3**	**11.4**	**0.04**	**0.05**	**0.05**						
mean rem. eff.														**13%**	**19%**	**41%**						
sum																				**1.03**	**1.57**	**4.54**
																			areal removal (g/m2/y)	**0.3**	**0.4**	**1.1**

* Phosphorous loading rate of the HFs higher than the literature value. No P removal assumed for HF beds.

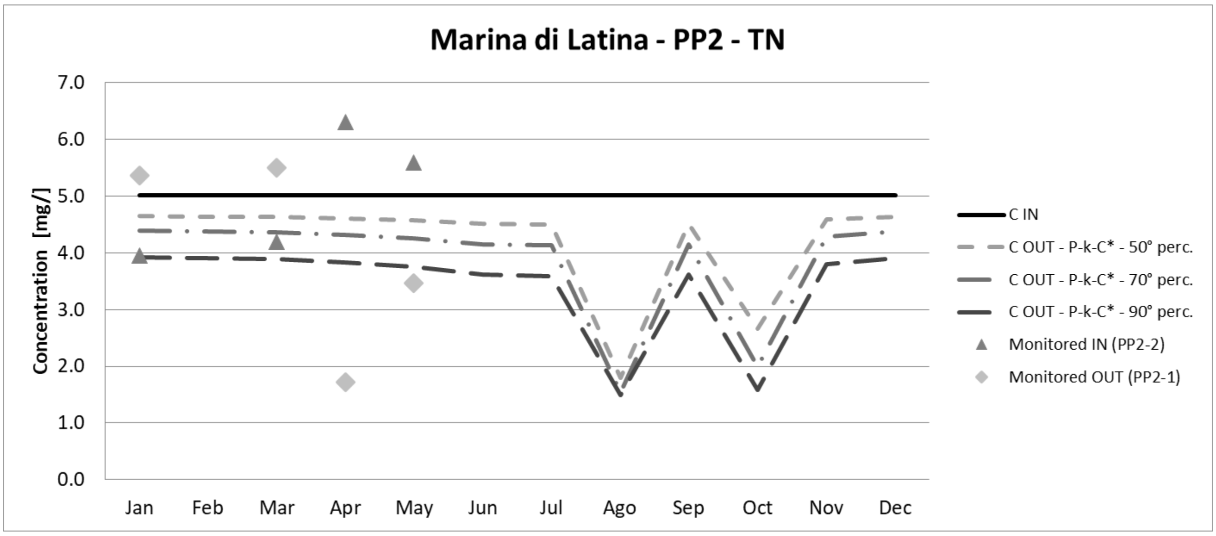


HF



FWS

Figure 30. Outlet TP concentration versus TP loading for HFs (left) and FWSs (right) from Kadlec and Wallace (2009) compared with the loading rate phosphorous of the PP2 wetland basins of Marina di Latina (red lines).



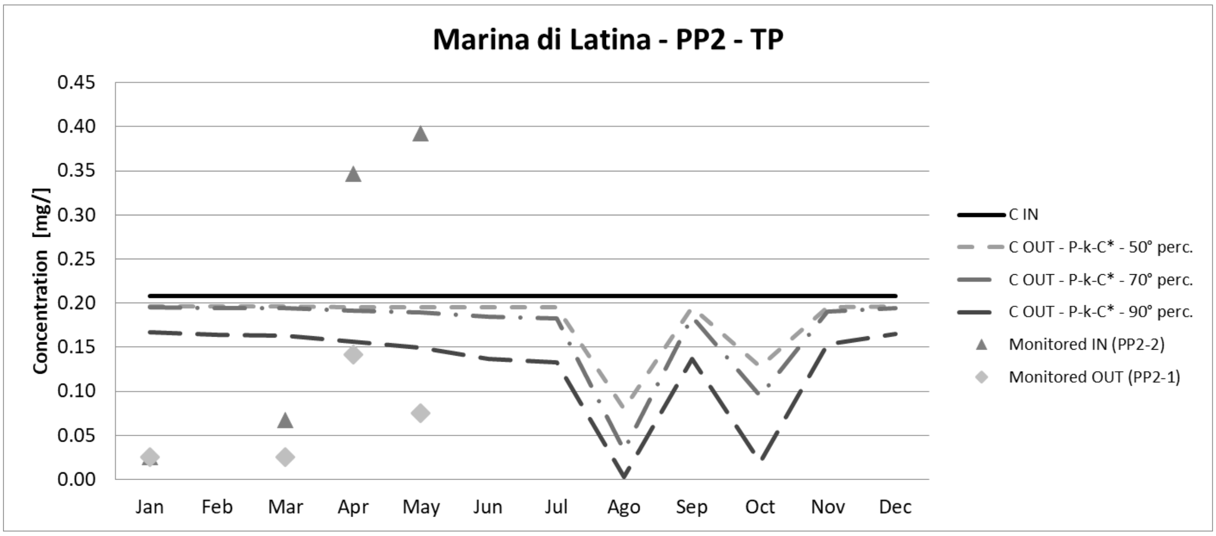


Figure 31. Influent and effluent concentrations for the wetland of Marina di Latina (PP2) simulated and monitored in 2014.

3.2.3 Comparison with literature evidences

The simulated results for the wetlands of REWETLAND from the P-k-C* model were compared with literature evidence. The results are summarized in **Table 8**, from which the following considerations can be done:

— The hydraulic loading rates (HLRs) are higher than the design value suggested by Kadlec and Wallace (2009) for dissolved pollutants removal (< 5 cm/d), but they remain in line with the values encountered in literature for similar applications;

— accordingly, the removal percentages simulated with the P-k-C* are in line with the values encountered in literature for similar applications;

— the nitrogen areal load removal simulated with the P-k-C* of PP1 (Villa Fogliano) is lower than that of PP2 (Marina di Latina); this is mainly related to the fact that influent TN concentrations of PP1 are lower than those of PP2;

— the FWS stage of PP2 (Marina di Latina) has nutrient removal performance similar to that of the whole multistage system (HF+FWS), highlighting the lack of an added value in implementing a HF on the overall mass load removal;

— the areal load removals simulated with the P-k-C* for agricultural runoff are lower than the values commonly encountered in FWSs (see values of Vymazal 2007); this is in line with the considerations made by Kadlec and Wallace (2009) and can mainly be attributed to the peculiarities of agricultural runoff pollution, i.e. stochastic hydraulic load (high variability of hydraulic retention times) and diluted concentration of nutrient pollutants; the effect of the diluted concentration is particularly relevant for TN removal, since a background effluent concentration of 1.5 mg/l was fitted by Kadlec and Wallace (2009), leading to a reduction in removal efficiency when the influent concentrations (C*, see 3.1.1.2) are proximal to this value, as happened for instance in PP1 (Villa Fogliano).

Table 8. Literature comparison of P-k-C* simulated performance of the REWETLAND wetlands with literature evidence

TN	Influent Conc. [mg/l]	HLR [cm/d]	Removal [%]	Areal load removal [g m^{-2} y^{-1}]
REWETLAND				
PP1 – Villa Fogliano	2.1 – 2.8	1.0 – 19.3	11% (mean P-k-C* 50th perc.) 15% (mean P-k-C* 70th perc.) 19% (mean P-k-C* 90th perc.)	2.2 (P-k-C* 50th perc.) 2.8 (P-k-C* 70th perc.) 3.5 (P-k-C* 90th perc.)
PP2 – Marina di Latina total	5.0	2.7 – 43.2	13% (mean P-k-C* 50th perc.) 19% (mean P-k-C* 70th perc.) 28% (mean P-k-C* 90th perc.)	8.1 (P-k-C* 50th perc.) 13.3 (P-k-C* 70th perc.) 21.8 (P-k-C* 90th perc.)
PP2 – Marina di Latina only FWS				8.7 (P-k-C* 50th perc.) 14.1 (P-k-C* 70th perc.) 18.6 (P-k-C* 90th perc.)
Literature				
Kadlec and Wallace (2009) Event-driven wetland for agricultural runoff	1.6 – 26.2	0.3 – 181	-11 – 67% median 26%	
Vymazal (2007) FWS (all types of WW)	14.3 (mean)			247
Kadlec (2021) FWS nitrate-rich WW				7.3 (as N-NO3-, 1st quartile) 182 (as N-NO3-, 3rd quartile)
TP	**Influent Conc. [mg/l]**	**HLR [cm/d]**	**Removal [%]**	**Areal load removal [g m^{-2} y^{-1}]**
REWETLAND				
PP1 – Villa Fogliano	0.09 – 0.22	1.0 – 19.3	25% (mean P-k-C* 50th perc.) 34% (mean P-k-C* 70th perc.) 63% (mean P-k-C* 90th perc.)	0.19 (P-k-C* 50th perc.) 0.27 (P-k-C* 70th perc.) 0.59 (P-k-C* 90th perc.)
PP2 – Marina di Latina total	0.2		13% (mean P-k-C* 50th perc.) 19% (mean P-k-C* 70th perc.) 41% (mean P-k-C* 90th perc.)	0.26 (P-k-C* 50th perc.) 0.39 (P-k-C* 70th perc.) 1.14 (P-k-C* 90th perc.)
PP2 – Marina di Latina only FWS				0.51 (P-k-C* 50th perc.) 0.79 (P-k-C* 70th perc.) 2.27 (P-k-C* 90th perc.)
Literature				
Kadlec and Wallace (2009) Event-driven wetland for agricultural runoff	0.015 – 1.15	0.3 – 181	-76% – 80% median 36%	
Vymazal (2007) FWS (all types of WW)	4.2 (mean)			70

3.3 Buffer strip mass balance

3.3.1 PP3, buffer strip of Canale Allacciante

The sub-basin of interest for the Allacciante canal is the MOS-790, shown in **Figure 32**, with a surface of 3470 ha, the area drained by the buffer strip was considered as a strip about 200 m wide along the buffer strip, excluding the areas in which there are canals or roads that intercept the buffer and which constitute preferential routes for the runoff (**Figure 33**). The calculated drained area resulted equal to 42 ha.

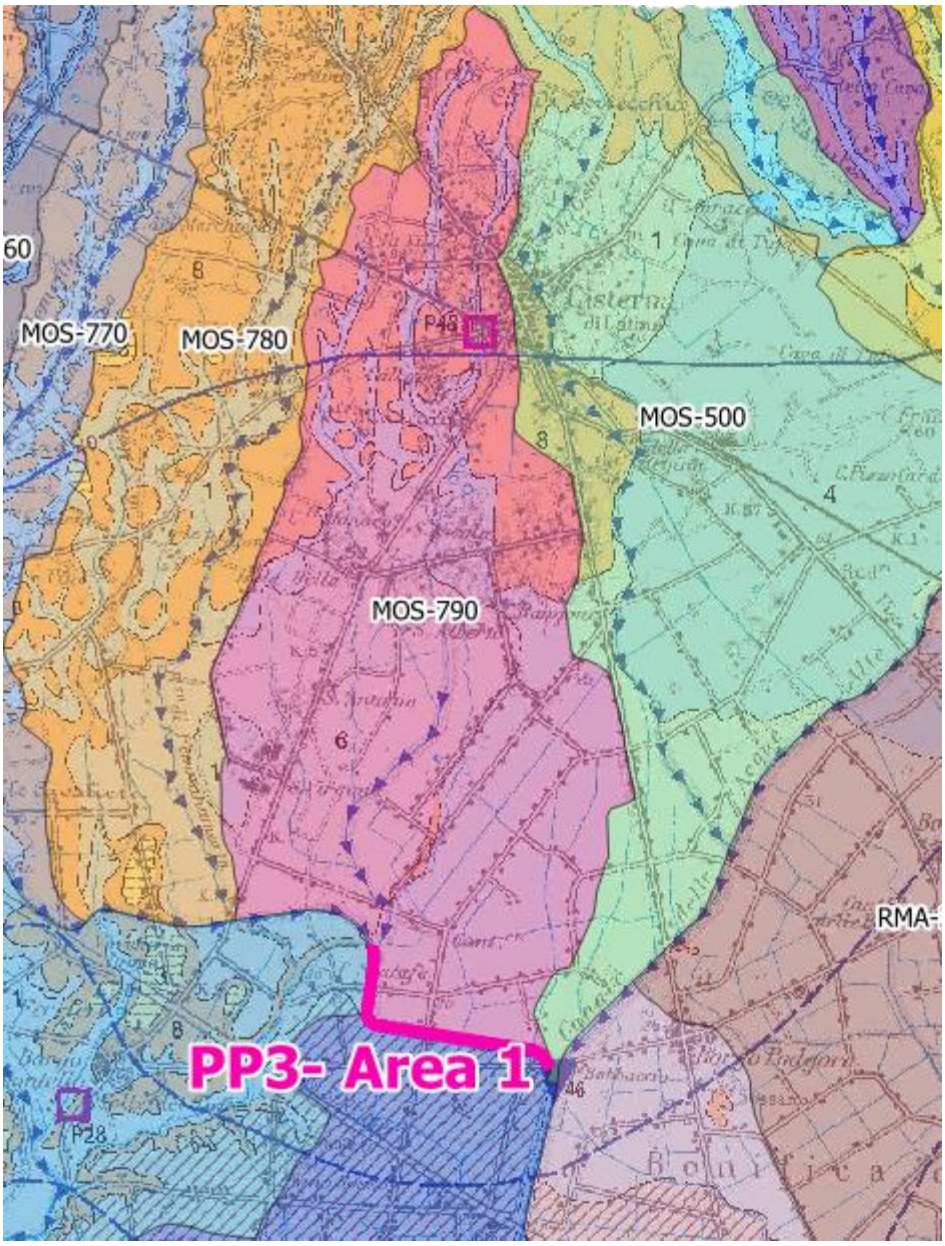


Figure 32. Map of the sub-basins of interest with the buffer area (PP3 – Allacciante canal)

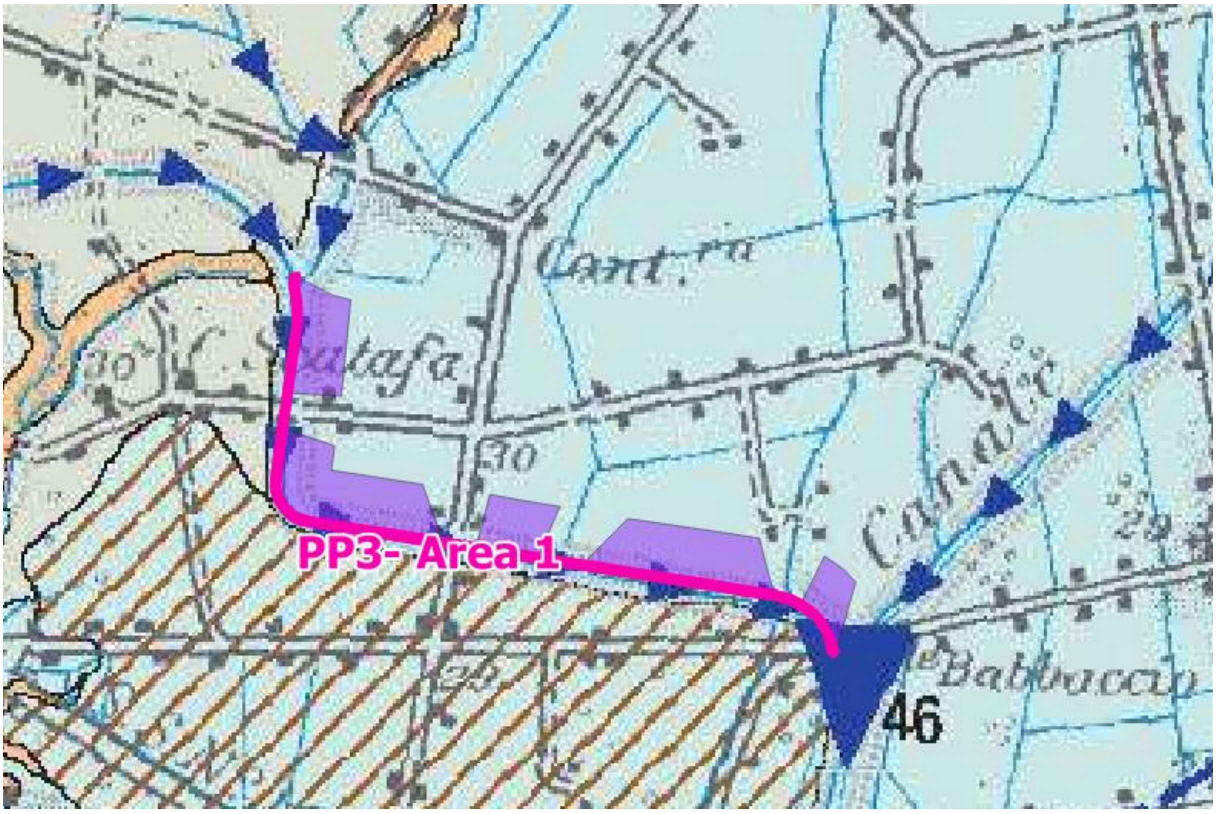


Figure 33. Close-up of the sub-basin map with the area drained to the buffer strip

The buffer strip has an average slope of 5%, a length of 3.7 km and an average width of 6.0 m, for a total surface of about 21969 m^2 (2.2 ha). This results in a buffer area/drained area ratio of 0.05, a ratio in line with the range 0.018 – 0.67 reviewed by Liu et al. (2008) investigating the trapping efficiency of buffer strips for runoff interception. Liu et al. (2008) reports a high range of sediment trapping efficiency, equal to 45 – 99.9 %, suggesting that sediment (and bonded nutrient pollutants) can be effectively removed within the reviewed buffer area/drained area ratio ranges. Therefore, also the PP3 buffer strip on the Allacciante canal was expected to provide a high sediment trapping efficiency.

The areal polluting loads of agricultural origin measured by the Latina province were used to estimate the input mass loads, and through the Zhang et al. (2010) model the removal output mass load was calculated. Dividing the mass removal by the buffer surface, the areal load removal for the PP3 buffer strip was estimated (**Table 9**). Being the Zhang et al. (2010) model not a function of the input load, but of the design variables (width, slope and type of vegetation), the overall areal load removal is strongly affected by the definition of the input mass load, the estimate of which is bringing uncertainties due to the definition of drained area and of areal pollutant load given by the Province of Latina. The areal pollutant load does not divide among superficial (on which PP3 could be effective) and subsuperficial diffuse pollution (on which PP3 could not be effective), while the drained area has only the confirmation of reliable buffer area/drained area according to the rather wide literature range of Liu et al. (2008). Literature on buffer strips for runoff interception usually focuses on key design variables (slope, width, type of vegetation) and percentage removal, not providing areal removal ranges for comparison of the values here calculated (Zhang et al., 2010; Liu et al. 2008; Mayer et al., 2007; Collins et al., 2009; Vidon et al., 2019). Despite the reliability with values of other NBSs such as wetlands (see **Table 8**), careful interpretation must be given to the obtained areal removal rate for the buffer strip of the Allacciante canal due to all the described uncertainties.

Table 9. Mass balance for the PP3 buffer strip on the Allacciante Canal

PP3 buffer TN	**M IN [kg/ha/y]**	**M IN [kg/y]**	**M OUT [kg/y]**	**M rem [kg/y]**	
	32.51	1377.418872	744.273	633.15	
			areal load removal	**28.8**	**g/m^2/y**
PP3 buffer TP	**M IN [kg/ha/y]**	**M IN [kg/y]**	**M OUT [kg/y]**	**M rem [kg/y]**	
	1.22	51.48247499	28.05014	23.43	
			areal load removal	**1.1**	**g/m^2/y**

3.4 Pesticides

A further analysis was carried out to investigate the pesticide removal capacity of the three NBSs, in particular, the removal of glyphosate and AMPA was analysed.

The literature review provides important data for an experience-based estimation of the areal removal efficiencies for those parameters (glyphosate and AMPA) 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 monitoring of the 3 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 likely be 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 contaminants similar to pesticides, i.e. pharmaceuticals: despite NBS removal processes (plant uptake, photodegradation, sorption, adsorption, and biodegradation) can differently affect pharmaceuticals 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 compound 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 3 NBSs of this study, a "proxy" representative molecule was selected. According to the most used pesticides in Italy[8], the herbicide **Glyphosate** (log Koc=3.84, strongly adsorbed on soil) was taken as target pesticide for the mass balance analysis, investigating its specific removal mechanism in wetlands and buffer strips according to the most recent available literature.

3.4.1 Pesticide removal in 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 our studied NBSs, 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), 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.

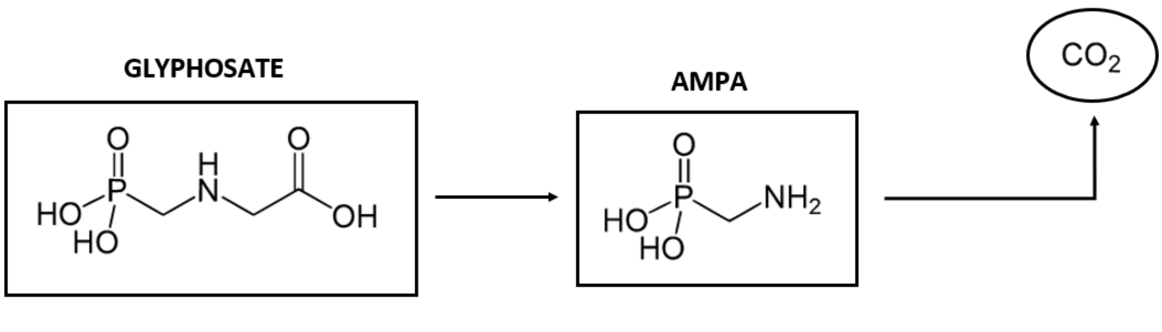


Figure 34. Schematic representation of the degradation of glyphosate through the formation of AMPA according to Imfeld et al. (2013).

[8] Rapporto nazionale pesticidi nelle acque – dati 2017-2018. Edizione 2020. https://www.isprambiente.gov.it/files2020/pubblicazioni/rapporti/rapporto_334_2020.pdf (Accessed August 2021)

The HRT and removal efficiencies of the constructed wetland found by the authors are reported in the **Table 10**. The Hydraulic Retention Times measured in the Villa Fogliano and Marina di Latina wetlands are generally lower than those of the constructed wetland described in the papers (4 – 7 hours for Villa Fogliano, and 1 – 2 hours for Marina di Latina), and to estimate the areal removal efficiencies of the wetlands it was decided to conservatively assume the lower removal efficiency of the range reported by the previous literature analysis, i.e. equal to 90% for glyphosate and 30% for AMPA.

Table 10. HRT and removal efficiencies reported by Imfeld et al., 2013.

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

3.4.2 Pesticide removal in buffer strips

The reduction of glyphosate and AMPA by buffer strips is documented by several authors (e.g., Syversen, 2005; 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 37-48 (Avg.=42.7%) and 51-67% (Average= 59.3%), respectively. Therefore, the Allacciante canal buffer is 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 40% for glyphosate and 50% for AMPA. The water inflow was calculated in the same way as for the wetlands, as described in paragraph 3.1.1.1.

3.4.3 Areal removal efficiencies for glyphosate and AMPA

The average concentrations and references used for the estimation of the areal removal of glyphosate and AMPA are shown in **Table 11**, since it has been noted that the waters conveyed by the Villa Fogliano intake canal are more diluted than those of the Marina di Latina wetland, the concentrations were assumed equal to literature average value for Marina di Latina (PP2) and decreased with the same dilution coefficient for Villa Fogliano (PP1).

Table 11. Glyphosate and AMPA concentrations found from the literature review.

	Glyphosate (μg/l)	AMPA (μg/l)	Reference
PP1: Villa Fogliano	9.78	1.6	Maillard et al., 2011 Imfeld et al., 2013
PP2: Marina di Latina	19.87	3.3	Maillard et al., 2011 Imfeld et al., 2013

PP3: Allacciante	42.25	8.8	Hénault-Ethier et al., 2017

The areal removal efficiencies of the 3 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 calculated (Hp 2). According to the simplified degradation pathway reported in **Figure 34**, 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 is lower and effectively estimate the overall removal pathway of the original glyphosate substance.

Table 12. Hp 1 **-** Glyphosate estimation areal removal efficiencies for the 3 NBSs investigated

NBS	Area [ha]	Water inflow [l/s]	IN [g/y]	removed [g/y]	Percentage removal	Areal removal [g/y/m²]
Villa Fogliano	0.85	12.34	3807.3	3426.5	90%	0.403
Marina di Latina	0.4	8.49	5319.1	4787.2	90%	1.197
Allacciante	2.2	11.3	15029.6	6011.8	40%	0.274

Table 13. Hp 2 **-** Glyphosate + AMPA estimation areal removal efficiencies for the 3 NBS investigated

NBS	Area [ha]	Water inflow [l/s]	IN [g/y]	removed [g/y]	Percentage removal	Areal removal [g/y/m²]
Villa Fogliano	0.85	12.34	4058.9	1217.7	30%	0.143
Marina di Latina	0.4	8.49	5670.6	1701.2	30%	0.425
Allacciante	2.2	11.3	9142.2	4571.1	50%	0.208

4 COST ANALYSIS

4.1 Investment costs

The investment cost analysis was carried out with reverse engineering, taking prices from the most recent local price lists[9].

4.1.1 Investment costs for wetlands

Villa Fogliano

The investment costs of Villa Fogliano were estimated on the basis of the **financial framework** of the original detailed design made in 2012, which counted the following expenditure items:

- A Working cost
    - A.1.a Complete works, unit rate
    - A.1.b Materials
    - A.1.c Plants
    - A.1.d Rental
    - A.1.e Labor
    - A.1.f Safety
- B: Funds for the authority (Sums available to the contracting authority)
    - B.1 Unforeseen events[10],
    - B.2 Elaboration and production of information materials[11]
    - B.3 Technical costs
        - B.3.a Preliminary, definitive and executive design
        - B.3.b Construction Management expenses, accounting and liquidation, certificate of regular execution drafting
        - B.3.c Safety coordination during the design phase
        - B.3.d Safety coordination during the execution phase
        - B.3.e Contribution to the workers' fund: 4% of 3a-3d
        - B.3.f RUP (Unique responsible for the design) competencies[12]: 2,0% of the working cost
        - B.3.g Charges relating to the civil and professional liability policy[13]
        - B.3.h Cost for publication, tender, testing

The financial framework of the original design made in the year 2012 reported the construction costs of the entire system envisaged in the Pilot Project 1:

- the 8500 m^2 FW CW of the A basin;
- the B system composed by a 450 m^2 SF CW followed by a 7050 m^2 FW CW;

[9] The latest price list of the Lazio Region, and the price list of the Central Italy crater (2018) - https://www.acca.it/prezzari-regionali
[10] Art. 133 paragraphs 4 and 7 of Legislative Decree 163/2006 and subsequent amendments
[11] Brochure on the project, guide on the naturalistic routes (VIA and charges including)
[12] Art. 92 c.5 of Legislative Decree 163/200 and subsequent amendments
[13] Art. 112 c. 4-bis of Legislative Decree 163/2006 and subsequent amendments

- the C pond, created through a few modifications of an existing basin.

The total cost of PP1 in 2012 was **195.223,66 €.** Through the "reverse engineering", the total cost of PP1 is estimated equal to **214,558.15 €** in 2019.

Since the focus, for PP1, was only on basin A, the bill of quantity was given only for basin A in **Table 14**. The cost of labour (excluding safety) is equal to **€ 38,583.10** in 2019, which is approximately 6% more than the cost of the year 2012.

Table 14. Bill of quantity for the original design (2012) and the "reverse engineering" (2019) of the wetland A in Villa Fogliano

Wetland A_ Villa Fogliano		
Item/Work	**Cost [€] 2012**	**Cost [€] 2019**
A.1 Working cost		
A.1.a Complete works, unit rate	11,441.60 €	11,714.54 €
A.1.b Materials	9,849.10 €	10,036.63 €
A.1.c Plants	1,303.07 €	1,543.72 €
A.1.d Rentals	5,645.48 €	5,645.61 €
A.1.e Labour	8,029.58 €	9,642.60 €
Total	**36,268.83 €**	**38,583.10 €**

All the other expenditures of the financial framework were calculated following a simplified approach, i.e. assuming a cost increase (+6%) equal to the one obtained from the reverse engineering of the tendered working cost. The financial framework of basin A of pilot PP1 in 2019 is given in **Table 15**, which corresponds to a total investment cost for the Villa Fogliano wetland A in 2019 of **51,060.82 €.** All the reported costs are VAT excluded.

Table 15. Estimated financial framework for the Villa Fogliano Wetland A in 2019

	Wetland A - Villa Fogliano		**2019**
A.1	**WORKING COST**		
A.1.a	Complete works, unit rate		11,714.54 €
A.1.b	Materials		10,036.63 €
A.1.c	Plants		1,543.72 €
A.1.d	Rentals		5,645.61 €
A.1.e	Labour		9,642.60 €
A.1.f	Safety		956.40 €
		Total A.1	**39,539.50 €**
B	**Funds for the authority**		
B.1	Unforeseen events		3,003.27 €
B.2	Elaboration and production of information materials		1,725.64 €
		Total B.1+B.2	**4,728.92 €**
B.3	**Technical costs**		
B.3.a	Preliminary, definitive and executive design		
B.3.b	Construction Management expenses, accounting and liquidation, certificate of regular execution drafting		5,466.84 €
B.3.c	Safety coordination during the design phase		
B.3.d	Safety coordination during the execution phase		
B.3.e	Contribution to the workers' fund: 4% of 3a-3d		205.56 €

	Wetland A - Villa Fogliano	2019
B.3.f	RUP competencies: 2,0% of the working cost	633.36 €
B.3.g	Charges relating to the civil and professional liability policy	243.32 €
B.3.h	Cost for publication, tender, testing	243.32 €
	Total B.3	**6,792.40 €**
	TOTAL	**51,060.82 €**

Marina di Latina

Even though the construction of the CW of Marina di Latina took place in two different phases (most of the plant was built in 2012 and in 2013 one of the two SF CWs of the first stage was added), the **financial framework** of the original design concerns the whole system; the cost analysis therefore refers to the 4 CWs of the system.

The financial framework counted the following expenditure items:

- A: Working cost
    - A.1: Lump sum works
    - A.2: Safety
- B: Funds for the authority (Sums available to the contracting authority)
    - B.1: Connections to public services
    - B.2: Unexpected events for works including VAT
    - B.3: Technical expenses (including social security charges) for:
        - B.3.1: Topographic surveys
        - B.3.2: Geological investigations
        - B.3.3: Design and safety coordination during the design phase
        - B.3.4: Construction management and Safety coordination
        - B.3.5: Testing
    - B.4: Additional fund for the authority[14]
    - B.5: Tender costs

The comparison between the bill of quantities of the original project and the updated prices is summarized in **Table 16**. The total working cost is equal to **€ 471,377.45 €** in 2019 (117.84 €/m^2), which is about 5% higher than the cost of seven years earlier (2012).

[14] Ex d. Lgs 163/06 and Art. 61 comma 8 Legge 133/2008

Table 16: Bill of quantity for the original design (2012) and the "reverse engineering" (2019) for the PP2

	Linear Park of Marina di Latina		2012-2013	2019
A	WORKING COST			
A.1	Lump sum works			
A.1.1	Hydraulic arrangements			
A.1.1.a	Pumping system		20,871.88 €	24,139.06 €
A.1.2.b	CW basins		129,324.34 €	128,201.37 €
A.1.3.c	Hydraulic connections and sluice gates		25,287.84 €	26,261.92 €
		TOTAL A.1	**175,484.06 €**	**178,602.35 €**
A.1.2	Earth movements			
A.1.2.a	Excavation costs		16,689.53 €	20,125.81 €
A.1.2.b	Embankment costs		30,101.30 €	26,651.28 €
		TOTAL A.2	**46,790.83 €**	**46,777.09 €**
A.1.3	Green accommodation and planting			
A.1.3.a	Plants for the CW		102,466.05 €	108,622.93 €
A.1.3.b	Plants for the renaturation of the area		35,484.10 €	37,336.75 €
		TOTAL A.3	**137,950.15 €**	**145,959.68 €**
A.1.4	Urban furnishings and accessories			
A.1.4.a	Photovoltaic cantilever roof		16,038.40 €	17,560.89 €
A.1.4.b	Naturalistic parking		11,925.60 €	12,502.20 €
A.1.4.c	Various arrangements		20,077.31 €	26,092.68 €
A.1.4.d	Photovoltaic - electric system		41,895.43 €	43,882.56 €
		TOTAL A.4	**89,936.74 €**	**100,038.33 €**
		TOTAL WORKING COST	**450,161.78 €**	**471,377.45 €**

All the other expenditures of the financial framework were calculated following a simplified approach, i.e. assuming a cost increase (+5%) equal to the one obtained from the updated construction costs. The financial framework is summarized in **Table 17**, showing a total investment cost in 2019 of **558,984.70 €**, (139.75 €/m^2). All the reported costs are VAT excluded.

Table 17: Estimated financial framework for the PP2

	Linear Park of Marina di Latina		2019
A	WORKING COST		
A.1	Lump sum works		471,377.45 €
A.2	Safety		12,128.90 €
		Total A	**483,506.35 €**
B	Funds for the authority		
B.1	Connections to public services		2,094.26 €
B.2	Unexpected events for works including VAT		13,464.24 €
B.3	Technical expenses (including social security charges) for:		
B.3.1	Topographic surveys		3,267.04 €
B.3.2	Geological investigations		3,204.21 €
B.3.3	Design and safety coordination during the design phase		26,136.34 €
B.3.4	Construction management and safety coordination		17,424.23 €
B.3.5	Testing		1,089.01 €
		Total B3	51,120.84 €
B.4	Additional fund for the authority		6,704.77 €
B.5	Tender costs		2,094.26 €

Linear Park of Marina di Latina	2019
Total B	75,478.36 €
TOTAL	558,984.70 €

4.1.2 Investment costs for buffer strips

The investment costs estimation for the buffers strips in the Circeo National Park was based on a simplified analysis, which considered only the following expenditure items in the **financial framework**:

- A: Working cost:
  - A.1: Tendered work
    - A.1.1: Complete works, unit rate
    - A.1.2: Expenditure for safety not subjected to markdown
- B: Funds for the authority:
  - B.1: Technical investigation and consultancy
  - B.2: Contingencies

The bill of quantities and estimated tendered working cost for the buffer strips were 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 5.11 €/m^3, from the local price list
- Embankment, defining the parametric cost of 4.09 €/m^3, from the local price list
- Trees, assuming the parametric cost used by the "reverse engineering" from 2012 to 2019 (including acquisition, transport and placement). The unit costs are reported in Table 18.

Table 18: Unit cost of plants from the Life 2008 REWETLAND Project – "reverse engineering" 2012

Type of trees	Cost
Salix caprea	37.70 €/tree
Salix triandra	36.40 €/tree
Cornus sanguinea	18.50 €/tree
Crataegus monogyna	59.90 €/tree

The simplified bill of quantities and estimated tendered working cost are reported in Table **19**. The total working costs are equal to **€ 32,616.00** and **62,538.00 €**, for the buffer strips of the Allacciante canal and of the Selcella canal, respectively.

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

- Expenditure for safety not subjected to markdown: 3% of the working costs;
- Technical investigation and consultancy: 12% of the working costs;
- Contingencies: 1.2% of the working costs

The financial framework for the buffers strips, supposed to be built in 2019, is summarized in the financial framework given in **Table 20**, which corresponds to a total investment cost in 2019 of **37,899.79 €** and **72,669.16 €**, for the buffer strips of the Allacciante canal and of the Selcella canal, respectively. All the reported costs are VAT excluded.

Table 19: Simplified bill of quantities and estimated tendered working cost for the buffer strips in the Circeo National Park

	Unit	Buffer – Allacciante Canal (right)	Buffer – Allacciante Canal (left)	Buffer - Allacciante Canal Total	Buffer -Selcella Canal
Bill of quantity					
Total length	m			3000	1300
Average width	m			2.7	4.8
Total surface	ha			0.81	0.62
Width of excavated area	m			2.7	4.8
Average excavation depth	m			0.3	1
Excavated volume	m^3			2430.0	6240.0
N° "isole"		30	30		30
N° of tree lines		1	1		1
Distance between the trees	m	1.5	1.5		1.5
N° of trees per isola		5	5		5
Type of trees		Salis caprea Salis triandra Cornus sanguinea Cornus sanguinea Crataegus monogyna	Salis caprea Salis triandra Cornus sanguinea Cornus sanguinea Crataegus monogyna		Salis caprea Salis triandra Cornus sanguinea Cornus sanguinea Crataegus monogyna
N° of trees in total		150	150	300	150
Working cost					
Excavation	€			12,417.30 €	31,886.40 €
Embankment	€			9,938.70 €	25,521.60 €
Trees	€	5,130.00 €	5,130.00 €	10,260.00 €	5,130.00 €
Total	**€**	**5,130.00 €**	**5,130.00 €**	**32,616.00 €**	**62,538.00 €**

Table 20: Estimated financial framework for the buffer strips in the Circeo National Park in 2019

		Buffer - Allacciante Canal 2019		Buffer - Selcella Canal 2019	
A	WORKING COST				
A.1	Tendered work				
A.1.1	Complete works, unit rate	32,616.00 €		62,538.00 €	
A.1.2	Expenditure for safety not subjected to markdown	978.48 €		1,876.14 €	
	Total A.1		33,594.48 €		64,414.14 €
B	FUNDS FOR THE AUTHORITY				
B.1	Technical investigation and consultancy	3,913.92 €		7,504.56 €	
B.2	Contingencies	391.39 €		750.46 €	
	TOTAL B		4,305.31 €		8,255.02 €
		TOTAL (VAT excluded)	**37,899.79 €**		**72,669.16 €**

4.2 Operational and Maintenance costs (OPEX)

4.2.1 O&M costs for wetlands

O&M costs were estimated through expert judgement and according to scientific literature (Rizzo et al., 2018) and the same local price lists used for the "reverse engineering" of the previous section. The following O&M items were considered:

- Management of accumulated sediment: the OPEX item was accounted with a simplified approach, i.e. considering an activity of excavation (parametric cost of 5.11 €/m^3) and embankment (parametric cost of 4.09 €/m^3) to be done every 25 years to recover the hydraulic functioning. For Villa Fogliano, it was assumed to remove the sediments from an area equal to 40% of the wetland A area (sediment height: 80 cm). For the Linear Park of Marina di Latina, it was estimated to remove the sediments from the HF 1st stage, assuming a sediment depth of 30 cm over an area equal to 1000 m^2.
- Energy consumption: the cost of energy consumption was calculated considering the power of the pumps used in the wetlands (3 kW for Villa Fogliano and 2.1 kW for Marina di Latina), multiplied by the number of operating hours (5848 h/year Villa Fogliano, 8760 h/year Marina di Latina) and by the price of energy (0.0779 €/kWh[15])
- Green maintenance: the assumed parametric cost for the maintenance activities is 330 €/km[16]; the parametric cost was applied to the perimeter of the wetlands (0.6 km for

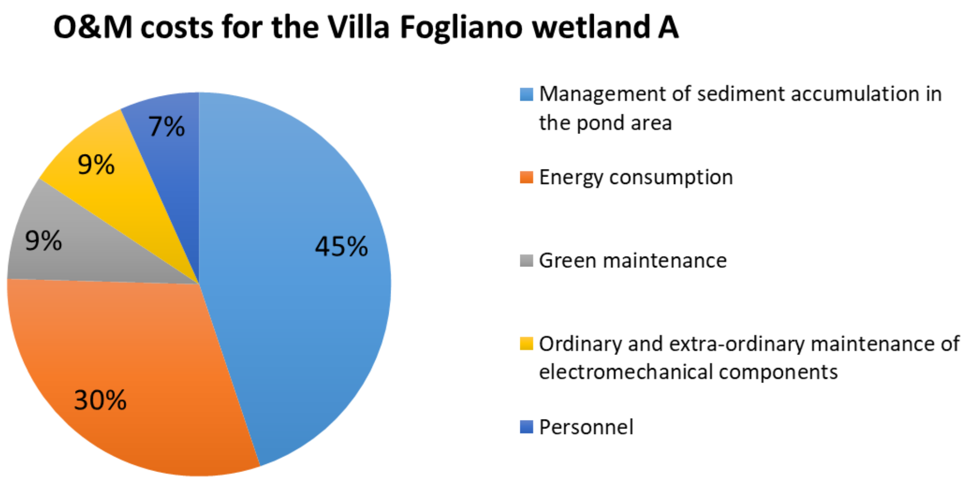
[15] https://www.acea.it/offerte-dual

[16] Parametric cost for a proper green maintenance, assumed equal to the value given by Acque Risorgive Consorzio di Bonifica in JRC LOT 5: LDP in a continental environment (JRC/IPR/2019/OP/0394)

wetland A Villa Fogliano and 0.9 km for Linear Park of Marina di Latina) and with a frequency of one per year;

- Ordinary and extraordinary maintenance of electromechanical components: this O&M item was accounted for 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 (only for the Linear Park of Marina di Latina);
- Personnel: this O&M item was calculated on the basis of the visit frequency for ordinary maintenance and after heavy rain falls, i.e. 4 visits/year; an average duration of the visit of 3 hours and the parametric cost for the planning of O&M activities, i.e. 25 €/hour, was assumed.
- No O&M expenses for water quality samples were assumed.

The details of the wetlands O&M costs are summarized in **Figure 35**, which correspond to a total O&M cost for the Villa Fogliano wetland A of **2,232.30 €/y** and **2,442.87 €/y** for the Marina di Latina wetland. All the reported costs are VAT excluded.



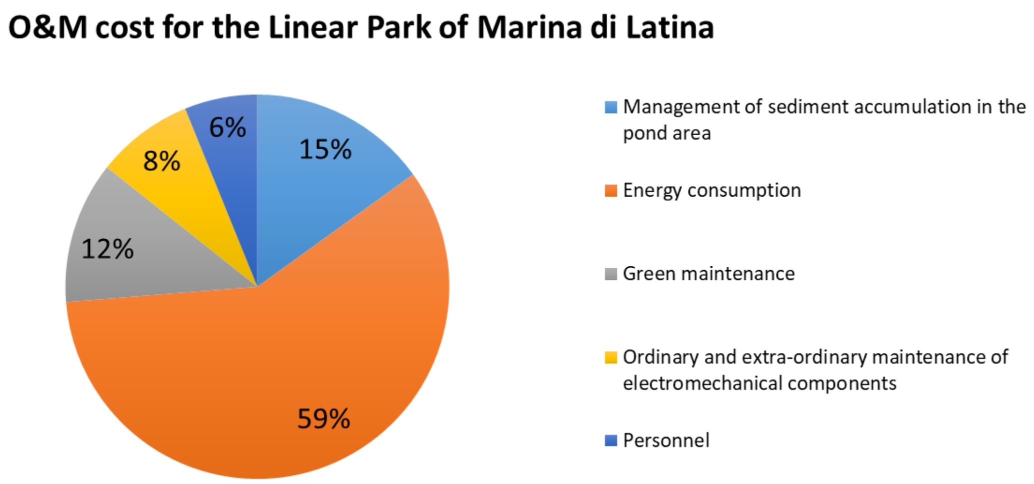


Figure 35. O&M costs for the Villa Fogliano wetland A (above) and for the Linear Park of Marina di Latina (below)

Table 21. Detail of O&M costs per year for the wetlands

O&M Wetlands			
n° Item	**Item**	**O&M Cost [€/y]**	
		Basin A-Villa Fogliano	**Linear Park of Marina di Latina**
1	Management of sediment accumulation in the pond area	€ 1,000.96	€ 368.00
2	Energy consumption	€ 683.34	€ 1,433.05
3	Green maintenance	€ 198.00	€ 291.83
4	Ordinary and extra-ordinary maintenance of electromechanical components	€ 200.00	€ 200.00
5	Personnel	€ 150.00	€ 150.00
Total		**€ 2,232.30**	**€2,442.87**

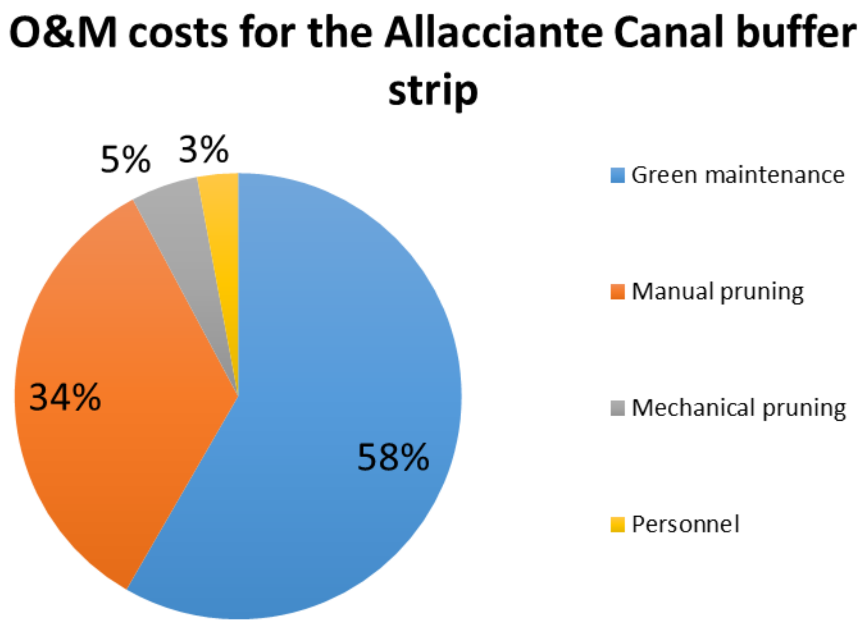
4.2.2 O&M costs for buffer strips

O&M costs were detailed with interviews to the staff of the management Authority (Land Reclamation Consortium of Agro Pontino), following the approach already used by the Tenderer (Rizzo et al., 2018) and considering the following O&M items:

- Green maintenance of grass: assuming the parametric cost for the design maintenance activities, i.e. 330 €/km[17]; the parametric cost was applied to the length of the buffer strips (3 km for the buffer strips – Allacciante Canal and 1.3 km for the buffer strip – Selcella Canal) and with a frequency of one per year;
- Manual pruning: assuming the parametric cost equal to 2300 €/km; the parametric cost was applied to the length of the buffer strips, i.e. 3 km and 1.3 km, and with a frequency of one manual pruning every 6 years;
- Mechanical pruning: assuming the parametric cost equal to 660 €/km; the parametric cost was applied to the length of the buffer strips 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, equal to 2 visits/year; an average duration of the visit of 2 hours and the parametric cost of 5 €/hour was assumed.

The details of the buffer strips O&M costs are summarized in **Figure 35**, which correspond to a total O&M cost for the buffer strips – Allacciante Canal of **3,395.00 €/y**, and **2,649.83 €/y** for the buffer strip – Selcella Canal. All the reported costs are VAT excluded.

[17] Parametric cost for a proper green maintenance, assumed equal to the value given by Acque Risorgive Consorzio di Bonifica in JRC LOT 5: LDP in a continental environment (JRC/IPR/2019/OP/0394)



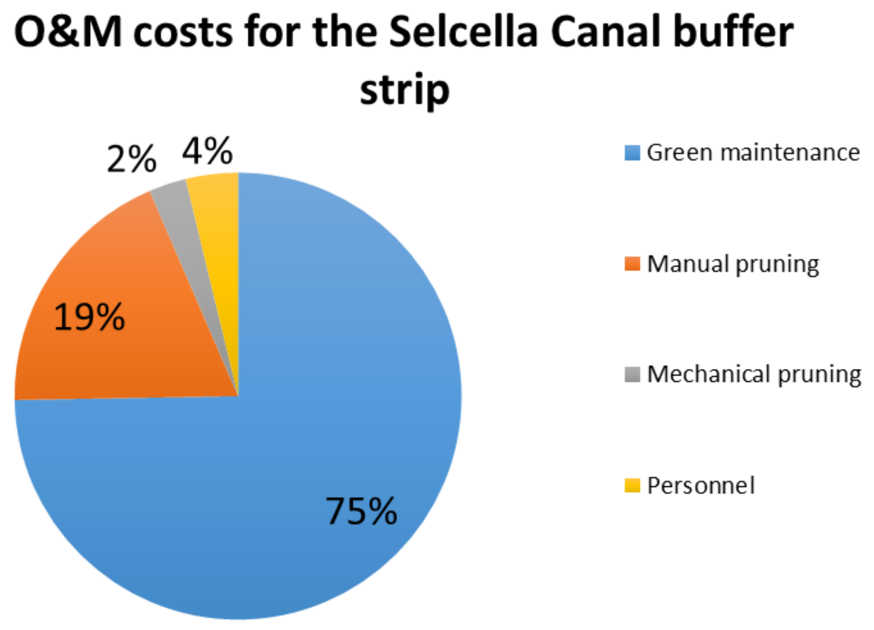


Figure 36. O&M costs for the buffer strips – Allacciante Canal A (Above) and for the buffer strip – Selcella Canal (Below)

Table 22. Detail of O&M costs per year for the buffer strips

n° Item	Item	O&M Cost [€/y] Buffer strip Allacciante Canal	O&M Cost [€/y] Buffer strip Selcella Canal
1	Green maintenance	€ 1,980.00	€ 1,980.00
2	Manual pruning	€ 1,150.00	€ 498.33
3	Mechanical pruning	€ 165.00	€ 71.50
4	Personnel	€ 100.00	€ 100.00
Total		**€ 3,395.00**	**€ 2,649.83**

4.3 Literature verification of working and O&M costs for the studied NBS

The unit construction costs for the FWS Villa Fogliano - Basin A is equal to **4.54 €/m²**. It is lower than the typical costs of free water surface (FWS) CWs, which are typically in the range of 20-60 €/m² (for instance, the FWS tertiary stage of Castelluccio di Norcia cost 32 €/m² - Rizzo et al., (2018)). The construction costs of the Basin A - Villa Fogliano refer only to the completion costs of the wetland, because excavation and subsequent embankment works are not foreseen. Considering the excavation (5.11 €/m³) and embankment (4.09 €/m³) for a depth of 0.8 m of the Basin A, the additional costs would be **34,748.00 €** and **27,812.00 €** respectively, for a total of **101,143.10 €** in 2019**.** The unit cost would become **11.9 €/m²**, which is comparable with the literature values. The unit construction costs for the Linear Park of Marina di Latina is equal to **117.84 €/m²**; the higher cost per square meter is due to the presence of a sub-surface flow stage, which typically costs 100-200 €/m² (for instance, the FWS tertiary stage of Castelluccio di Norcia cost 182 €/m² - Rizzo et al., (2018)).

The O&M costs for the FWS Villa Fogliano (PP1) and the Linear Park of Marina di Latina (PP2) are 2,298.96 and 2,509.83 €/y, respectively, corresponding to a range of **0.26-0.61 € m^{-2} y^{-1}.** These values are lower in comparison to those reported for CWs treating municipal wastewater. For instance, Rizzo et al, 2018 reports 1.73 € m^{-2} y^{-1} for the CW WWTP of Castelluccio di Norcia.

The working costs for the Allacciante Canal buffer strip and the Selcella Canal buffer strip is about **11 €/m²** (4 €/m) and **48 €/m²** (10 €/m) respectively. They are comparable to conventional buffer strips (5-10 €/m – CIRF[18]), in which trees are simply planted in proximity of the ditches, without excavation works. O&M activities for the buffer strips of the Allacciante Canal and the Selcella Canal are equal to **1.13 € m^{-1} y^{-1}** (€ 0.42 € m^{-2} y^{-1}) and **2 € m^{-1} y^{-1}** (€ 0.42 € m^{-2} y^{-1}). They are comparable with the values reported by CIRF in Italy, ranging from 1.8 to 3.9 €/m.

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

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. Then, the cash outflow are represented in 3 project phases: design, project implementation and project life cycle (see **Figure *37***). In **Table 13** 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.

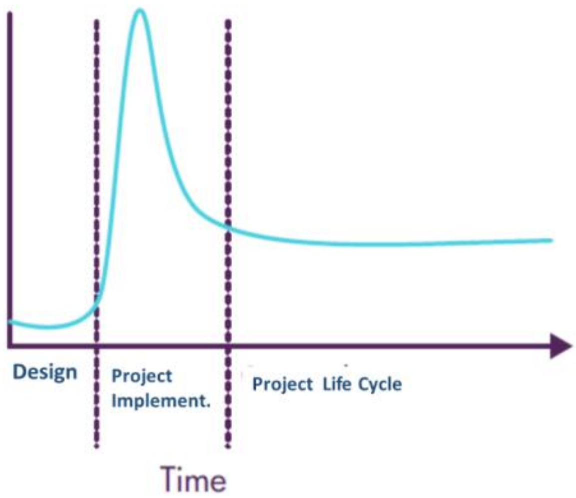


Figure 37. Cash outflow project phases

Table 23. Cash outflow of the studied NBSs [€/y]

Project Phase	Design	Project implementation	Project Life Cycle						
Year	**-1**	**0**	**1**	**2**	**3**	**…**	**10**	**…**	**50**
Wetlands									
Villa Fogliano	11.521	39.540	2.299	2.299	2.299	2.299	2.299	2.299	2.299
Marina di Latina	75.478	483.506	2.510	2.510	2.510	2.510	2.510	2.510	2.510
Buffer Strips									
Canale Allacciante	4.305	33.594	3.395	3.395	3.395	3.395	3.395	3.395	3.395
Canale Selcella	8.255	64.414	2.650	2.650	2.650	2.650	2.650	2.650	2.650

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), with the general objective of collecting and analysing the issues affecting the social sustainability of the NBS technology applications for diffuse pollution treatment sited in the Watershed of Agro Pontino (Latina province).

The analysis was carried out in two steps. A first phase of data collection concerned the REWETLAND project and was conducted between October 2019 and February 2020. The limitations and criticalities emerged from the findings led to consider also the GREENCHANGE project that followed REWETLAND, thus carrying out a second phase of research activities in July 2021.

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

1. To understand the main relations among stakeholders and local actors and their perceptions about NBSs;
2. To explore the main issues that affect the social sustainability of the territory where the NBS solutions are placed;
3. To collectively identify and evaluate the functional capacity of the case as a successful model of local development and its replicability in other areas.

On the social level, in order to explore the perceptions, among farmers, citizens, and other stakeholders, of the installation of the NBS solution in the target area, a **Need Analysis** was carried out (see **Table 24**).

Table 24. Methodology, actors involved and objectives

Method and target	Objective
Semi-structured interviews with representatives of the main institutions and stakeholders (Province of Latina, Municipality of Latina, Water Drainage Authority (Consorzio di Bonifica Agro Pontino) and Circeo National Park)	Understanding the main strengths and critical issues and assessing the role of each stakeholder within the value chain.
Online meeting with the key partners of the GREENCHANGE project	Analyse the drawbacks of the REWETLAND project and the different approach proposed by the GREENCHANGE project

5.2 The REWETLAND project: point of view of the main stakeholders

The use of NBS technology for diffuse pollution control in the area started with the REWETLAND project. Since then, a network of the key stakeholders has started to work together to promote the use of NBSs in the area. The stakeholders of this network are the following:

- Province of Latina (the coordinator of the REWETLAND project)

- Municipality of Latina
- Circeo National Park (the public body managing the protected natural area)
- Consorzio di Bonifca dell'Agro Pontino (drainage authority in charge of the hydraulic works of the Agro Pontino, mainly for the purposes of irrigation and flood risk mitigation);
- U-Space srl: a private consulting company with experience and competence in the field of environment and spatial planning.

Province of Latina

Through the *delegation of powers* appointed by the regional law LR 14/99, the Province has been studying the surface water network, focusing on springs characteristics, estimation of the environmental pollution load, analysis of the quality of coastal marine waters. In 1999, the Lazio Region allocated dedicated funds to the Province with the aim of reducing water pollution (around € 512,000/year). In this framework, NBSs (constructed wetlands and buffer strips) have been identified as the most suitable solution to reduce diffuse pollution sources, mainly agricultural runoff including fertilizers (nitrogen and phosphorus loads) and pesticides.

The REWETLAND project aimed precisely at facilitating the introduction of NBSs in the Agro Pontino Plain. The project, developed and coordinated by the Province together with the Municipality of Latina, the Circeo National Park, the Consorzio di Bonifica dell'Agro Pontino and U-Space, was co-financed by the EU Commission Life+ 08 Program, lasted four years and concluded in June 2014. In this context, the Province played a key role by creating, coordinating and promoting a new model of water management in the territory in a radically innovative way. The idea behind the project was to promote a participatory decision-making process including all stakeholders involved in the territorial management (institutions, public and private bodies, farmers and citizens), and the inter-institutional collaboration among the bodies responsible for programming, planning and implementing the NBSs to reduce diffuse pollution. This participatory decision-making process aimed at tackling the problem of governance fragmentation, that is one of the most important drawbacks for the implementation of innovative water policies in the area. Indeed, several public administrations play important roles to this respect: the Lazio Region, the Province of Latina, the Municipality of Latina and the Circeo National Park Authority. Moreover, different supervisory authorities are involved in the process, namely: the Forestry Carabinieri and the Regional Environmental Protection Agency (ARPA).

However, the participatory model created through the REWETLAND Project began to decline in March 2015, following the abolition of the Provincial Authority, as part of a reform of the Italian territorial authorities, that cancelled the delegated powers provided by the Region to the Province, as well as the financial resources provided annually for water bodies management and monitoring. Thus, the Province of Latina lost its key role of supervisor within REWETLAND, as well as of maintenance and decision-making over new investment activities, as previously foreseen by the "water body environmental restoration plan" ("Programma di riqualificazione ambientale delle acque superficiali dell'Agro Pontino"), one of the main deliverables of the REWETLAND project.

The other institutional partners were unable to implement the actions envisaged by the restoration plan due to lack of the Province coordination. Moreover, some of the REWETLAND pilot NBS technologies were abandoned, even though post-project agreements were elaborated in order to ensure structural maintenance of the systems. In particular, the buffer strips were lost, while the other two plants managed by the Municipality of Latina and the Circeo National Park are still in operation.

According to the point of view of the Latina Province, the main weaknesses of the management model initially created through the REWETLAND project are the following:

- the complexity of the governance and the fragmentation of competences that still affect the system;
- the lack of an open and innovative mentality by the institutions;
- the fragility of the organizational and operational system. In particular, the Lazio Region, even though it recognised the importance of the REWETLAND restoration plan and integrated it into the Regional Water Safeguard Plan, did not provide the financial resources to implement it;
- the lack of a strategic vision in transferring project results among different regional departments;
- the farmers' distrust of the project. Indeed, farmers have always been wary of the project, and in this framework, they were not properly involved as active parties but only as stakeholders.
- The project failed to trigger a significant cultural change in the area, especially with regard to farmers. The failure to involve them directly in decision-making aspects made the project appear distant and without opportunities for them.
- The progressive decrease of partners' interest in the project due to low involvement.
- The lack of a strong role on the part of the Lazio Region, which has not been able to adapt to the change caused by the depowering of the provincial government.

According to the Latina Province, the actions needed to implement NBSs to reduce diffuse pollution in the Pontinian plain are the following:

- adjustment of the technical management rules of the hydrographic network as well as of water withdrawal, providing clear guidelines for an effective management of the rivers, streams and canals, according to the different climate conditions and the transformations undergone in the area;
- the water management system must be tailored on single areas, rather than set up in a standard way;
- the Lazio Region should fill the management/operational gap by creating a new and effective managing body, with a wide knowledge and an overall vision on the area;
- an upgrade of the entrepreneurship culture in the area;
- in order to involve farmers, it is not enough to adopt a good communication plan. It is requested to structure a model capable of generating new dynamics of economic feasibility.

Municipality of Latina

The Municipality of Latina is one of the few "foundation towns", established during the land reclamation of the Thirties. Part of this territory belongs to the protected areas of the Circeo National Park.

Within the REWETLAND project, the Municipality co-financed a constructed wetland in Marina di Latina, covering an area of about 3,200 m^2 and representing the second planned pilot project. It is an experimental plant designed and built with the aim of integrating water purification functions with leisure facilities: it includes a peri-urban park with pedestrian and cycle paths and green areas, with trees and shrubs of native species.

The area is currently owned and managed by the Municipality, while the maintenance is entrusted by the Municipality to a private company. Before the REWETLAND project the area was unused and degraded, regularly flooded and subject to illegal waste disposal.

Today, thanks to the creation of the wetland, it has been transformed into a valuable area from an aesthetic and natural point of view: an important urban park in the city, creating a significant natural context, particularly popular among the local people from spring to autumn for outdoor activities or simply to enjoy nature.

Moreover, the wetland in Marina di Latina harbours some species of aquatic migrant birds, namely the moorhens (Gallinula chloropus L.). For this reason, the urban park is often a destination for birdwatchers and photographers.

An important communication activity was carried out within the REWETLAND project, including brochures, totems, Facebook posts and workshops, also involving the neighbouring municipalities. Citizens actively participated in the decision making process related to the project and in all the dissemination activities. Their feedback on the wetland creation is still very positive, they have completely understood its value.

The municipality also participates in an international environmental education program in schools: the ECO-SCHOOL project, one of the Foundation for Environmental Education – FEE - international programs for environmental education, management and certification that start in classrooms, expanding to the school and eventually fostering change in the community at large. Through this programme, young people experience a sense of achievement at being able to have a say in the environmental management policies of their schools, ultimately steering them towards acquiring environmental certifications in order to be awarded a Green Flag. In this framework, NBSs and biodiversity preservation are the main issues in local schools. Today, 18 schools participate to the program, which is financed by the Municipality.

The Municipality seized the opportunity opened by the REWETLAND project in order to begin a new path towards the diffusion of constructed wetlands for the environmental improvement of the area. By the end of the project, the implementation of two new plants have been carried out thanks to EPLUS funding Programs, and by internal co-financing of management activities.

Circeo National Park

Pilot Project 1 was carried out in the beautiful scenery of the Circeo National Park, along the coast between the Lake of Fogliano and the Canale Cicerchia. Placed along the Tyrrhenian coast of southern Lazio, between Anzio and Terracina, the Circeo National Park covers about 8,500 hectares, all in the Province of Latina and in particular in the municipalities of Latina, Sabaudia, San Felice Circeo and Ponza (Isle of Zannone).

The area is owned by the State Property and is managed by the "Carabinieri Forestali per la biodiversità" of Fogliano. Within the REWETLAND project, an agreement was signed, therefore the park authority provided funding for the construction works, entrusting the management and maintenance to the Carabinieri. Moreover, within the REWETLAND project, an educational program was designed in order to foster the presence of visitors and the observation of the abundant resident and migratory bird fauna.

One of the most important results of the activities developed within the Park, is the strong involvement of younger citizens of the Agro Pontino. The Circeo National Park has implemented an educational campaign involving more than 1,600 students of primary and secondary schools. Through lessons and guided tours, the project staff has shown them the area, its biodiversity, the natural purification techniques and the good practices for water saving.

Although no new investments have been made in the REWETLAND project plants, up to now all the activities have been carried out also in the period following REWETLAND.

According to a park ranger, the constructed wetlands have had positive impacts on the local area and community, in particular in terms of:

- improvement of water quality;
- increase in biodiversity - the presence of birds and nests has increased;

- increase in educational visits from schools, coming from all provinces, with an ever positive trend;
- the creation of pleasant natural environments around the lake, which attracts many local inhabitants. Today *Area 2* is considered by the residents as a new *urban park* where people can spend their time and enjoy recreational activities. In addition, a particular category of visitors has increased exponentially in recent years in *Area 1*, namely birdwatchers and nature photography lovers.

Consorzio di Bonifica dell'Agro Pontino

The Consorzio di Bonifica Agro Pontino is a public body operating in the field of flood risk prevention and protection of water resources and the environment. It is placed in Latina and operates on an area of about 170,000 hectares covering 25 municipalities (19 in the Province of Latina, 2 in the Province of Rome and 4 in the Province of Frosinone).

Its tasks include the management and ordinary and extra-ordinary maintenance of the land reclamation works and devices (about 4,000 kilometres of surface waters: drainage canals and natural watercourses, and 22 pump stations), and the construction of new works (with public funding).

Within the REWETLAND project, buffer strips were created by the Consorzio di Bonifica in two different areas.

The local farmers, contributors of the Consorzio di Bonifica, were involved in the REWETLAND project through their market organisations (CIA, Coldiretti and Confagricoltura). In addition, all the activities carried out by the Consorzio di Bonifica within the REWETLAND project were communicated and promoted through the press and e-news on its website (www.bonifica-agropontino.it).

However, the final feedback was not positive, especially from farmers. The "maintenance of waterways" carried out with ecological practices, is not perceived as beneficial. On the contrary, it is generally considered oblivious to the needs of the territory. People claim that waterways must be maintained as "gardens", with the complete eradication of wild vegetation. This would prevent the proliferation of species considered invasive and harmful (rats, snakes, etc.).

During the interview, the following remarks have been raised:

- the complexity and legislative division of competences represents one of the main limits to the activity management framework in the area;
- improving the local governance should represent a short-term priority at the regional level;
- promoting, supporting and disseminating the key role of ecological practices is fundamental in order to increase awareness in citizens;
- tools as financial incentives/tax relief/access to subsidized loans for farmers and citizens are needed. The aim is supporting the development of good management and ecological practices (e.g. buffer strips), thus improving the quality of the water discharged into surface water bodies;
- In a long term perspective, the model will remain heavily dependent on external funding if measures and incentives are not implemented to foster entrepreneurial initiatives.

U-Space

U-Space was established in 2008 by a group of architects, engineers and planners with different backgrounds. Within the REWETLAND project, this lab of ideas and projects for architecture and design, urban and spatial planning, was in charge of the following activities:

- project monitoring;
- drafting of the State of Environment Report;
- definition of the elements structuring the landscape and interventions to enhance the ecological network;
- drafting of the Strategic Environmental Assessment;
- creation of the local database;
- creation of the website and WebGIS.

Considering its role and being multi-faceted and transversal, U-Space had the opportunity to test the social effects of the pilot plants and the relative feedback by citizens and stakeholders.

As already remarked, the management of the water bodies (surface waters) is, still today, based on the hydraulic studies carried out before the land reclamation works. Therefore, it is no longer compatible with the different climate conditions and with the transformations undergone by the area, causing the problems related to flood risk (due to the growth of sealed surface), quality and availability of water (due to the growth of human populations and economic activities).

In the REWETLAND project, communication and education activities were carried out to inform people on the role of NBSs as a tool for water bodies management, with the involvement of both farmers and citizens. Yet, despite this process, citizens still believe that rivers and riparian drainage canals should be vegetation-free. The situation has exacerbated in recent years, following the two recent major floods in 2017 and 2018 causing severe damages.

The Consorzio di Bonifica dell'Agro Pontino has been strongly accused of negligence through the main media complaints, for not properly managing the water courses.

Today any proposed activity on rivers and canals, such as buffer strips, is generally opposed by the public opinion. In the collective belief, shelterbelts and windbreaks should be managed in a radical way.

5.3 From REWETLAND to GREENCHANGE

During the analysis of the case study, the limits of the REWETLAND project emerged, in particular the difficulties in applying the business model envisaged by the project. Hence the need for an in-depth social analysis through a further meeting with U-Space (partner of REWETLAND and GREENCHANGE), Confagricoltura Lazio (one of the actors involved in REWETLAND and partner of GREENCHANGE) and Poliedra (partner of GREENCHANGE). The considerations that emerged from this meeting are reported in the following two paragraphs.

5.3.1 The limits of REWETLAND

Overall, although the project had the characteristics to create a winning model as the result of a participatory process, in reality it showed a series of weaknesses that compromised its complete implementation and above all its sustainability at the end of the project. Within REWETLAND, two important documents were produced, among others:

— The *Integrated Environmental Restoration Program* (ERP) *of the Pontine Plain*, a strategic policy document approved by the Province of Latina for the implementation of interventions to improve the quality of surface waters, including through the dissemination of NBSs and the application of good practices in agricultural activities;

— The Guidelines for watercourse management interventions, drawn up by the Consorzio di Bonifica.

At the conclusion of the REWETLAND project process, the Lazio Region inserted the ERP as an implementation tool for the proceedings of the Region *Water Protection Plan*. However, it does not provide for specific implementation rules or resources to carry out the interventions: the ERP has therefore remained inapplicable. The construction of NBSs in the Pontine plain thus came to a halt with the end of REWETLAND. Only the Province has carried out autonomously and with its own funds some small river restoration and constructed wetland interventions, as well as financing the "river contracts" (contratti di fiume) as instruments of participation.

Another important consideration concerns the Consorzio di Bonifica and its relations with the Lazio Region. Although the Consorzio had drawn up guidelines for the management of waterways that provided for more ecological management methods, it was unable to put them into practice; partly due to strong opposition from civil society and the media, but also due to the lack of a "mandate" to that effect from the Region. In fact, the Consorzio does not act autonomously but on the basis of a specification established by the Region, which determines its operating methods and resources. The inactivity of the Lazio Region, highlighted above, led to the non-application of the guidelines, and the proper maintenance of the interventions implemented within REWETLAND was not even carried out.

Finally, in the REWETLAND project, farmers have always had a marginal, not direct role, having participated only as designated subjects. This factor is to be considered one of the main reasons that undermined the success of the project. During the design phase it was thought that the Consorzio di Bonifica could act as a bridge with the farmers, managing their involvement and also being the bearer of their requests. This choice turned out to be inadequate due to the difficult relations between the Consorzio di Bonifica and the farmers.

5.3.2 The GREENCHANGE project

The LIFE Natura GREENCHANGE project "Green infrastructures for increasing biodiversity in Agro Pontino and Maltese rural areas" - LIFE17 NAT/IT/000619, launched in July 2018, involves:

— The Province of Latina, (lead partner, also partner of REWETLAND),

— CIRF (Centro Italiano per la Riqualificazione Fluviale, Italian Center for River Requalification),

— U-Space (also partner of REWETLAND),

— Confagricoltura (trade association that brings together dozens of farms active in the Agro Pontino),

— Miema (Malta Intelligent Energy Management Agency).

The project aims to protect biodiversity and consolidate the ecological value of the ecosystems of the Agro Pontino and Maltese rural areas, through the construction of decision-making processes and governance mechanisms based on the evaluation of ecosystem services, and through the implementation of demonstration interventions for green infrastructure.

The project was born with the aim of capitalizing on the REWETLAND experience: starting from the lessons learned to rethink a different model for the creation of NBSs for environmental restoration. A governance and stakeholder engagement model, also capable of being sustainable over time: the direct involvement of the agricultural world (Confagricoltura is a partner of GREENCHANGE while it did not participate in REWETLAND) indicates the different approach.

In a nutshell, the NBS implementation and management model envisaged by GREENCHANGE is based on the enhancement of state-owned areas to be managed by farmers to create arboreal, shrubby and herbaceous hedges and rows, which can also function as buffer strips. In the Agro Pontino the strips bordering the drainage network were used to plant windbreaks, mostly of eucalyptus, and remained state property; it is an area that occupies a total of about 6.5 km^2, consisting of linear bands on average 5 meters wide of public property. The model is based on the Patto per la Biodiversità (Pact for Biodiversity), which together with the implementation of multifunctional demonstration interventions, represents the heart of the actions of the Life GREENCHANGE project. By signing the Pact for Biodiversity (a sort of territorial pact) the actors (Municipalities and Farms) undertake to improve the capacity of the territory to offer ecosystem services, experimenting innovative contractual forms oriented towards Land Stewardship.

Farms have an interest in taking over these areas because in this way they are able to access the "direct contributions" provided for by the Common Agricultural Policy (CAP), without having to give up portions of production area (see paragraph 7.2).

Confagricoltura's intention is to involve over 60 local farms over the next few years through its information desk, replicating the model applied experimentally by GREENCHANGE on 5 companies. Considering the consistent presence of farms over 15 hectares, and their significant interest in taking over state-owned areas, according to Confagricoltura it will be possible - when fully operational - that about 70% of state-owned areas will be given to farms.

As part of GREENCHANGE, Poliedra (a spin-off of the Politecnico di Milano that operates on environmental sustainability issues) has developed an IT platform with a GIS map of all state-owned areas that can be entrusted through Land Stewardship agreements. Through the Confagricoltura information desk, farms will be able to easily verify the possibility of managing state-owned areas close to their company and activate the agreements.

6 QUANTIFICATION of DIRECT and INDIRECT BENEFITS

From the previous chapters, it clearly appears that of the 4 NBSs considered, only the two wetlands and the enhancement of the Selcella canal are still in operation and presently providing the expected benefits. The quantification of direct and indirect benefits of these 3 systems would be of scarce interest. However, the *Integrated Environmental Restoration Program* (ERP) *of the Pontine Plain* envisages – in a wider framework of actions concerning point and non-point pollution sources – a specific action (Action 2.3.1) aimed at "increasing the self-purification capacity of the hydrographic network". The ERP does not set a quantitative objective regarding the pollution load to be removed by the different actions but proposes to carry out each action to its maximum potential through a participatory process. This action is achieved by means of "implementation of wetlands and buffer strips along the drainage network". The results of the social analysis show that, for several reasons, the ERP has not been enforced; however, the new approach developed through the GREENCHANGE project, could allow the diffusion of NBSs on the Pontinian plain.

Thus, the assessment of costs and benefits was carried out considering the scenario of the implementation of the approach proposed by GREENCHANGE at its "full capacity", estimating the possible impact on diffuse pollution together with the other environmental, social and economic benefits/costs. The first scenario analysed is therefore a simulation of the effects of the GREENCHANGE model when fully operational.

Since the GREENCHANGE approach is focused on the creation of linear NBSs only (hedgerows and tree lines acting as buffer strips), another scenario was analysed where, to the BSs created through the GREENCHANGE model, a few wetlands located in key sections of the hydrographic network are added, to treat pollutants not intercepted by BSs. In this second scenario, the both capital and O&M costs are covered by the Region, as originally envisaged by the REWETLAND Project.

The analysis was based on the Rio Martino Basin: one of the most important of the whole Pontinian plain, where the city of Latina is located. The area of the Rio Martino basin is 411 km^2, of which 62% is for agriculture use. This basin includes an inner lowland, an area of clayey soil and, along the coast, a higher sandy soil area on the fossil dune.

The Rio Martino basin analysis was based on the information given by the Ecology and Environment Sector of the Province of Latina, which had elaborated in 2009 a detailed analysis of the hydrographic basins on its territories both in terms of hydrologic-hydraulic functioning and of civil, zootechnical, and diffuse pollution loads [19]. According to this study, the Rio Martino basin can be divided in the following hydrographic basins (see **Figure 38**):

— MOS-RMA (Shore basins between "Torre di Foce Verde" and "Torre di Fogliano" – Area 19.1 km^2)

— RMA ("Rio Martino" basin – Area 195.8 km^2)

— RMA-SIS (Shore basins between the "Rio Martino" and "Sisto" rivers – Area 61.4 km^2)

— SIS ("Sisto river" basin – Area 135.1 km^2)

The total surface, the percentage of agricultural surface, and the estimated average annual diffuse pollutant loads in terms of tonnes per year of TN and TP of each sub-basin of the Rio Martino basin are reported in **Table 26**.

Two suitability criteria were defined to identify areas suitable for implementing NBSs for diffuse pollution control in the Rio Martino basin, one for buffer strips and one for wetlands:

— <u>Suitability criterion 1 for buffer strip.</u> The suitable state-owned areas had already been identified by the GREENCHANGE project on the Rio Martino basin (see **Figure 39**) and

[19] Origine dei carichi inquinanti e stato di eutrofizzazione delle acque interne della Provincia di Latina – Atlante dei Bacini Idrografici. Tecnostudi Ambiente S.r.l., May 2009 (www.provincia.latina.it)

are extended by 4.08 km^2. All the sites are located nearby a canal or a drainage ditch, therefore all of them could be considered suitable to buffer diffuse pollution. According to the estimation provided by Confagricoltura reported by the social analysis, 70% of the public areas identified by GREENCHANGE will be converted into multipurpose vegetated buffer strips. This led to estimate an overall area of **2.86 km^2** of new buffer strips homogenously distributed on the whole Rio Martino basin and corresponding to an average buffer strip to watershed area ratio (B-WAR) of **1.0%** (**Table 26**).

— <u>Suitability criterion 2 for wetlands.</u> As observed from the mass balance analysis in chapter 3, it is important to feed wetlands with agricultural drainage water as concentrated as possible to maximize the treatment efficiency of this NBS. According to the analysis of the water pollution conveyed by the Rio Martino drainage network of the study of the Province of Latina (see **Table 25**), the highest concentrations (>5 mg/L of nitrates) are mainly found within the main canal network and near the extremity of the basins, where all the diffuse pollution of the agricultural areas is conveyed. Therefore, potential wetland areas were identified following these indications, i.e. considering to convert agricultural land of low value (no greenhouse areas, no fruit tree orchards) near the main rivers of the basins (the Rio Martino river for the RMA basin and the Sisto river for the SIS basin). Moreover, suitable areas have been identified as far as possible downstream of the basin. It resulted in a more concentrated location of potential wetland areas in comparison to those identified for buffer strips (**Figure 40**). The total wetland area resulted equal to **4.01 km^2**, corresponding to an average wetland to watershed area ratio (W-WAR) of **1.4%** (**Table 26**).

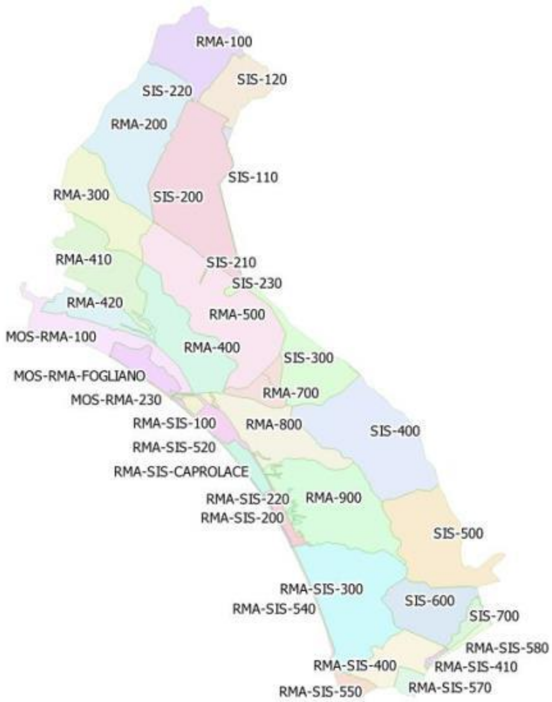


Figure 38. Rio Martino Catchment: hydrographic sub-basins as defined by the Province of Latina

Table 25. Nitrate concentrations (expressed in mg/l of N-NO3-) for the main rivers of the Rio Martino basin

	Rio Martino River	**Rio Martino River**	**Rio Martino River**	**Sisto River**

	(RMA basin) Upstream	(RMO basin) Downstream - right	(RMO basin) Downstream - left	(SIS basin)
05/08/2003	1.92		12.11	
30/03/2004	1.81			
03/04/2004				2.80
30/04/2004				1.70
18/05/2004		0.30		
20/05/2004			4.70	
29/04/2005		3.90		
11/05/2005	1.89			0.39
17/05/2005			0.50	
15/06/2006			8.81	
24/06/2006	1.62			3.80
29/06/2006		4.81		
mean	**1.81**	**3.00**	**6.53**	**2.17**

Source: Origine dei carichi inquinanti e stato di eutrofizzazione delle acque interne della Provincia di Latina – Atlante dei Bacini Idrografici. Tecnostudi Ambiente S.r.l., May 2009 (www.provincia.latina.it)

Figure 39. Rio Martino catchment: suitable state-owned areas for the implementation of buffer strips according to suitability criterion 1 (in black)

Figure 40. Rio Martino catchment: suitable areas for the implementation of wetlands according to suitability criterion 2 (in blue) on available areas in proximity of the main drainage canals (in red)

Table 26. Rio Martino catchment: sub-basins characterícts and identified NBS areas

Rio Martino Basin and Sub-basin	Basin Area*	Agricultural Area*		Agricultural non-point source diffuse pollution*		B Area**	B-WAR	W Area***	W-WAR
	[sq. km]	[%]	[sq. km]	[tN/y]	[tP/y]	[sq. km]	[%]	[sq. km]	[%]
MOS-RMA-100	12.7					0.08		0.87	6.9%
MOS-RMA-110	0.6					0.00			
MOS-RMA-220	0.1					0.00			
MOS-RMA-230	0.1					0.00			
MOS-RMA-FOGLIANO	5.2					0.00			
MOS-RMA - Total	**19.1**	**55%**	**10.5**	**36.6**	**1.4**	**0.08**	**0.8%**	**0.87**	**8.3%**
RMA-100	17.5					0.00			
RMA-200	30.3					0.37			
RMA-300	17.2					0.22			
RMA-400	18.6					0.14			
RMA-410	16.5					0.18			
RMA-420	8.2					0.03			
RMA-500	35.1					0.30		0.40	1.1%
RMA-600	1.3					0.00			
RMA-700	3.9					0.03			
RMA-800	17.1					0.21			
RMA-900	29.1					0.12			
RMA-MONACI	1					0.00			
RMA - Total	**195.8**	**69%**	**135.1**	**551.25**	**20.6**	**1.61**	**1.2%**	**0.40**	**0.3%**
RMA-SIS-100	4.4					0.00		1.12	25.5%
RMA-SIS-110	0.2					0.00			
RMA-SIS-120	0.1					0.00			
RMA-SIS-200	2.5					0.00			
RMA-SIS-210	0.2					0.00			
RMA-SIS-220	0.4					0.00			
RMA-SIS-300	31					0.07			
RMA-SIS-400	9.8					0.00			
RMA-SIS-410	0.5					0.00			
RMA-SIS-510	0.1					0.00			
RMA-SIS-520	0.1					0.00			
RMA-SIS-530	0.6					0.00			
RMA-SIS-540	0.8					0.00			
RMA-SIS-550	2.6					0.00			
RMA-SIS-570	2.1					0.00			
RMA-SIS-580	1.1					0.00			
RMA-SIS-CAPROLACE	3.1					0.00			
RMA - SIS - Total	**61.4**	**44%**	**27.0**	**94.6**	**3.5**	**0.08**	**0.3%**	**1.12**	**4.2%**
SIS-100	11					0.00			
SIS-200	35.2					0.27		0.41	1.2%
SIS-210	0.1					0.01			
SIS-220	0					0.00			
SIS-230	0.5					0.00			
SIS-300	14.8					0.05		0.53	3.6%
SIS-400	32.9					0.30		0.67	2.0%
SIS-500	23.4					0.25			
SIS-600	14.6					0.20			
SIS-700	2.6					0.01			
SIS - Total	**135.1**	**79%**	**106.7**	**436**	**16**	**1.09**	**1.0%**	**1.61**	**1.5%**
TOTALE	**411.4**	**62%**	**279.3**	**1118**	**42**	**2.86**	**1.0%**	**4.01**	**1.4%**

B: buffer strips
W: wetlands
B-WAR: buffer to watershed area ratio
W-WAR: wetland to watershed area ratio
* Origine dei carichi inquinanti e stato di eutrofizzazione delle acque interne della Provincia di Latina – Atlante dei Bacini Idrografici. Tecnostudi Ambiente S.r.l., May 2009 (www.provincia.latina.it)
* Suitability Criterion 1: 70% of public space available from the GREENCHANGE census of suitable areas for buffer strips
** Suitability Criterion 2: suitable areas for the implementation of wetlands on main drainage courses

Based on the defined suitability criteria, **two watershed analyses** were investigated:

- Scenario 1: implementation of buffer strips only according to suitability criterion 1, representative of the business model proposed by GREENCHANGE; therefore, analysis 1 counts **2.86 km²** of NBSs (all buffer strips) for agricultural diffuse pollution control within the Rio Martino basin, corresponding to an average NBS to watershed area ratio (NBS-WAR) of **1.0%** (**Table 26**).
- Scenario 2: in addition to the buffer strips expected according to analysis 1, this analysis also assumed to create the wetlands identified by suitability criterion 2, i.e. implementing the NBSs that proved to be more effective after the end of the REWETLAND project; the wetlands were assumed to be implemented on private lands acquired and managed by a well-structured "Consorzio di Bonifica", supposing to be able to recreate one of the business models that had turned out to be the most successful for agricultural diffusion control in Italy, i.e. that of the "Consorzio di Bonifica Acque Risorgive" for the reduction of the eutrophication risk of the Venice Lagoon[20]; as a technological solution, it was chosen to hypothesize the creation of free water surface (FWS) systems only, since the use of hybrid solutions is not common in agricultural diffuse pollution control for full scale systems (Ioannidou and Stefanakis, 2020), the theoretical areal removal does not highlight a significant contribution from the horizontal subsurface flow stage in the PP2 Marina di Latina site (chapter 3), and FWSs are significant cheaper than subsurface flow wetlands (chapter 4); analysis 2 counts **6.87 km²** of NBSs (buffer strips plus wetlands) for agricultural diffuse pollution control within the Rio Martino basin, corresponding to an average NBS to watershed area ratio (NBS-WAR) of **2.5%** (**Table 26**).

It must be noted that the NBS-WAR of the investigated analysis can be considered reliable for the agricultural contest of European countries. According to Kadlec and Wallace (2009), NBS-WAR ratios reported in literature for agricultural pollution control (nitrogen removal target) span from 0.06% up to 19%. This variability is related to a balance between local climatic conditions, area needed to maximize the pollutant removal, and local area availability. Areas for NBS implementations are expected to be few in the European territory, where the urbanization is dense and not-urbanized areas are mainly used for agriculture. Indeed, the range reported by Kadlec and Wallace (2009) sees a higher ratio for US applications (up 0.10-19.17%) and a lower ratio for European ones (Norway and Finland, 0.06-5.00%). Therefore, a ratio below 3–5% can be considered a good rule of thumb for the European context.

To assess direct and indirect benefits a Multi Criteria Analysis (MCA) was proposed in the technical offer for the feasibility study, following the methodology already used to estimate the **Ecosystem Services of NBSs** in the OpenNESS project (EU FP7 funds – Liquete et al., 2016). Accordingly, in the technical offer, a preliminary list of criteria to be used for the quantification of the benefits was provided (see table below), classified in 3 categories: social, environmental and economic benefits.

The list of MCA criteria envisaged in the technical offer was 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 and the tools used to estimate their value is contained in paragraph 6.2

[20] JRC LOT 5: LDP in a continental environment (JRC/IPR/2019/OP/0394)

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
	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

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 chapter 5) both the social criteria proposed are relevant.

The capacity to help reduce **flood risk** is one important feature of NBSs, which has increased their acceptability, especially by farmers, the stakeholder group most affected by NBSs. Obviously not all NBSs provide the ecosystem service of flow regulation and their performance depends on several aspects: the intensity of the 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 NBSs is very difficult; however, the issue must be considered, possibly using a "proxy" indicator.

For what concerns **recreation and health**, the wetland of Marina di Latina appears to be the most interesting in terms of recreational service for the local population. The wetland of Villa Fogliano allowed to increase the presence of birdwatchers and wildlife photographers, but is located nearby the Fogliano lake, an area already providing the ecosystem service of recreation. Generally speaking, the new NBSs expected in the two envisaged scenarios could offer recreational opportunities: the linear shape of the buffer strips could be exploited to create pedestrian/cycling tracks, to be used by tourists and residents for leisure, while the new wetlands could be equipped for bird watchers.

Other ecosystem services could be provided by the NBSs, which concern 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. According to the interviewed stakeholders (see chapter 5), the first one (aesthetic quality) is less important than other benefits. 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 NBSs: this is shown by the educational activity carried out by the Circeo National Park, involving more than 1,600 pupils of primary and secondary schools, and the 18 schools taking part to the ECO-SCHOOL project promoted by the Municipality of Latina. 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 benefit of the analysed NBSs is the **improved water quality** thanks to diffuse pollution control. According to the analysis carried out in chapter 3 this benefit will be assessed and quantified by the amount of pollutant removed (or expected to be removed) per year.

The NBSs 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 NBSs 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 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 (specially insects, reptiles, small mammals) thanks to the "ecotone" effect, while the positive effects of herbaceous buffer strips are nearly negligible.

The criterion "biodiversity" will then be considered in the evaluation process, through an "expert judgment" approach, based on the scientific literature mentioned above.

6.1.3 Economic effects

The two possible economic benefits considered in the hypothesis before the analysis appear not to be significant: in fact, the NBSs analysed are located far from residential property and therefore no **property appreciation** due to landscape improvement could have been recorded. 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 the NBSs 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 NBSs (the criterion **loss of farmland income**) will be taken into account.

6.2 Prediction of the effects

6.2.1 Quantification of criteria

The following paragraphs report how direct and indirect benefits were estimated considering the selected criteria. Some benefits were estimated based on existing data through simple models (e.g. costs, nutrient recovery). For other benefits, the estimation of the effects relies on Expert judgement. Expert knowledge has gained momentum as a source of information for decision making, particularly in contexts where empirical information is sparse or unobtainable (Sutherland 2006).

6.2.1.1 Flood risk

The flood risk as a side-benefit of NBSs for diffuse pollution control, and in general of wetlands sparse over the territory (as the so-called geographically isolated wetlands), was a matter of discussion within the Scientific community. A number of recent works (e.g. Salzar et al., 2012; Acreman and Holden, 2013; Lane et al., 2018) have actually helped to clarify the role of NBSs on this side benefit. Substantially, it is true that NBSs, like 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), while it is of little relevance for extreme events (return time >30 years) usually targeted in flood protection policies[21]. This does not mean that multipurpose NBSs cannot be designed for both significant flood protection and nutrient diffusion control. For instance, big retention basins for flood protection, foreseen to reduce flood hazard according to flood directives, 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 NBSs here proposed; since they aim to intercept diffuse pollution within the catchment, NBSs need to be as much diffused as possible, reducing the potential additional volume for flood retention. Accordingly, the NBSs here proposed for diffuse pollution control can give some interesting benefits to farmers in terms of flood risk, reducing the disadvantages driven by rain events with low return time; for this reason, the flood risk benefit is not excluded from the proposed analysis.

On the basis of the previous considerations, a full hydrological-hydraulical model is not significant for the scope of estimating the flood risk benefits of the proposed NBSs. Therefore, to estimate the effects of **wetlands** in term of flood risk reduction a “proxy” indicator is used: the additional storage volume available thanks to the NBSs. Since detailed information on the storage volume for each of the analysed NBS is not available, a simplified approach was used. It was estimated that during high flow the water level in the wetlands could increase by 1 metre, retaining 1 cubic metre for each square metre of wetland. The beneficial side benefit on flood protection of wetlands was considered only for wetlands upstream of urban areas, neglecting it in uninhabited coastal areas as flood protection is not necessary. The estimation of the ecosystem service is summarised in **Table 27**, from which is visible how often the available volume can be significant for very frequent events (rainfall height < 20 mm, return time < 2 years) but a more significant contribution can be delivered for some sub-basins (20 < rainfall height < 40 mm; 2 < return time < 10 years).

Table 27. Flood protection benefits of the wetlands foreseen in the Rio Martino Basins for Scenario 2

Rio Martino Basins	Wetland area with flood control side benefit [km^2]	Additional retention volume [m^3]	equivalent rainfall height over the whole watershed [mm/event]	Return time (rain duration 1 hour)*
MOS-RMA-100	0.18	176405	13.9	< 2 years
RMA-500	0.40	402088	11.5	< 2 years
SIS-210	0.41	412228	11.7	< 2 years
SIS-400	0.53	528448	35.7	> 2 years < 10 years
SIS-500	0.67	669260	20.3	< 2 years

* According to the rainfall depth-return time curve representative of the Rio Martino basin – See Annex 2 for details

[21] 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 is commonly identified with a return time equal to 30 years in Italy, which is out of the range of effectiveness for the NBSs targeted by this study.

Conventional low-cost **buffer strips** were assumed in the analysis, i.e. not considering the possibility to increase the retention volume with additional excavation (but with an extra cost for construction) as implemented, for instance, in the Veneto Region (Gumiero & Boz, 2017). Therefore, no retention volume and, therefore, no flood mitigation effect, was considered for the foreseen buffer strips.

6.2.1.2 Recreation

The Rio Martino basin includes the urban centre of Latina, the most important centre of the Agro Pontino, with a population of over 80.000 inhabitants, around 2/3 of the total population residing in the Rio Martino sub-basin, accounting to 125.000 inhabitants settled in 8 Municipalities. Therefore, the envisaged NBSs could be a valuable opportunity to create pedestrian and cycle paths, exploiting the diffuse network of new buffer strips of the two scenarios.

The recreational service will be then considered directly proportional to the NBS area for the following reasons:

— <u>buffer strips area</u>, potential area for new pedestrian and cycle paths;

— <u>wetland area</u>, potential new sites of interest for birdwatchers.

So the indicator used to quantify the "recreation" criterion is the area of the NBS.

6.2.1.3 Education

The possibility to exploit the NBSs to provide an educational service depends on the typology of the NBSs, their location and the availability of an organisation to develop the educational activity. During the lifespan of REWETLAND, according to the results of the social analysis, a total number of 2500 educational beneficiaries have been involved in activities related to wetlands, while no educational activity concerned buffer strips. Wetlands, in fact, have a much higher educational interest than buffer strips, offering the opportunity to "explore" an "unusual" ecosystem, hosting peculiar animals and plants (amphibians with their characteristic life cycle, large birds, submerged and emergent plants).

Only the wetlands envisaged under scenario 2 were considered able to offer educational opportunities. However, considering that the two wetlands created by REWETLAND were located nearby a large City (Marina di Latina) and the new wetlands should be implemented in less populated areas, the number of possible beneficiaries of educational services could be expected to increase by about 1/3, from 2500 to 3300 units.

Thus the indicator used to quantify the "education" criterion is: the number of possible beneficiaries.

6.2.1.4 Water quality

NBSs contribute to improve water quality. In this analysis, the pollutants considered are: <u>total nitrogen</u> (TN); <u>total phosphorus</u> (TP); <u>pesticides</u>, considering the removal of glyphosate + AMPA as a "proxy", in agreement with the literature analysis provided in chapter 3. The methodology for water quality estimation is reported in the following sections. The areal load removal of the NBSs were assumed according to the estimation done in chapter 3, considering the value reported in **Table 28**. It must be noted that data presented in **Table 28** must not be used to state: "Buffer strips are more efficient than wetlands; therefore, buffer strips must be preferred to wetlands". Indeed, the literature on buffer strips for runoff interception (BS-R) is highly uncertain, as confirmed by the current lack of a widely accepted model to design and simulate the performance of BS-Rs. Despite the intrinsic uncertainties of event-driven wetlands, the available models to design wetlands are more robust (Kadlec and Wallace, 2009) in comparison to what is available for BS-Rs. Moreover, also the intercepted pollutant mass load is much more uncertain in BS-Rs: indeed, it is not possible to easily differentiate if the diffuse pollutant load from agricultural runoff is conveyed mainly on surface – i.e. bonded to sediments – or in subsurface – i.e. within groundwater. Contrarily, wetlands treat water from agricultural ditches, with an intercepted pollutant load more certain in comparison to that of BS-Rs. Therefore, the areal removal of **Table 28** is only a simplified way to estimate potential pollutant removal of NBSs within the Rio Martino watershed based on elaboration made in Chapter 3. Whether to implement BS-Rs or wetlands, is a choice that should be guided by aspects other than simply the areal removal rate, in particular the availability of the area and the sustainability of the long term business model.

Table 28. NBSs areal load removal assumed for the watershed analysis

	Pollutant	**Areal removal**	**Source**
FWS - Wetlands	TN	14.1 g m^{-2} y^{-1}	Mass balance chapter 3 PP2 Marina di Latina: only FWS, 70th percentile
	TP	0.65 g m^{-2} y^{-1}	Mass balance chapter 3 PP2 Marina di Latina: only FWS, 70th percentile
	Pesticide (glyphosate + AMPA)	0.42 g m^{-2} y^{-1}	Mass balance chapter 3 PP2 Marina di Latina
Buffer strips for runoff interception	TN	28.8 g m^{-2} y^{-1}	Mass balance chapter 3 PP3 Allacciante Canal
	TP	1.1 g m^{-2} y^{-1}	Mass balance chapter 3 PP3 Allacciante Canal
	Pesticide (glyphosate + AMPA)	0.21 g m^{-2} y^{-1}	Mass balance chapter 3 PP3 Allacciante Canal

6.2.1.5 Biodiversity

As already said, wetlands are more important than buffer strips to support biodiversity: this difference among the two kinds of NBSs must be considered in the estimation of the effects.

For what concerns wetlands, according to Gibbs (2000) and Strand and Weisner (2013), their role in providing habitat for insects and amphibians does not depend on their size; every wetland, even the smaller ones, can contribute to provide habitat for plants, insects, amphibians and reptiles. Among these taxonomic groups there is no evidence that species richness increases with the size of the wetland, even though, obviously, the larger is the wetland, the bigger is the available habitat.

Going to the role of wetlands in providing habitat for birds, Strand and Weisner – based on the results of the analysis done on 24 wetlands in Sweden – notes that "*the maximum number of bird breeding species in the 24 wetlands showed positive relations with wetland size* [size of the wetlands ranges between 0.25 and 6.1 hectares] *but for wetlands smaller* *than 2 hectares no relation could be seen*". So species richness appears to increase with the size of the wetland for wetlands larger than 2 hectares.

Based on such considerations, and given that the new wetlands envisaged under scenario 2 are all larger than 0.25 hectares, all wetlands have been taken into account, and the benefits in terms of biodiversity can be considered directly proportional to the wetland surface: the benefit will be expressed by an adimensional value per m^2 and quantified through monetization by value transfer.

For what concerns buffer strips, their contribution to support biodiversity regards **insects, reptiles, birds (mainly *Passeriformes*) and small mammals**. The benefit is still directly proportional to the area and quantified through monetization by value transfer.

6.2.1.6 Investment costs, O&M costs, Loss of farmland income

Investment and O&M costs are considered from the perspective of public authorities. Therefore, no investment and O&M costs were considered for **buffer strips**. Indeed, the GREENCHANGE business model plans to leave the area to implement buffer strips free of charge to the private sector, which will cover investment and O&M costs. As a result, also no loss of farmland is expected for the implementation of the buffer strips.

Investment costs, O&M costs, and loss of farmland were assumed for the implementation of **wetlands**. The criterion used to define the investment costs for wetlands is to define an average investment €/m^2 cost, based on the financial framework (i.e. comprehensive of working costs, land acquisition, services) of the NBSs analysed in this report. Indeed, the aim is to provide an overall investment cost for the NBSs of the entire watershed and not just the cost for the construction of the NBSs (i.e. the cost reviewed in section 4.3). The investment costs for the wetlands were assumed in line with the costs obtained for Villa Fogliano, and equal to 15 €/m^2 (considering also the costs for excavation and embankment[22]), since only cheaper FWS wetlands were considered in the watershed analysis. The unit cost does not include the cost of expropriation and refunding. The assumed expropriation and refunding cost is equal to 5.0 €/m^2, i.e. the value considered in the GREENCHANGE project for agricultural land of low value (no greenhouse areas, only arable land). The total areal investment cost for the wetlands is, therefore, **20.0 €/m^2.**

Similarly, O&M parametric costs were estimated in line with the O&M costs of Villa Fogliano (section 4.2), i.e. **0.3 € m^{-2} y^{-1}.**

Loss of farmland income due to wetland implementation was assessed considering an estimation of the income per hectare of arable land of 1200 €. Such evaluation is based on the data used for the compensation for loss income used by the Rural Development Plan of the Lazio Region, according to the recent estimation made in the GREENCHANGE project[23].

[22] Considering improbable, for the new foreseen wetlands, to find other favourable conditions to implement a wetland without excavating the soil, as happened for the Villa Fogliano wetland.
[23] lifegreenchange.eu/wp-content/uploads/2021/04/A1_Mapping_ES_report.pdf

6.2.1.7 Synthesis: quantification of costs and benefits

The following table summarize costs and benefits and the variables (indicators) used to directly quantify the ecosystem services provided (e.g. flood retention volume, annual pollutant removal capacity) or to quantify them by value transfer approach (generally the total area except for "education").

Costs/Benefits	Indicators	Scenario N°1	Scenario N°2
Reduce flood risk	Peak flow reduction (retention volume)	0 m^3	2,188,492.00 m^3
Use for recreation	Area of the NBS available for potential new pedestrian and cycle paths (buffer strip area)	2,858,831.00 m^2	2,858,831.00 m^2
	Area of the NBS available as site of interest for Birdwatchers and Wildlife tourism (wetland area)	0 m^2	4,007,062.00 m^2
Use for education	Number of potential users	0	3.300
Contribute to water quality	Nitrogen removal	82 t_N/year 7.4% of agricultural diffuse pollution load of the basin	123 t_N/year 11.0% of agricultural diffuse pollution load of the basin
	Phosphorus removal	3.0 t_P/year 7.4% of agricultural diffuse pollution load of the basin	4.9 t_P/year 11.9% of agricultural diffuse pollution load of the basin
	Pesticide removal	0.6 $t_{glyph + AMPA}$/year	1.8 $t_{glyph + AMPA}$/year
Support biodiversity	Area of the NBS supporting species of insects, reptiles and small mammals (buffer strip area)	2,858,831.00 m^2	2,858,831.00 m^2
	Area of the NBS supporting insects, amphibians, birds (wetland area)	0 m^2	4,007,062.00 m^2
CAPEX	€	0 €	80,141,240.00 €
OPEX	€/year	0 €/year	1,773,896.80 €/year
Loss of farmland income	€/year	0 €/year	480,847.44 €/year

6.2.2 Value transfer

The economic valuation of the NBSs (Wetlands and Buffer strips) benefits 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 was carried out with the aim of recognizing the most common benefits (Ecosystem Services) deriving from the implementation of wetlands and buffer strips. 19 benefits were identified, which were 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 was carried out to proceed with the Value Transfer (VT). In this report, only the results concerning the 5 "non-economic" criteria selected and listed above (flood risk, recreation, education, water quality, biodiversity) are presented.

Value transfer (VT) is an economic valuation method that 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 it was decided for the 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 to the policy site.

Economic values resulting from this dataset (in attachment) 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, the most suitable candidates for the transfer were selected. The choice consisted on several criteria: values expressed in per hectare per year were preferred; study sites with the most similar characteristics were ranked; more recent studies were prioritized.

The last step of the value transfer exercise was 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 the confidence level is applied (the highest value is chosen 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 was chosen). Indeed, a conservative choice was made by deciding to underestimate the original value.

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

Table 29. 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 the 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

The following confidence levels were applied:

Table 30. 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

The final values, transferred onto the policy site, are reported in **Table 31** and have been used to estimate the value given by the total watershed basin in terms of ecosystem services, summarised in **Table 32**.

Table 31. 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	3102	6204	€/ha/yr	5441	6045	€/ha/yr
	4	8	€/person/visit	-	-	-
AWARENESS/EDUCATION	18	40	€/person/visit	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 32. Ecosystem service monetization with the value transfer method for the NBSs within the total basin (Scenario N°1 (Above) and Scenario N°2 (Below)

Ecosystem services in the total basin **SCENARIO N°1**	**Minimum ecosystem service value** **(€/y)**	**Maximum ecosystem service value** **(€/y)**
Flood Risk	0.00	0.00
Recreation and Tourism	1,555,523	1,728,200
Awareness/education	59,400	132,000
Water quality	18,869.00	37,737.00
Natural habitat and biodiversity support	8,291.00	10,292.00
Total	**1,642,082**	**1,908,229**

Ecosystem services in the total basin **SCENARIO N°2**	**Minimum ecosystem service value** **(€/y)**	**Maximum ecosystem service value** **(€/y)**
Flood Risk	41,580.00	76,134.00
Recreation and Tourism	2,798,513	4,214,181
Awareness/education	59,400	132,000
Water quality	1,240,588.00	3,883,715.00
Natural habitat and biodiversity support	187,807.00	209.844.00
Total	**4,291,859**	**8,515,874**

6.3 Final considerations on costs and benefits under the two scenarios

The implementation of BSs on the Rio Martino basin (Scenario 1) would contribute to a marginal (7.4%) reduction of the total diffuse pollution load. In this scenario, only a few supplementary ecosystem services would be provided: recreational opportunities and new habitat supporting biodiversity (even though the more sensitive taxa – related to aquatic ecosystems – are not supported in this scenario). According to the value transfer analysis the economic value of the NBSs implemented on the Rio Martino basin, under scenario 1 could be estimated between 1,642,000 €/y and 1.900.000 €/y. Even though the forecasted benefits are not that great, the business model proposed by the GREENCHANGE project allows to completely eliminate the public costs for the NBSs implementation and management. The implementation of the NBSs under scenario 1 is therefore feasible and recommendable.

The simulation analysis of scenario 2 doesn’t significantly increase the reduction of the total diffuse pollution load (3.6% more than scenario 1). Under scenario 2, more supplementary ecosystem services are provided (flood risk prevention and education, beside the ones provided under scenario 1) and the total economic value of the ES is more than 4 times higher than the one estimated for scenario 1 (between 4.2 and 8.5 million euros). On the other hand, the investment and O&M costs to implement the wetlands envisaged under scenario 2 are huge: over 80 million euros of capital costs and nearly 1.8 million euros/year of O&M costs, plus 0,5 million euros/year of farmland income loss.

Without further investigation allowing for a more detailed and trustable estimation showing better removal rates for the wetlands, the implementation of scenario 2 cannot be considered recommendable.

7 BUSINESS MODEL ANALYSIS

7.1 The business model of the REWETLAND Project

Considering the REWETLAND Business Model, it is important not to forget that until a century ago the Agro Pontino was an immense wetland that has been turned into fertile farming soil by a terrific reclamation effort. As a consequence, the idea of even just part of the land returning to wetland is not easily acceptable by the local population...

Until 2014, the Province of Latina was in charge of planning actions to reduce pollution to water bodies. Within the LIFE project REWETLAND, the Province of Latina adopted the Agro Pontino Environmental Restoration Program (ERP), a strategic planning tool aimed at improving the surface water quality, through the implementation of NBSs and the application of good practices for water pollution control.

The background idea of the REWETLAND project was to implement some demonstration NBSs, showing to the local people that they could provide benefits, develop a program (the ERP) to replicate the NBSs on a larger scale, find the financial resources to implement NBSs on a large scale through the ordinary funding channels (River basin management plans, Flood risk management plans, funds supporting habitat and biodiversity). Thus, the business model mainly relied on public resources to be provided by ordinary water and biodiversity management sources.

However, the participatory model created through the REWETLAND Project went into decline in March 2015, when the national law 56/2014 deprived the Provinces of their authority, as well as of their financial resources. In addition, not all the demonstration sites implemented by the REWETLAND project showed evidence of providing benefits: the buffer strip located along the Allacciante Astura Canal was blamed to be one of the causes of the severe floods occurred in 2017 and 2018.

The Business Model envisaged by REWETLAND failed for two main reasons:

1. the lack of knowhow transfer and capacity building towards a key actor: the Consorzio di Bonifica Agro Pontino;
2. the lack of financial resources through ordinary channels to replicate the NBS implementation on a larger scale.

The first reason deals with the poor technical skills of the Consorzio di Bonifica Agro Pontino for what concerns the design and management of multipurpose NBSs. Even though they fully agree with the new "NBS" approach, they were not able to correctly locate and design, at least one of the two buffer strips (but more generally speaking the design of the BSs was poor...), and they had to remove it to avoid flood risk problems. But the Consorzio di Bonifica Agro Pontino is not to blame: the technical approach of all Drainage Authorities in Italy has always been very far from the "green infrastructure" approach; their technical background lies in the conventional hydraulic engineering and land reclamation practices. Since the Consorzio plays a key role not only for the REWETLAND Project but also for the scaling up of the demonstrative experience to the whole Agro Pontino area, they should be equipped with a well-trained technical staff. Such condition, however, is not compatible with the time and financial constraints of the "Life+" program.

The second issue concerns the possible scaling up of the NBSs on the basin. Even though the ERP elaborated by REWETLAND has been acknowledged by the Lazio Region in its Water Quality Plan, none of the measures envisaged by the program has been financed by the Region nor by the River Basin Authority. That is a key point: the business model envisaged by REWETLAND must rely on a certain – even though small – dedicated annual budget.

A final remark concerning the business model deals with the process governance that mainly relies on the role of the Latina Province. When the Law 56/2014 deprived the Latina

Province of its authority and financial resources, some other institutional actor should have taken the lead for the implementation of the ERP: presently neither the Lazio Region nor the Consorzio di Bonifica Agro Pontino appear to be able to play this role.

Indeed, REWETLAND was awarded the "Best Life Projects" label and it was of great importance to introduce new concepts and approach in the local community. The approach introduced by REWETLAND has been at least partially accepted by the local community, as shown by the fact that the Life project GREENCHANGE was conceived by local actors and approved in 2017.

7.2 The business model of the GREENCHANGE Project

As anticipated in paragraph 5.3.2, the GREENCHANGE business model is based on entrusting farms with state-owned areas bordering waterways for the construction and management of NBSs (typically linear arboreal/shrub formations or wetlands) whose primary objective is to support biodiversity, but which also perform a function of reducing diffuse pollution. The interest on the part of farmers is based on the first pillar of the Common Agricultural Policy (CAP): that of direct payments.

7.2.1 The Common Agricultural Policy

The EU's Common Agricultural Policy (CAP) is a partnership between agriculture and society, and between Europe and its farmers. It aims to:

— support farmers and improve agricultural productivity, ensuring a stable supply of affordable food;

— safeguard European Union farmers to make a reasonable living;

— help tackle climate change and the sustainable management of natural resources;

— maintain rural areas and landscapes across the EU;

— keep the rural economy alive by promoting jobs in farming, agri-foods industries and associated sectors.

The CAP takes action with:

— income support through **direct payments,** which ensure income stability, and remunerate farmers for environmentally friendly farming and delivering public goods not normally paid for by the markets, such as taking care of the countryside;

— market measures to deal with difficult market situations such as a sudden drop in demand due to a health scare, or a fall in prices as a result of a temporary oversupply on the market;

— rural development measures with national and regional programmes to address the specific needs and challenges faced by rural areas.

Under the CAP 2014-2020, which was extended temporarily until the end of 2022 for the COVID-19 health emergency, actions in favour of the climate and the environment are financed through direct payment called "greening".

Greening requires compliance with three beneficial practices for the climate and the environment:

— the first practice concerns the diversification of crops;

— the second, the maintenance of permanent pastures in the farms where they are present;

— the third, the maintenance or establishment of areas of ecological interest (EFA - Ecological Focus Area).

The areas of ecological interest were made mandatory for arable lands greater than 15 hectares. These will have to ensure that an area equal to 5% of the arable land is made up of EFA.

The value of the greening is defined as 50.16% of the basic payment. The basic payment in recent years has had a national average value of about 220 €/ha, therefore the value of the national average greening is about 110 €/ha. However, the distribution of the value of the basic payment is extremely different on the national territory (**Figure 41**), with maximum values up to 3000 €/ha. For the Agro Pontino area, the values of the basic payments are between 200 and 400 €/ha. Therefore, an average greening value for the study area should be at least 100 €/ha.

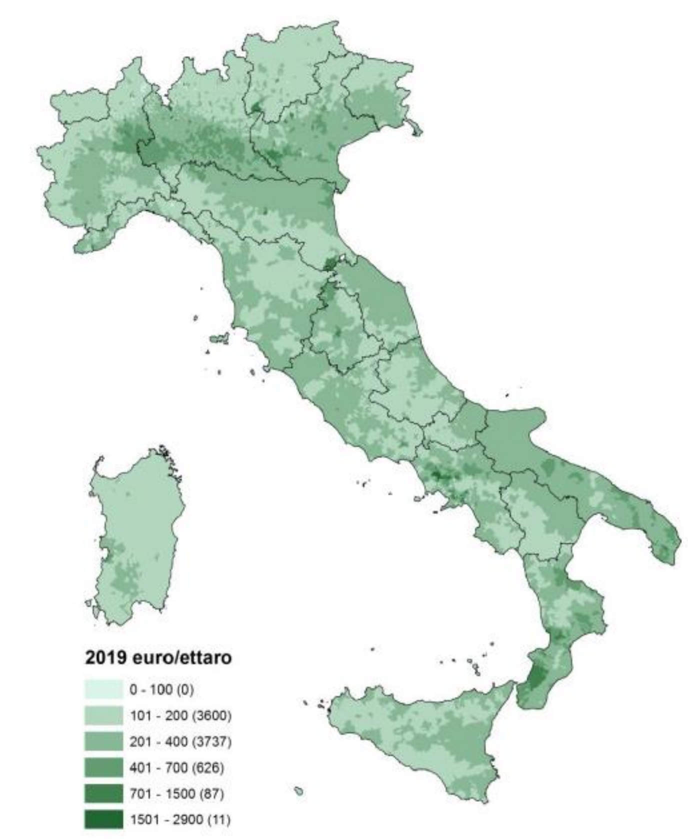


Figure 41. *Territorial distribution of direct payments 2019 - basic payment + greening (Source: Pierangeli, 2017)*[24]

Greening will no longer be envisaged as part of the CAP 2021-2027. The abolition of the greening payment does not mean that the environmental objectives of the CAP will be downsized; rather, they will be strengthened, confirming the environmental role entrusted to direct payments. In fact, the basic support will be called "Basic income support for sustainability", making clear the role of direct support as income aid to remunerate farmers' contribution to sustainability. Most of the greening commitments will be transferred to cross compliance, simplifying and enriching the basic requirements that the farmers will have to comply with to receive support. At the moment, the value of basic income support for sustainability is not defined. Based on some estimates for Italy, basic support is expected to be around 225 €/ha (Pierangeli 2017)[24].

Furthermore, the CAP 2021-2027 will provide for a direct payment for voluntary actions called eco schemes (or ecological schemes). The definition of eco-schemes will contemplate

[24] Pierangeli, 2017, La distribuzione dei pagamenti diretti in Italia e in Europa. Nell'ambito del seminario SIDEA "Il sostegno all'agricoltura: finalità economiche, ambientali o sociali. Sono ancora utili i pagamenti diretti?" Bologna, 17 novembre 2017. http://www.sidea.org/wp2/wp-content/uploads/2017/11/Pierangeli.pdf

a potential list of agricultural practices that will be established in certain areas of action to respond to specific objectives within the strategic plans, with each practice having to contribute to at least two "action areas". The list of "areas of action", prepared by the European Commission[25], includes:

- mitigation and adaptation to climate change,
- the protection of biodiversity,
- the reduction of pesticides
- the conservation of water resources.

At the moment it is not possible to quantify the financial support for these actions.

7.2.2 Why farmers should implement and manage NBSs

The model proposed by GREENCHANGE is advantageous for the farm because the state-owned areas entrusted to the company through land stewardship agreements (administratively a loan agreement) are recognized as Ecological Focus Areas (EFAs). This allows them to take advantage of the CAP incentives without having to subtract part of their land from agricultural production, thus obtaining immediate benefits.

There is also an interest on the part of farmers in the Pontinian plain to manage the state-owned areas where the old eucalyptus windbreaks are planted because the plants are too tall and old (they are now about a hundred years old) and no longer serve as windbreaks.

In perspective, another advantage could be added, which is not yet precticable at the moment but which the GREENCHANGE project intends to activate within its deadline. It consists in rewarding the territories in which land stewardship agreements have been activated, providing facilitations for the farms involved to access the agri-environmental measures of the Rural Development Program (RDP).

Finally, there is also an advantage for the public body (the Lazio Region in particular), which no longer has to guarantee the maintenance of state-owned areas entrusted to farmers in custody.

The surveys carried out by Confagricoltura show a growing interest in the project by medium-large farms (greater than 15 hectares), which increasingly look to their business from a multifunctional perspective: not only production of agri-food goods (primary function) but also provision of secondary services useful to the community (tourism and accommodation capacities). In addition to the immediate benefits described above, the creation of NBSs allows the creation of paths that facilitate access to the farms for the urban population and tourists.

Confagricoltura estimates that, if the conditions for direct payments remain advantageous (as it would seem from the provisions of the new CAP 2021-2027, see paragraph 7.2.1), about 70% of the state-owned areas of the Agro Pontino could be allocated to NBSs and entrusted to farms in the near future.

[25] https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/factsheet-agri-practices-under-ecoscheme_en.pdf

8 CONCLUSIONS

The analysed case study provides several useful hints, even though it does not always allows clear answers to all the questions that are the objective of the present study (see paragraph 1.1).

For what concerns BSs, it is interesting to notice that the monitoring protocol does not envisage the collection of groundwater samples, upstream and downstream the subsurface flow crossing the BS, but the collection of surface water samples from the water body along which the BS was located. Such unusual monitoring protocol suggests a poor knowledge by the designers of how a BS works. Such impression is further confirmed by the fact that both the BSs were located in the inner lowland, a clayey soil area, where the low soil permeability heavily reduces the nitrogen removal performance of BSs. Moreover, one of the BS was located along the Allacciante Astura canal, a wide watercourse that drains the flow from the Lepini mountains and is subject to important water level variations during high flow: the watercourse is confined on both banks between two high embankments hindering any water flow from the surrounding farmed areas to the canal and consequently making the presence of the BSs unable to intercept the runoff from the floodplain. It is interesting to notice that – even though the role of buffer strips for diffuse pollution control has been well known in the scientific community for at least 30 years – very often the NBSs pollutant removal mechanism is still poorly known by the public technical bodies and professional designers. In the end, the wrongly located buffer strip did not endure: the Allacciante Astura BS was removed after the end of the REWETLAND project to answer the pressing demand by the local farmers to "keep clean" the canal to avoid flood risk.

The pollutant removal capacity of the NBSs was estimated through specific models and the removal rates are in the range expected according to scientific literature but lower than the most performing existing case studies.

Investment and O&M costs of the NBS implemented in the present case study are in line with similar systems implemented in other Italian sites.

To assess direct and indirect costs and benefits of the implementation of NBS at basin scale, two scenarios were developed on the Rio Martino basin: scenario 1 envisages only the implementation of buffer strips by the farmers – at their own costs but on public land entrusted to them through land stewardship agreements; scenario 2 envisages supplementary wetland NBSs, to be implemented and managed by the Consorzio di Bonifica making use of public (Regional) funds. Both scenarios do not excel in term of diffuse pollution reduction: pollutant removal of nitrogen and phosphorus range between 7.4% and 12% of the total load. Such a weak performance depends on several factors.

The buffer strips network envisaged is too coarse to intercept the important pollutants load due to intensive farming activity: even though their areal removal rate is in line with the best performance of similar NBSs according to the available scientific literature (Zhang et al 2010), their contribute in reducing the pollutant load is not sufficient.

For what concerns the wetlands envisaged under scenario 2, their areal removal rate is very low, compared to the international literature: the areal removal rate of N estimated for the NBSs of the present case study is 14 g/m^3/year while the average for wetlands (Kadlec 2012) is 70. Such low areal removal rate depends on the low concentration of pollutant that emerges from the available data, provided by studies carried out by the Latina Province. According to these data, the $N\text{-}NO_3$ concentration is always lower than 2 mg/L, while in similar intensive agriculture European sites the N concentration is 3 to 5 times higher. If this low concentration is not due to some bias in the monitoring campaigns carried out by the Latina Province, it may depend on the dilution by groundwater. If this is the case, in this specific local context the use of wetlands to reduce diffuse pollution shows to be poorly effective and is not recommendable.

The results of the MCA and the monetization of the ES provided by the NBSs under the two scenarios developed, confirm the significant value of the ES provided by the NBSs, ranging between 1,5-2 million €/year for scenario 1 and 5-8 million €/year for scenario 2. However, while scenario 1 shows a clear economic feasibility, providing valuable ES – even though not satisfactory in terms of diffuse pollution removal – without any public cost, scenario 2 is much less "profitable", presenting high capital, (80 million euros) O&M (1,7 million euros/year) and opportunity (0,5 million euros/year of lost farming income) costs. The annual value of the ES provided by the NBSs under scenario 2 is at least double of the annual running costs (O&M plus lost income) of the new NBSs, but the payback time of the investment costs would be very long (around 40 years) compared to similar NBSs located in more appropriate geographic contexts.

Finally, for what concerns the business model, the approach proposed by REWETLAND – to implement some demonstration NBSs, show to the local people that they could provide benefits, develop a program to replicate the NBSs on a larger scale, find the financial resources to implement NBSs on a large scale through the ordinary funding channels (River basin management plans, Flood risk management plans, funds supporting habitat and biodiversity) – clearly failed. The GREENCHANGE project developed a completely different "win-win" approach, involving the farmers and entrusting them to manage public areas to implement NBSs (buffer strips). These areas are recognised as "ecological Focus Areas", allowing farmers to access to the direct payment of the "CAP greening" without withdrawing part of their farming land from production. The condition for this business model to be replicable is the availability of public land properly located to allow the implementation of effective NBSs for diffuse pollution removal. Such condition occurs on the pontinian plain as a heritage of the land reclamation occurred 100 years ago, that created stripes of public land along the draining ditches, used for windbreaks plantation. It is certainly a very peculiar "land property pattern", probably not very common – and therefore with scarce replication opportunity – however a similar pattern could exist in other European geographical contexts subject to land reclamation in the past.

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Value transfer method (https://oppla.eu)

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 - http://dati.lazio.it/catalog/it/dataset/carta-tecnica-regionale-1991)
- Soil type: Regional soil type map (https://geoportale.regione.lazio.it/geoportale/web/guest/catalogo?p_p_id=GNet_WAR_GNetportlet&p_p_lifecycle=0&_GNet_WAR_GNetportlet_lifportrend=carta%20geologica)
- Flood and risk maps (Bacini Regionali Lazio) (http://www.regione.lazio.it/prl_ambiente/?vw=contenutidettaglio&id=211)
- Hydrogeological map (https://www.idrogeologiaquantitativa.it/?p=2022&lang=it)

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

All the drawings attached are listed in the following table.

ID	Title	Scale
01	Satellite view	1:15000
02	Topography	1:15000
03	Soil type	1:15000
04a-b	Land use and infrastructure	1:15000
05a	Flood maps	1:15000
05b	Risk maps	1:15000
06a-b	Hydrogeological map	1:30000

Summary of the features of the sites.

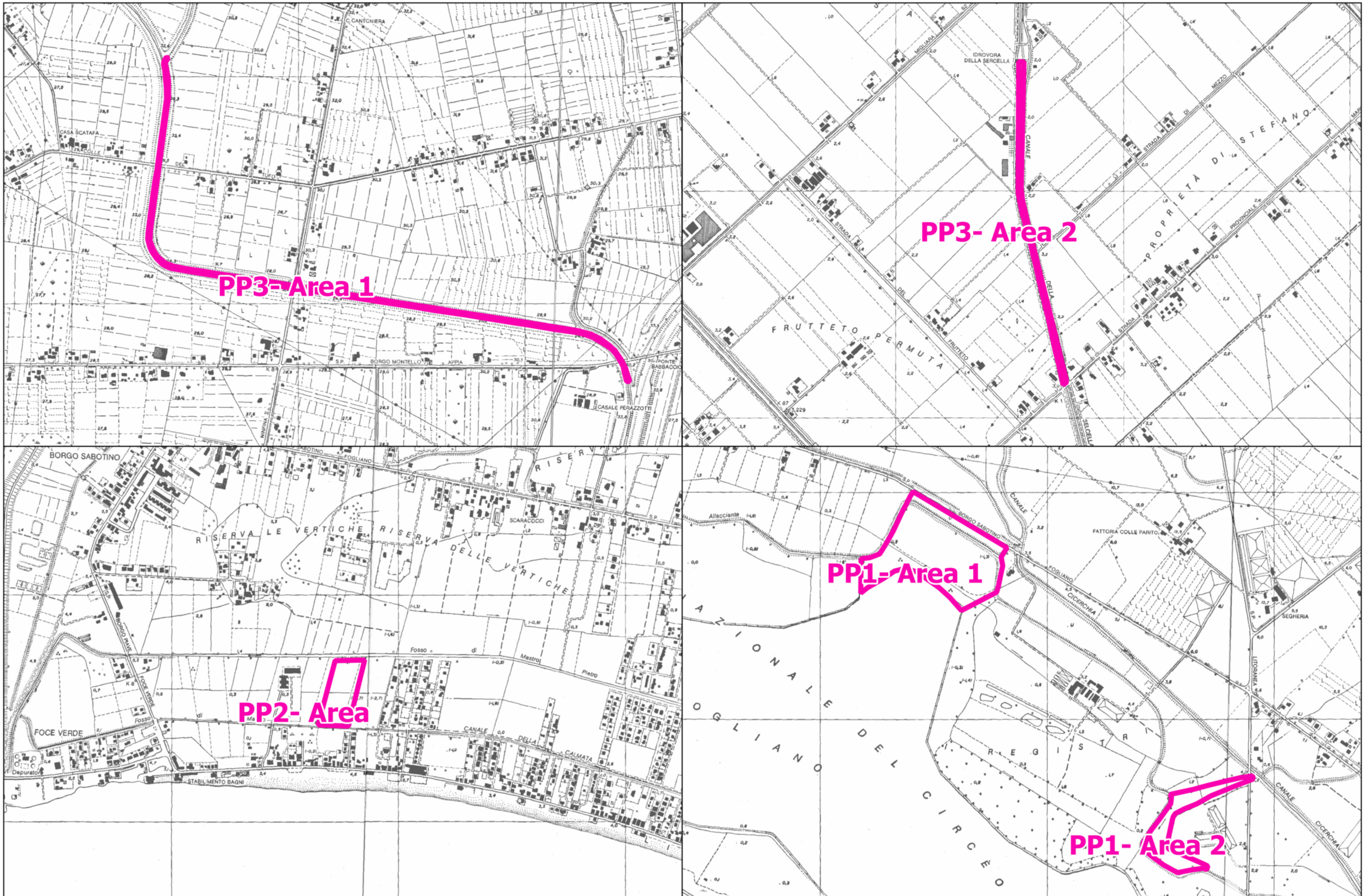
NBS	Features of Soil Type
PP3-Area1	Backfill; Sands; Colluvium / sand / gravel
PP3-Area2	Silts and clays
PP2-Area	Silts and clays
PP1-Area1	Sands; Silts and clays; Calcareous silts / peaty clay / peat
PP1-Area2	Calcareous silts / peaty clay / peat; Clays / sand / gravel

NBS	Features of Land use and infrastructure (Corine)
PP3-Area1	Non-irrigated arable land; Fruit trees and berry plantations
PP3-Area2	Non-irrigated arable land
PP2-Area	Non-irrigated arable land; Discontinuous urban fabric
PP1-Area1	Non-irrigated arable land; Inland marshes
PP1-Area2	Non-irrigated arable land

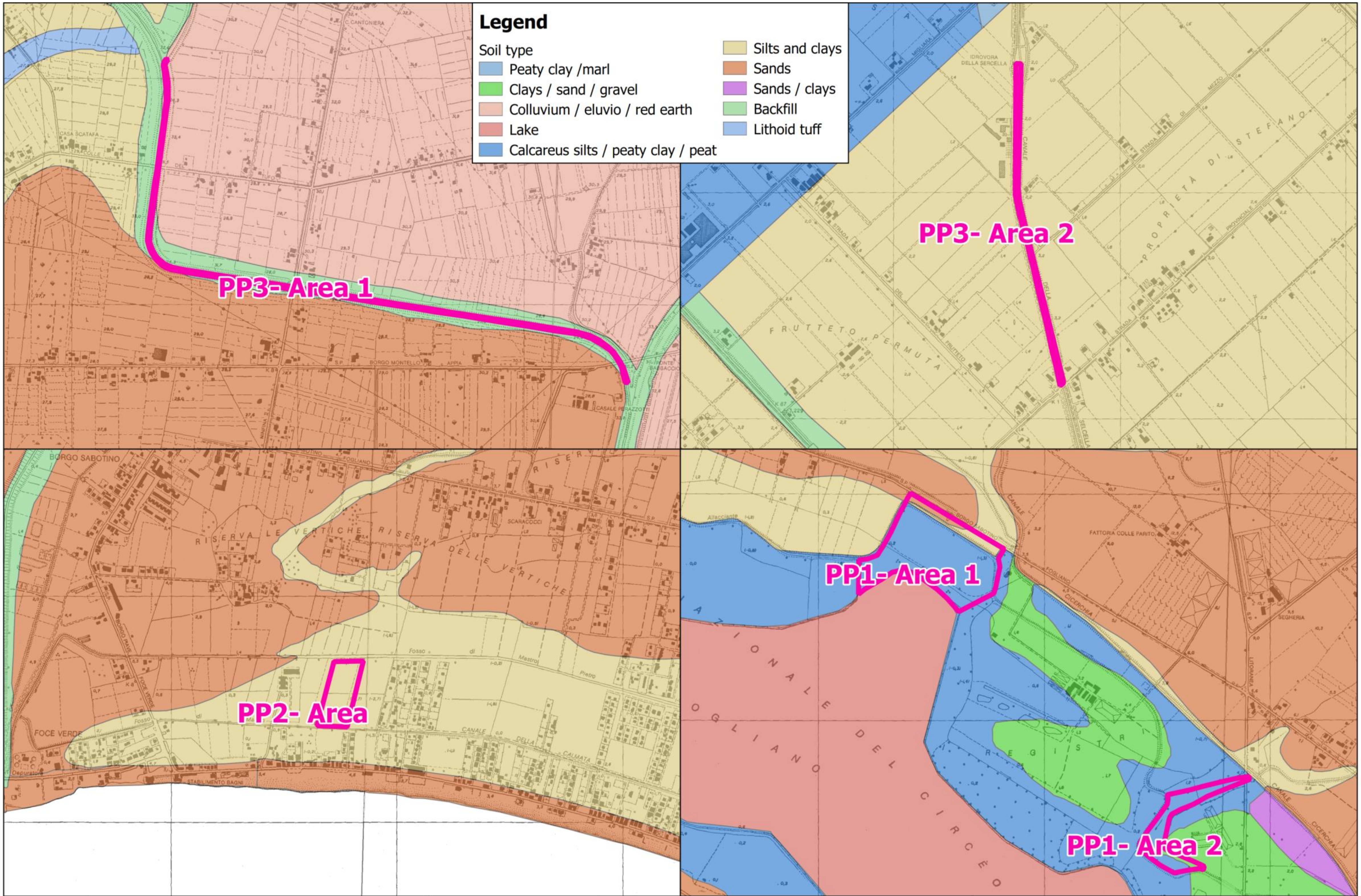
NBS	Features of Flood and risk maps
PP3-Area1	Medium flood probability (P2); Moderate or non-existent risk (R1)
PP3-Area2	-
PP2-Area	Medium flood probability (P2); High flood probability (P3); Moderate or non-existent risk (R1); Medium risk (R2)
PP1-Area1	Medium flood probability (P2); High flood probability (P3); Moderate or non-existent risk (R1); Medium risk (R2)
PP1-Area2	Medium flood probability (P2); High flood probability (P3); Moderate or non-existent risk (R1); Medium risk (R2)

NBS	Features of Hydrogeological map
PP3-Area1	Water Table Depth above 20m
PP3-Area2	Water Table Depth below 5m
PP2-Area	Water Table Depth below 5m
PP1-Area1	Water Table Depth below 5m
PP1-Area2	Water Table Depth below 5m

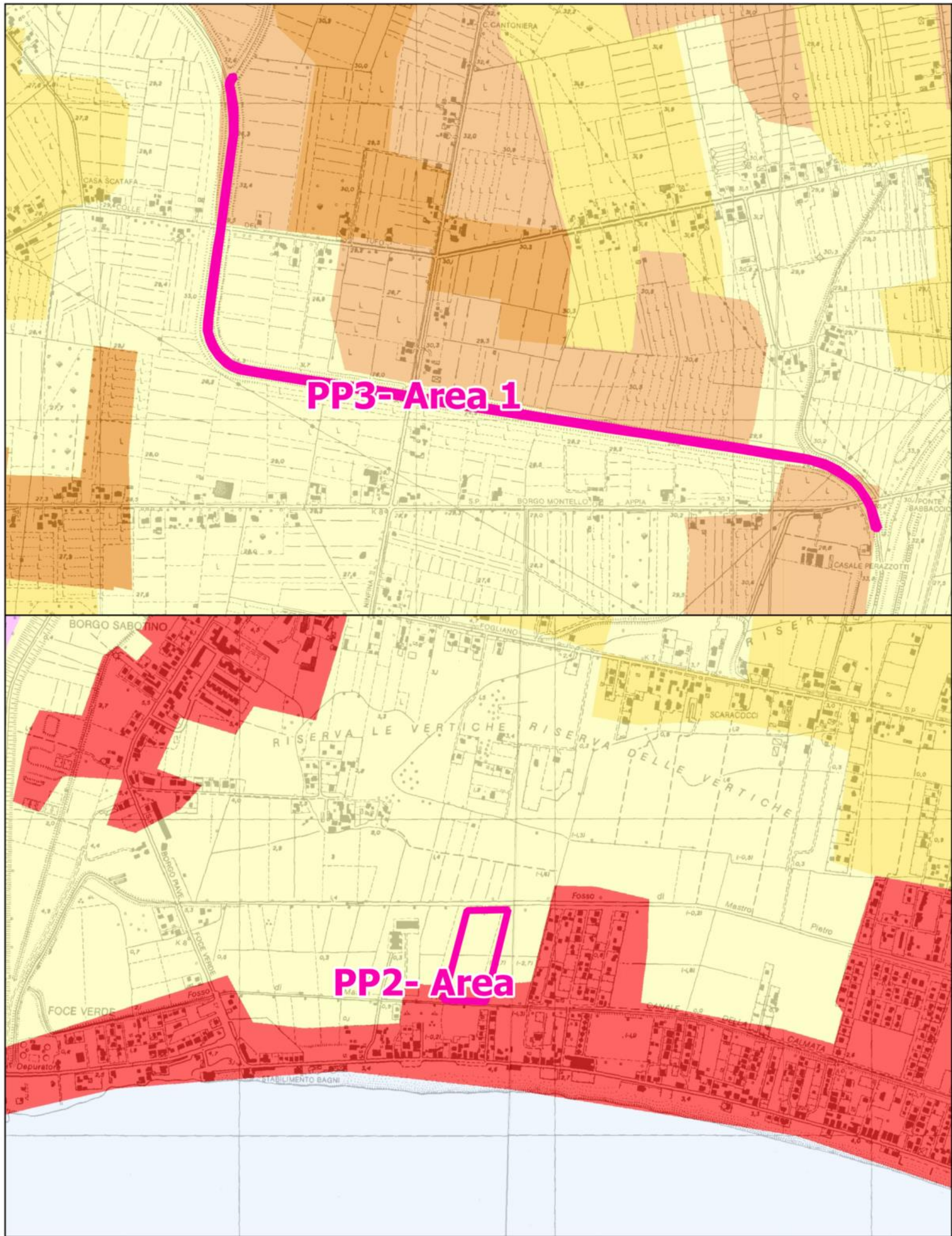
01	NBS CONSORZIO LIFE	Satellite View	Source: Google Satellite Access: June 2020	0 300 600 900 1200 1500 m Scale 1:15000



02	**NBS CONSORZIO LIFE**	**Topography**	**Source: Geoportale Regione Veneto** **Access: June 2020**	0 100 200 300 400 500 m Scale 1:15000



03	NBS CONSORZIO LIFE	Soil Type	Source: Geoportale Regione Lazio Access: June 2020	0 300 600 900 1200 1500 m Scale 1:15000

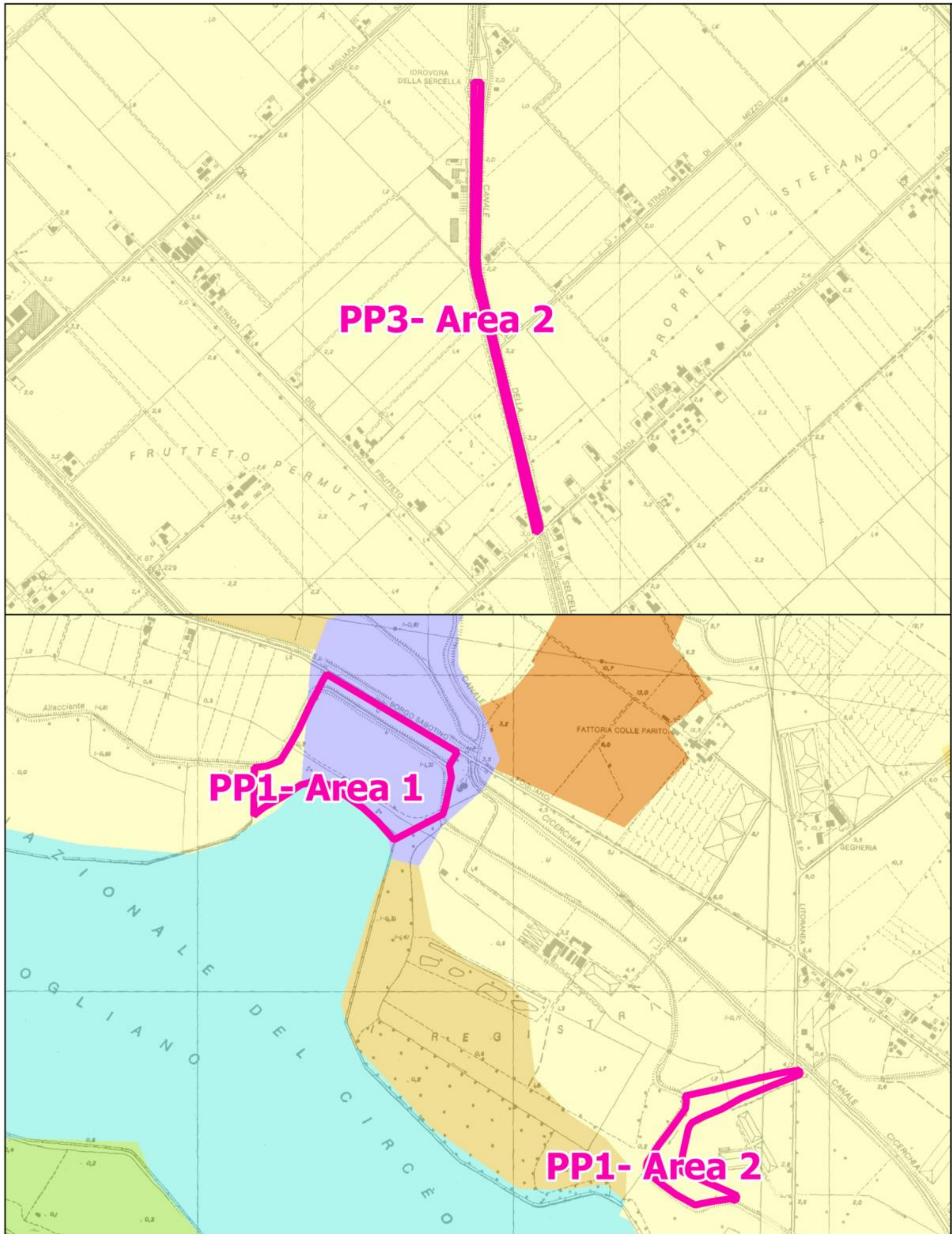


Legend

Corine Land Cover 2018 vector

CLC Code
- 111: Continuous urban fabric
- 112: Discontinuous urban fabric
- 121: Industrial or commercial units
- 122: Road and rail networks and associated land
- 123: Port areas
- 124: Airports
- 131: Mineral extraction sites
- 132: Dump sites
- 133: Construction sites
- 141: Green urban areas
- 142: Sport and leisure facilities
- 211: Non-irrigated arable land
- 212: Permanently irrigated land
- 213: Rice fields
- 221: Vineyards
- 222: Fruit trees and berry plantations
- 223: Olive groves
- 231: Pastures
- 241: Annual crops associated with permanent crops
- 242: Complex cultivation patterns
- 243: Land principally occupied by agriculture, with significant areas of natural vegetation
- 244: Agro-forestry areas
- 311: Broad-leaved forest
- 312: Coniferous forest
- 313: Mixed forest
- 321: Natural grasslands
- 322: Moors and heathland
- 323: Sclerophyllous vegetation
- 324: Transitional woodland-shrub
- 331: Beaches, dunes, sands
- 332: Bare rocks
- 333: Sparsely vegetated areas
- 334: Burnt areas
- 335: Glaciers and perpetual snow
- 411: Inland marshes
- 412: Peat bogs
- 421: Salt marshes
- 422: Salines
- 423: Intertidal flats
- 511: Water courses
- 512: Water bodies
- 521: Coastal lagoons
- 522: Estuaries
- 523: Sea and ocean

04a	NBS CONSORZIO LIFE	Land Use and infrastructure	Source: Corine Land Cover 2018 Access: June 2020	0 100 200 300 400 500 m Scale 1:15000



Legend

Corine Land Cover 2018 vector

CLC Code

- 111: Continuous urban fabric
- 112: Discontinuous urban fabric
- 121: Industrial or commercial units
- 122: Road and rail networks and associated land
- 123: Port areas
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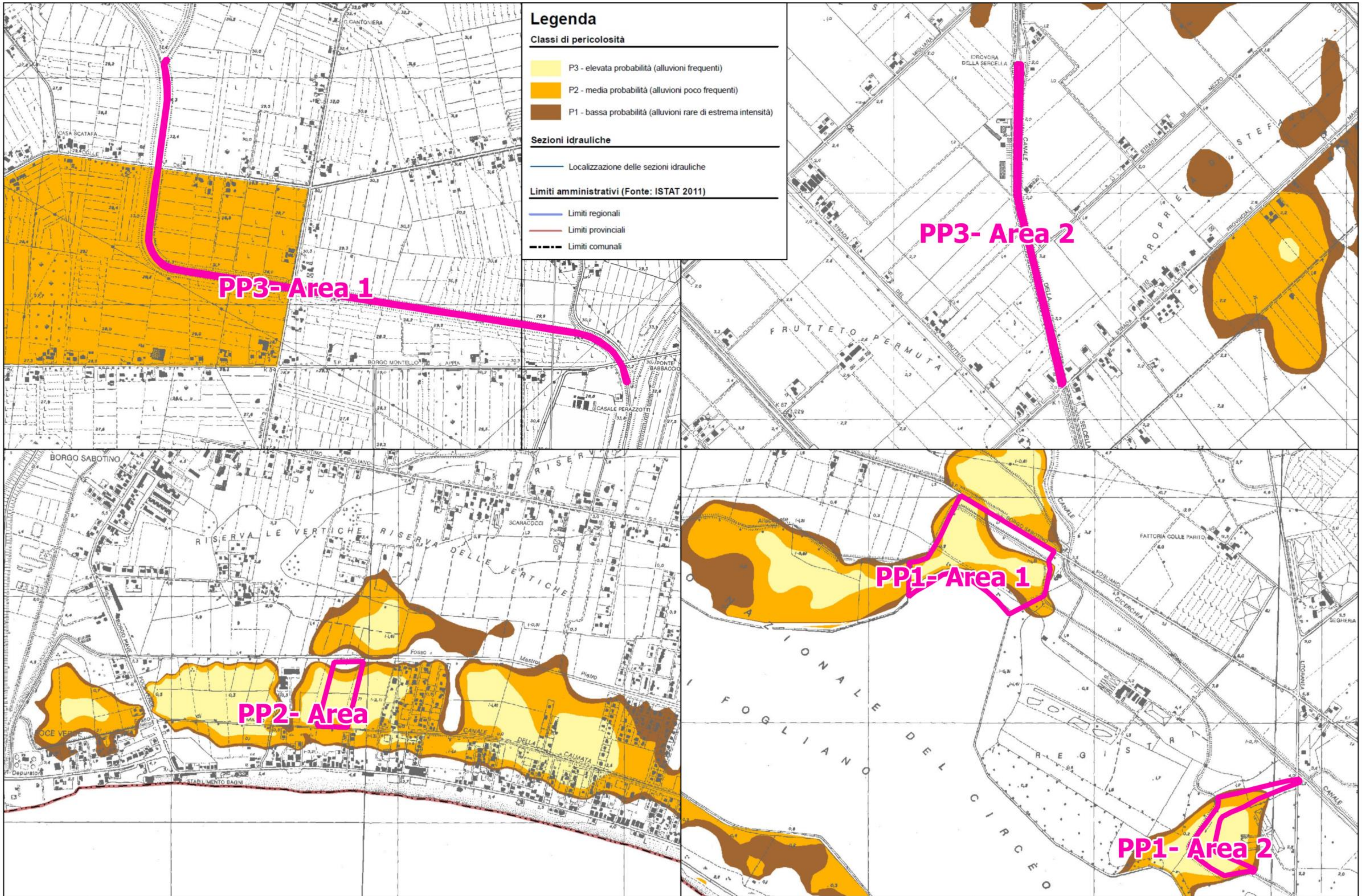
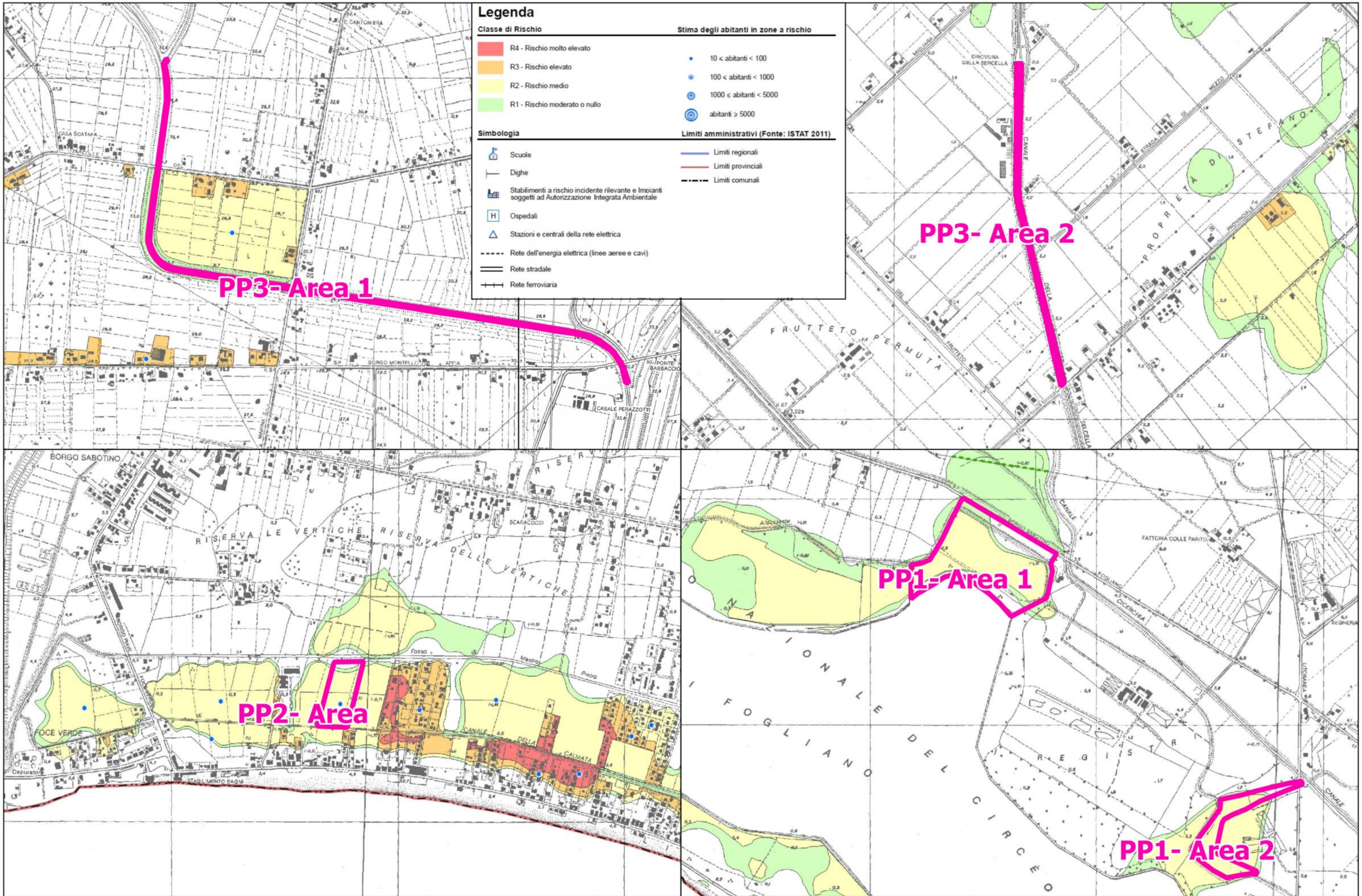
- 334: Burnt areas
- 335: Glaciers and perpetual snow
- 411: Inland marshes
- 412: Peat bogs
- 421: Salt marshes
- 422: Salines
- 423: Intertidal flats
- 511: Water courses
- 512: Water bodies
- 521: Coastal lagoons
- 522: Estuaries
- 523: Sea and ocean

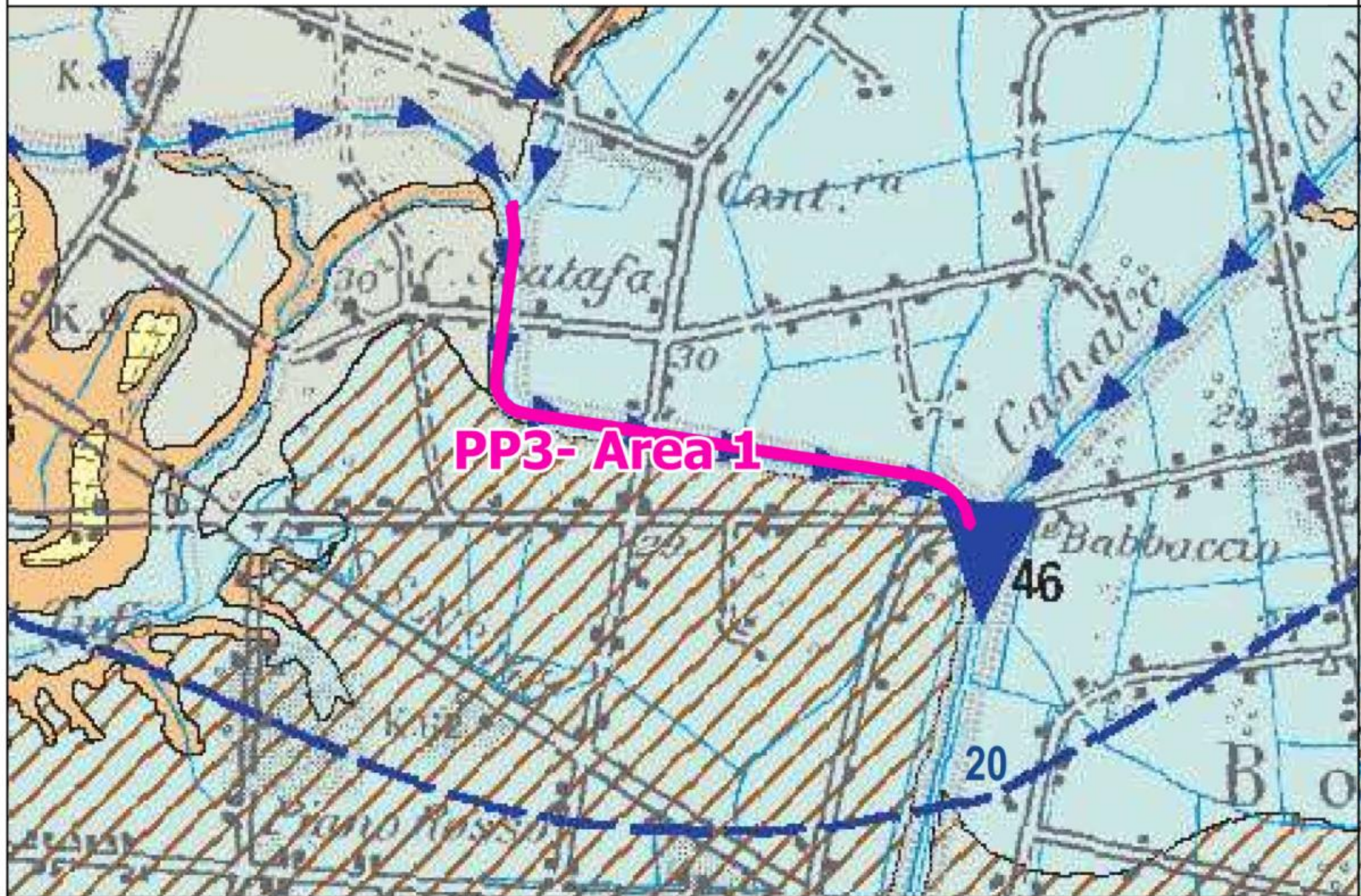
04b	NBS CONSORZIO LIFE	Land Use and infrastructure	Source: Corine Land Cover 2018 Access: June 2020	0 100 200 300 400 500 m Scale 1:15000

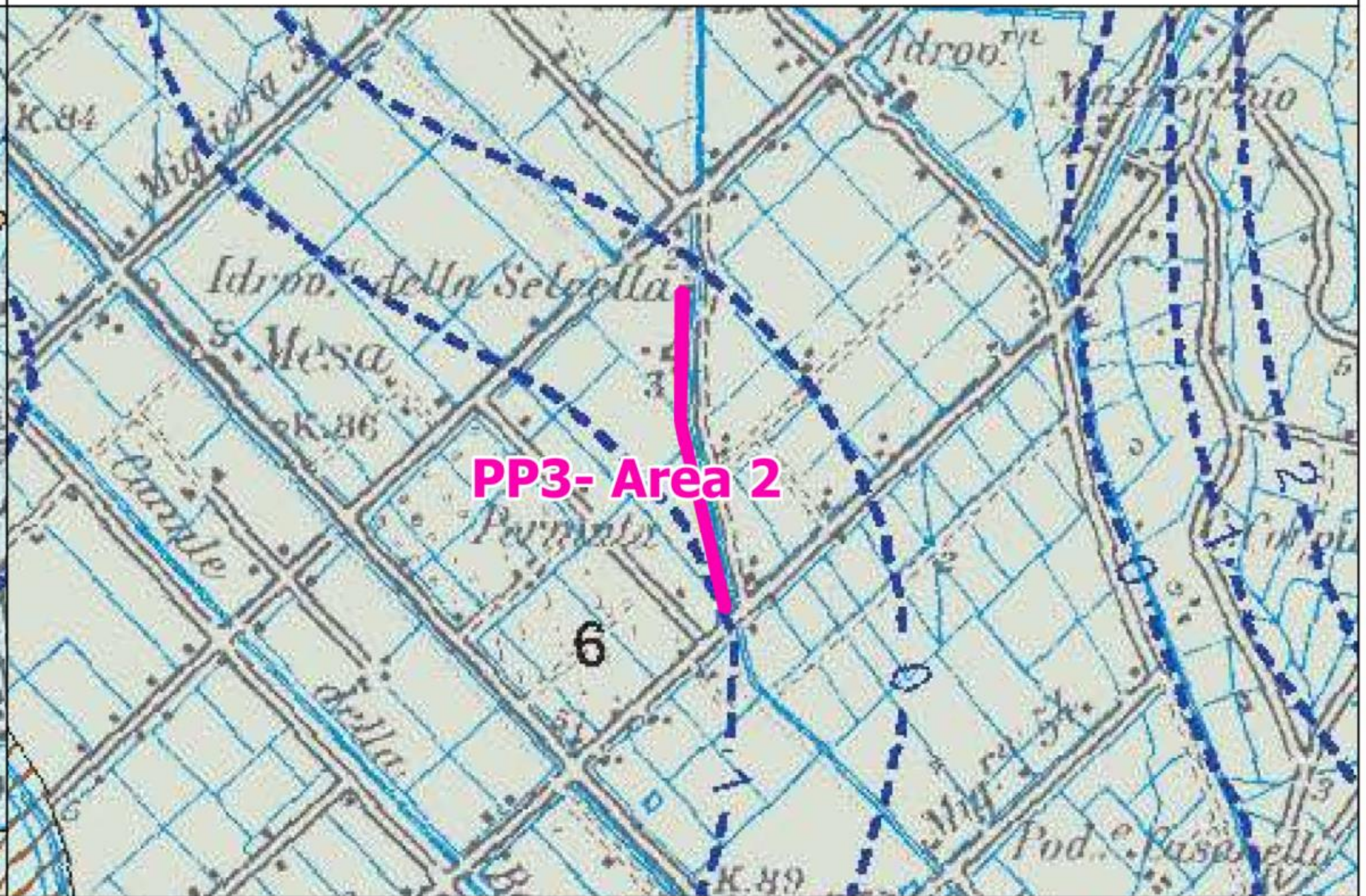


05a	**NBS CONSORZIO LIFE**	**Flood maps**	**Source: Bacino Regionale Lazio** **Access: June 2020**	0 300 600 900 1200 1500 m Scale 1:15000

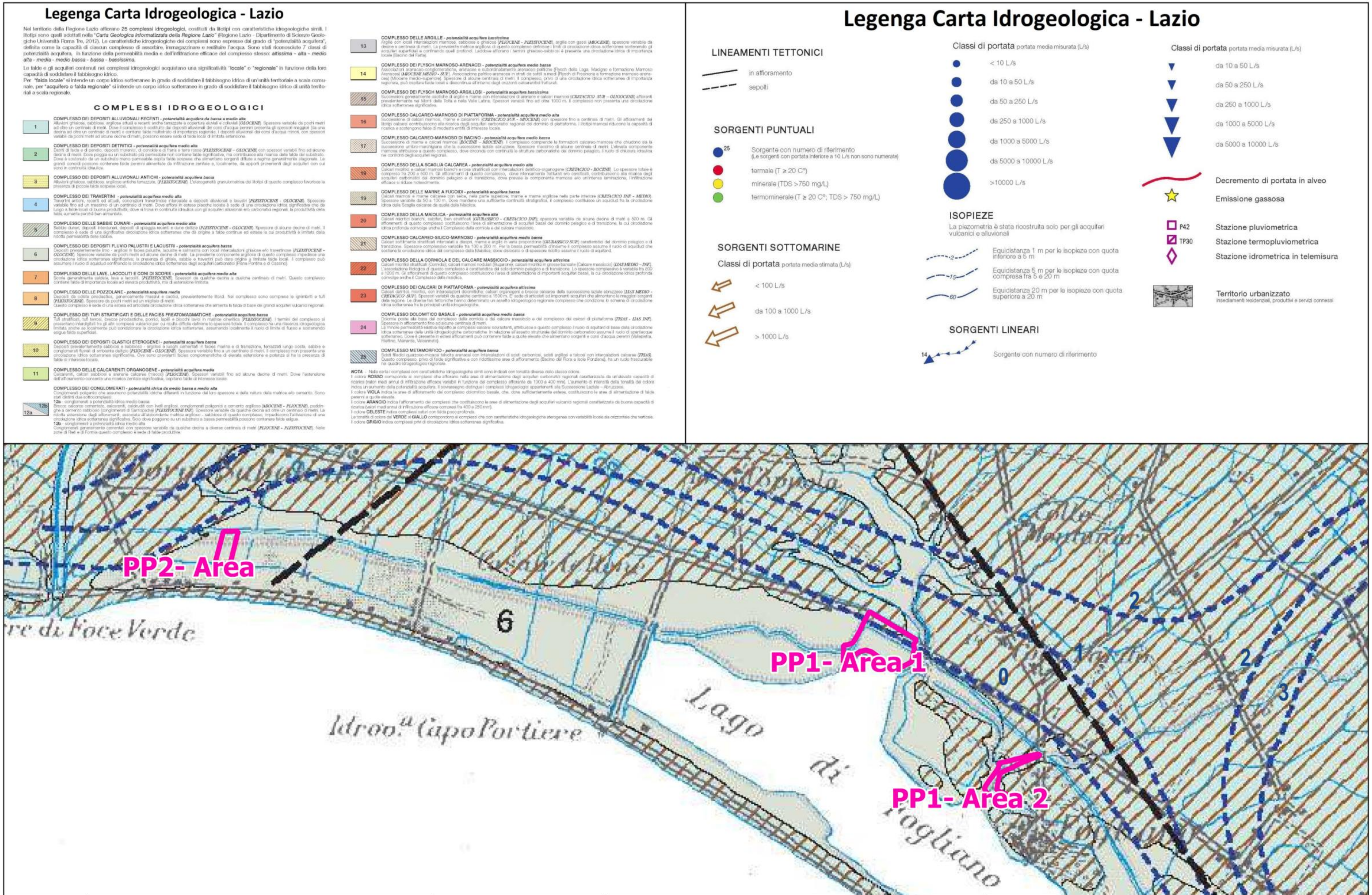


05b	NBS CONSORZIO LIFE	Risk maps	Source: Bacino Regionale Lazio Access: June 2020





06a	NBS CONSORZIO LIFE	Hydrogeological map	Source: Idrogeologia quantitativa Access: June 2020	0 600 1200 1800 2400 3000 m Scale 1:30000



06b	**NBS CONSORZIO LIFE**	**Hydrogeological map**	**Source: Idrogeologia quantitativa** **Access: June 2020**

0 600 1200 1800 2400 3000 m

Scale 1:30000

ANNEX 2: Detailed climatic analysis

Climatic framework

The weather station in the Lazio region nearest to the area of interest is Sabaudia (**Figure 42**).

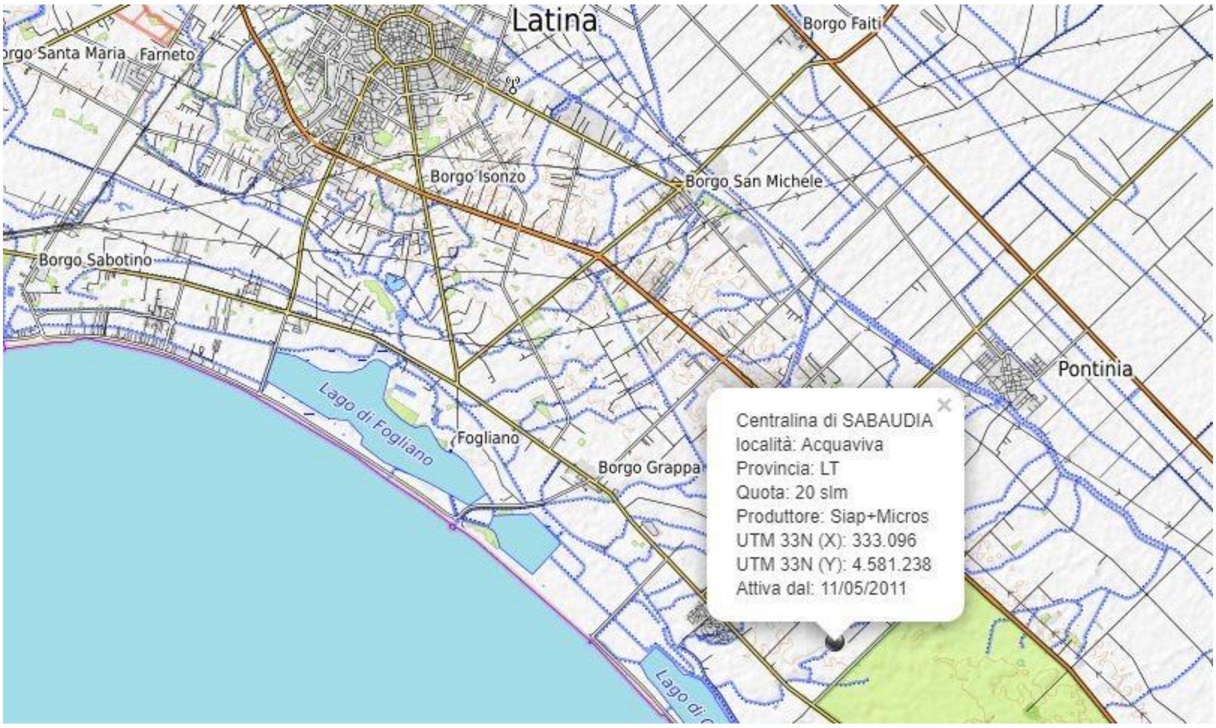


Figure 42. Sabaudia meteo-climatic station (http://www.arsial.it/portalearsial/agrometeo/C1.asp)

The monthly average climatic values, calculated as the average of the data recorded by the station for the years 2003-2017, are shown in the following table and represented in the graphs.

Table 33. Monthly average climatic values for the years 2003-2018 (Regional Functional Centre)

Month	Sabaudia Station			
	P	T_{MED_MIN}	T_{MED_MAX}	T_{MED_MED}
	[mm]	[°C]	[°C]	[°C]
Jan	76.80	5.9	13.37	9.02
Feb	86.84	5.7	13.55	9.64
Mar	77.51	7.9	16.01	9.76
Apr	38.07	11.1	19.60	15.31
May	31.35	14.5	23.37	18.94
Jun	24.10	18.4	27.24	22.84
Jul	12.13	20.9	29.70	25.31
Aug	19.87	21.0	30.00	25.50
Sep	82.79	17.7	26.56	22.13
Oct	94.51	14.3	23.01	18.57
Nov	121.96	10.5	18.31	14.41
Dec	93.70	6.7	14.63	10.67

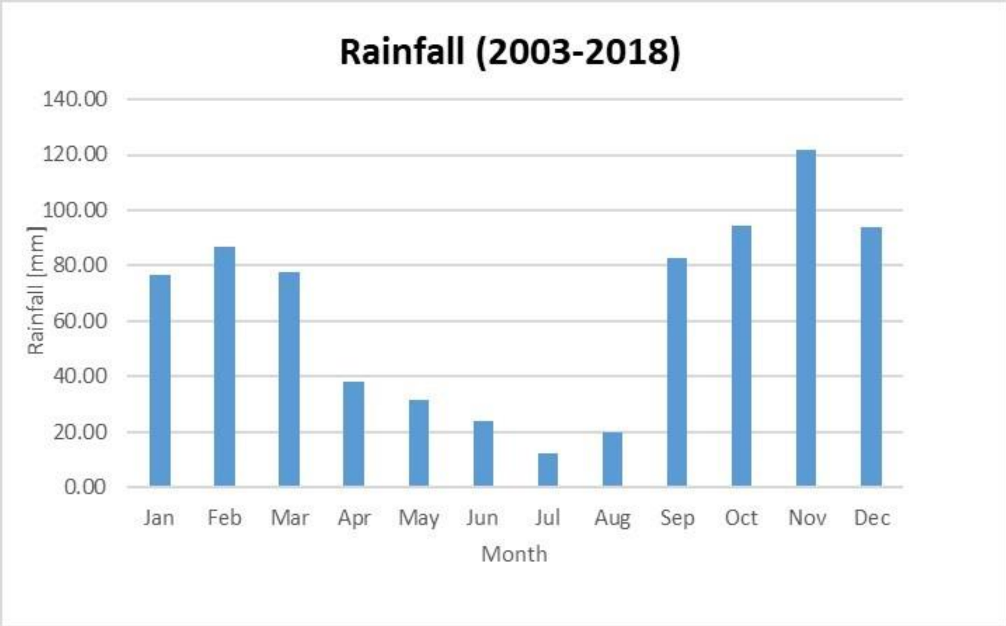


Figure 43. Monthly average rainfall (2003-2018) – Sabaudia Station

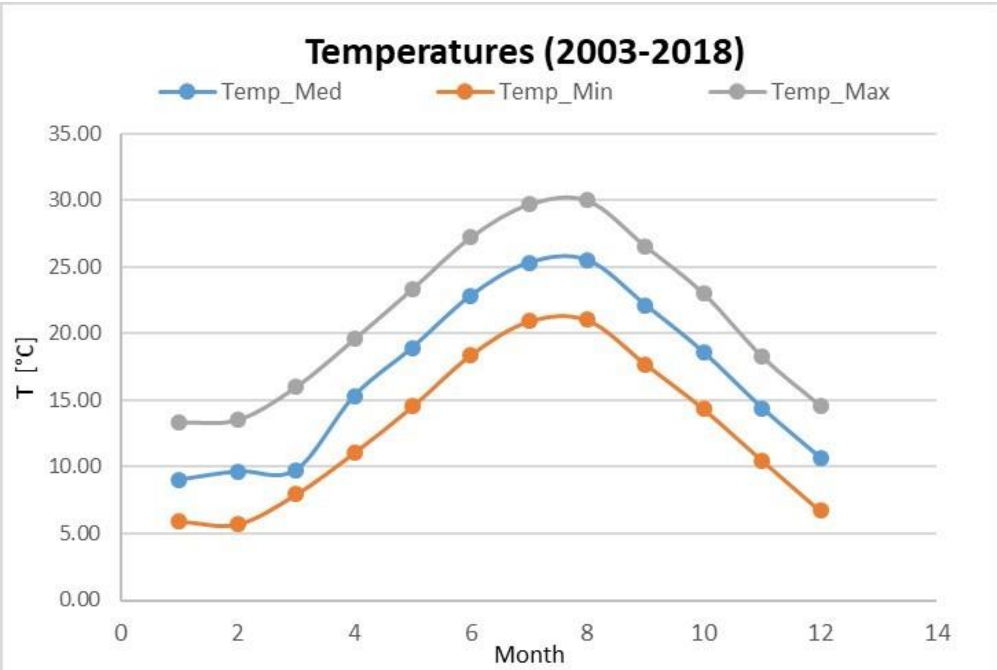


Figure 44. Monthly average temperatures (2003-2018) – Sabaudia Station

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

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

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

$$\sum_{i=1}^{12} \frac{T_i}{5}^{1.514}$$ Equation 2

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

$$a = 675x10^{-9}xI^{3} - 771X10^{-7}xI^{-5}xI + 0.49239$$ Equation 3

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

Having set the north latitude of 41° for Latina, for every month, the L_i value is provided below:

Table 34. Astronomical corrective values of ET_0 calculated according to the relation of Thornthwaite[26]

Latitudine	MESE											
Nord	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

The average evapotranspiration calculated for the years 2003-2018 for the Sabaudia weather station is shown in the following table, considering the mean average temperature from the Sabaudia station.

Table 35. Average monthly evapotranspiration for the years 2003-2018

Month	Sabaudia station ETP [mm]
Jan	16.7
Feb	18.8
Mar	23.9
Apr	56.8
May	93.1
Jun	130.5
Jul	157.7
Aug	149.7
Sep	101.9
Oct	69.0
Nov	37.7
Dec	21.7
	877.35

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

The same analysis was carried out for 2014, the year of the monitoring of the NBSs by REWETLAND. Mean monthly precipitation and evapotranspiration in 2014 are reported in the following table:

Table 36. Average monthly evapotranspiration for the year 2014

Month	Sabaudia station - 2014	
	P	ETP
	[mm]	[mm]
Jan	145.3	22.6
Feb	71.5	27.6
Mar	113.9	35.3
Apr	45.4	58.0
May	34.1	85.9
Jun	76.4	130.1
Jul	60.8	142.5
Aug	3.6	143.5
Sep	88.2	107.4
Oct	3.6	79.4
Nov	173.9	48.9
Dec	218.7	25.1
	1035.4	**906.4**

Hydrological framework

The hydrological framework is made on the basis of the rainfall depth-duration frequency curves provided by the Lazio Region. The rainfall depth-return times curves are provided for each station in the Lazio Region[27]. The areas under investigation are located in the city of Latina. For the Latina station the curves are shown in **Figure 45**, while for the Sabaudia station in **Figure 46**.

[27] Regional Functional Center (Lazio Region) http://www.idrografico.regione.lazio.it/std_page.aspx-Page=curve_pp.htm

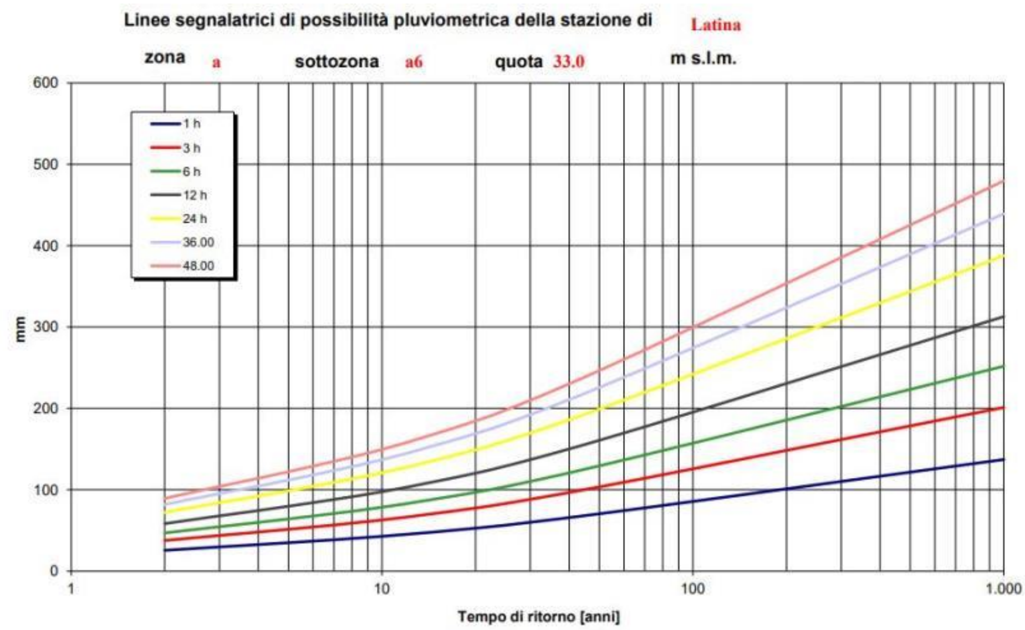


Figure 45. Rainfall depth-return times curves function of different duration frequencies (1, 3, 6, 12, 24, 36, 48 hours) for the Latina station (Source: Regional Functional Center – Lazio Region)

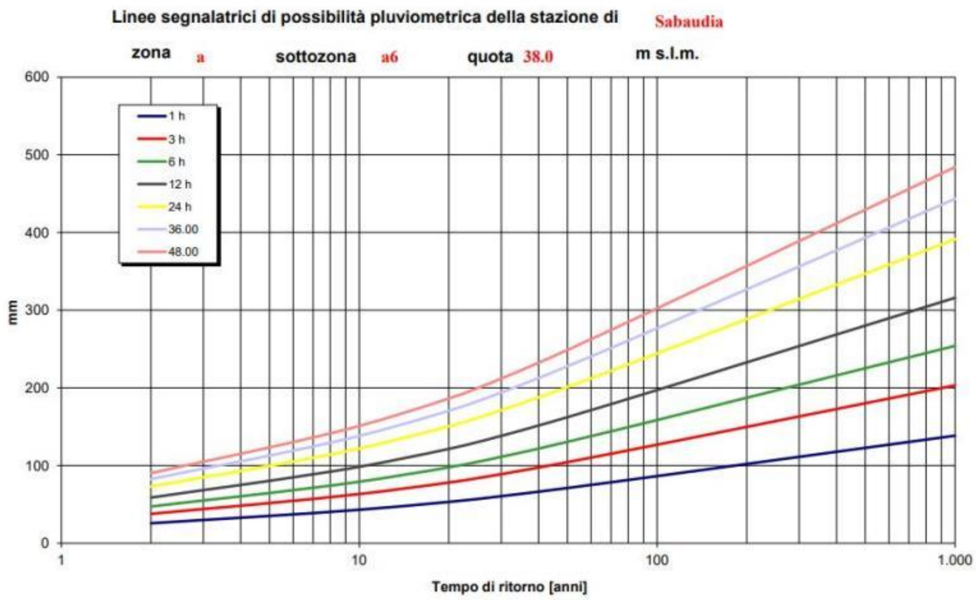


Figure 46. Rainfall depth-return times curves function of different duration frequencies (1, 3, 6, 12, 24, 36, 48 hours) for the Sabaudia station (Source: Regional Functional Center – Lazio Region)

Table 37. Rainfall depths (in mm) for extreme events estimated from the depth-return times curves function of different duration frequencies (1, 3, 6, 12, 24, 36, 48 hours) for the Latina station

Latina station							
Tr	**Rainfall duration (h)**						
	1	**3**	**6**	**12**	**24**	**36**	**48**
2	24.8	36.8	45.9	56.7	72.2	82.3	90.2
10	42.8	62.5	78.3	96.53	121	136.5	15.3
100	86	125	158.5	197.9	244.1	275.2	300

Table 38. Rainfall depths (in mm) for extreme events estimated from the depth-return times curves function of different duration frequencies (1, 3, 6, 12, 24, 36, 48 hours) for the Sabaudia station

Sabaudia station							
Tr	**Rainfall duration (h)**						
	1	**3**	**6**	**12**	**24**	**36**	**48**
2	24.3	37.8	47.5	58.6	72.4	82.0	91.4
10	42.6	63.9	77.7	100.0	122.1	139.6	152.0
100	85.8	129.5	161.4	200.0	246.5	280.3	300.0

Agricultural Runoff coefficients

The Ecology and Environment Sector of the Province of Latina has elaborated in 2009 a detailed analysis of the hydrographic basins on its territories[28], which have been divided into main basins (according to main drainage courses and rivers) and smaller sub-basins (according to soil use and secondary agricultural drainage networks). The NBSs implemented in the REWETLAND project are in included in the following basins:

— PP1, Villa Fogliano and Pantano Cicerchia (**Figure 47**):
  - Main basin: MOS-RMA (Shore basins between "Torre di Foce Verde" and "Torre di Fogliano" – Area 19.1 km^2)
  - Sub-basins: MOS-RMA-100 (Area 12.7 km^2) and MOS-RMA-110 (Area 0.6 km^2)

— PP2, Marina di Latina (**Figure 47**)
  - Main basin: MOS-RMA (Shore basins between "Torre di Foce Verde" and "Torre di Fogliano" – Area 19.1 km^2)
  - Sub-basins: MOS-RMA-100 (Area 12.7 km^2)

— PP3, Allacciante canal (**Figure 48**)
  - Main basin: MOS (Morscarello canal – Area 611.0 km^2)
  - Sub-basins: MOS-790 (Area 34.7 km^2)

[28] Origine dei carichi inquinanti e stato di eutrofizzazione delle acque interne della Provincia di Latina – Atlante dei Bacini Idrografici. Tecnostudi Ambiente S.r.l., May 2009 (www.provincia.latina.it)

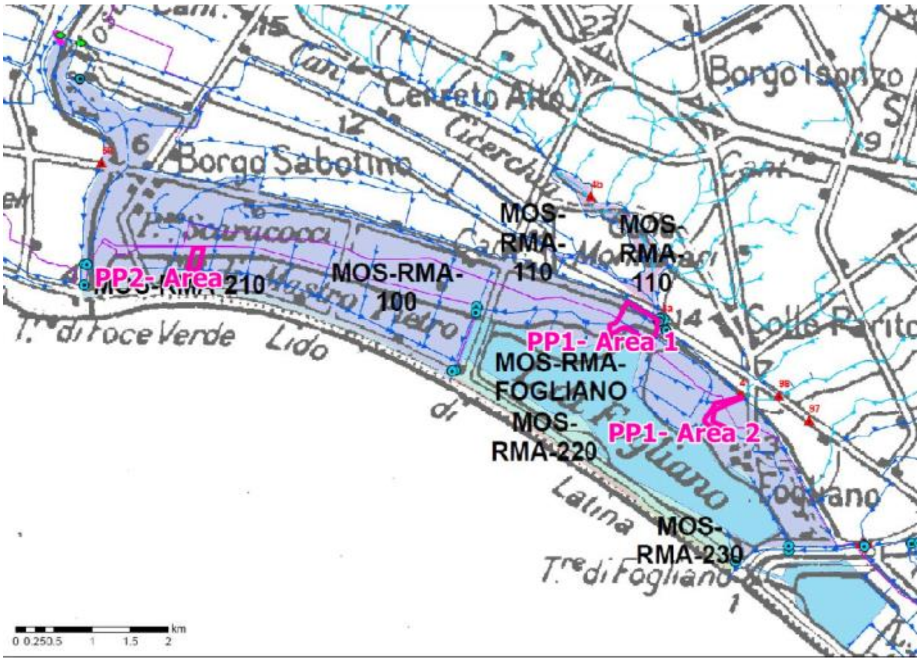


Figure 47. Sub-basin MOS-RMA 100 representative of REWETLAND's sites PP1 of Pantano Circerchia (Area 1) and Villa Fogliano (Area 2)

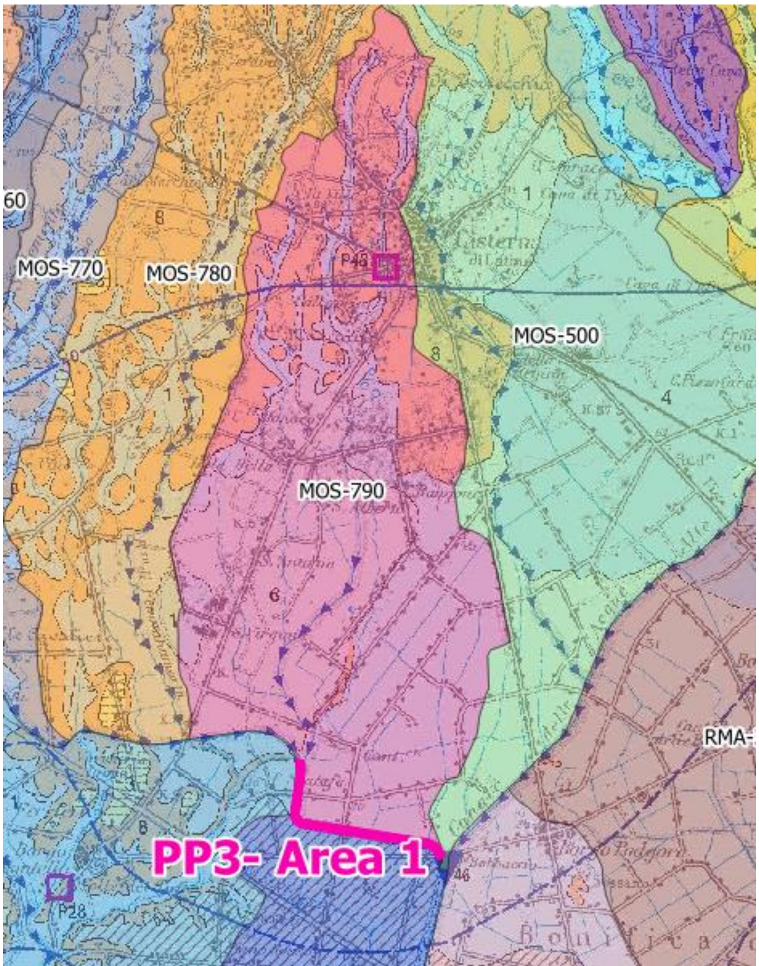


Figure 48. Sub-basin MOS-RMA 100 representative of REWETLAND's site PP3 of the Allacciante Astura canal (Area 1)

Based on sub-basin characteristics (average slope; maximum, average and minimum altitude; watershed surface; soil use), the study provides the estimate of the average monthly runoff in function of average monthly mean precipitation for each sub-basin. The data for the sub-basins of interests is reported in **Table 39** and was used to fit the linear runoff coefficient equation in function of the mean precipitation for each sub-basin (**Figure 44**).

Table 39. Mean monthly precipitation and runoff for the sub-basins of interest.

	MOS-RMA-100			**MOS-RMA-110**			**MOS-790**		
	P [mm]	**R [mm]**	**Runoff coef.**	**P [mm]**	**R [mm]**	**Runoff coef.**	**P [mm]**	**R [mm]**	**Runoff coef.**
Jan	66.61	25.98	0.39	55.00	30.00	0.55	75.793	19.020	0.25
Feb	78.98	30.39	0.38	65.00	35.00	0.54	98.559	24.784	0.25
Mar	58.35	15.20	0.26	48.33	16.67	0.34	71.470	11.816	0.17
Apr	78.74	4.41	0.06	63.33	8.33	0.13	107.493	10.375	0.10
May	28.27	0.47	0.02	25.00	3.33	0.13	47.262	1.441	0.03
Jun	32.60	2.13	0.07	28.33	3.33	0.12	45.245	2.305	0.05
Jul	23.78	1.57	0.07	21.67	3.33	0.15	24.496	0.865	0.04
Aug	22.36	0.39	0.02	18.33	1.67	0.09	47.839	2.594	0.05
Sep	82.68	25.20	0.30	68.33	30.00	0.44	83.862	12.104	0.14
Oct	135.98	53.54	0.39	108.33	56.67	0.52	154.467	35.159	0.23
Nov	145.59	62.20	0.43	120.00	70.00	0.58	167.435	43.516	0.26
Dec	88.90	39.76	0.45	71.67	43.33	0.60	110.663	30.548	0.28

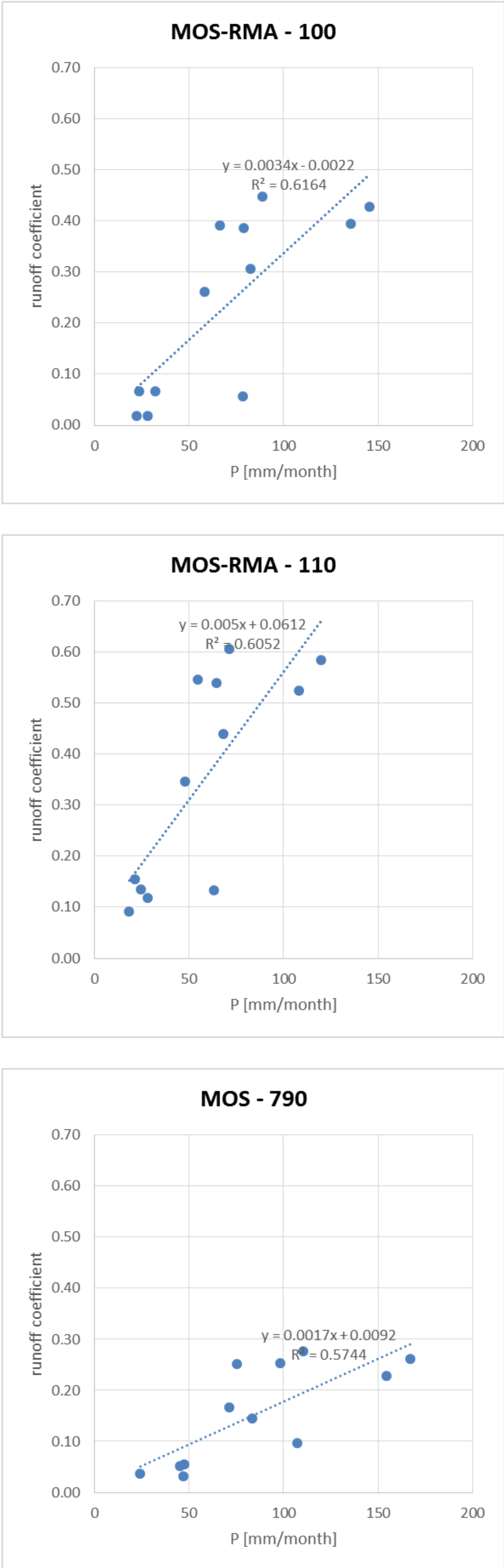


Figure 49. Linear fitting of the runoff coefficient equation for the sub-basins of interest

ANNEX 3: Data from the REWETLAND monitoring

FWS of Villa Fogliano

The sampling stations chosen for the mass and hydraulic balance are PP1-A2-8 and PP1-A2-5 for the basin A. In particular, the station PP1-A2-8 is located along the Irrigation Canal, while the station PP1-A2-5 is located upstream of the Basin A discharge section.

The concentration of pollutants recorded in the two stations is shown in the following tables and figures.

Table 40. Chemical analysis results for the PP1-A2-8 station (influent)

		29/01/2014	12/03/2014	16/04/2014	13/05/2014
COD	mg/l O2	n.d.	26.50	2.50	2.50
BOD5	mg/l O2	n.d.	6.20	1.25	1.25
NH4	mg/l NH4	n.d.	0.29	0.17	0.09
N-NH4*	mg/l N-NH4	n.d.	0.23	0.13	0.07
T.N.	mg/l N	n.d.	3.37	1.57	1.47
P	mg/l P	n.d.	0.03	0.11	0.13
PO4	mg/l PO4	n.d.	0.08	0.08	0.20
P-PO4*	mg/l P-PO4	n.d.	0.02	0.02	0.07
NO2	mg/l NO2	n.d.	0.12	0.28	0.06
N-NO2*	mg/l N-NO2	n.d.	0.04	0.08	0.02
NO3	mg/l NO3	n.d.	12.10	4.50	6.69
N-NO3*	mg/l N-NO3	n.d.	2.73	1.02	1.51
100-DO	%sat	n.d.	22.20	30.60	11.90
Conductivity	µS/cm 25°C	n.d.	833.00	557.00	527.00
pH		n.d.	7.65	7.93	7.92
Temperature	°C	n.d.	15.20	14.20	18.40
Alcalinity T	mg/L CaCO3	n.d.	281.00	240.00	241.00

* Calculated concentrations

Table 41. Chemical analysis results for the PP1-A2-5 station (effluent)

		29/01/2014	12/03/2014	16/04/2014	13/05/2014
COD	mg/l O2	23.80	25.10	41.00	21.60
BOD5	mg/l O2	13.60	5.50	3.30	5.10
NH4	mg/l NH4	0.14	0.16	0.02	0.19
N-NH4*	mg/l N-NH4	0.11	0.12	0.01	0.15
T.N.	mg/l N	0.50	1.02	1.30	0.50
P	mg/l P	0.05	0.07	0.17	0.03
PO4	mg/l PO4	0.08	0.08	0.08	0.08
P-PO4*	mg/l P-PO4	0.02	0.02	0.02	0.02
NO2	mg/l NO2	0.01	0.01	0.01	0.01
N-NO2*	mg/l N-NO2	0.00	0.00	0.00	0.00
NO3	mg/l NO3	0.63	0.63	0.63	0.63
N-NO3*	mg/l N-NO3	0.14	0.14	0.14	0.14
100-DO	%sat	88.10	74.20	74.50	92.70
Conductivity	µS/cm 25°C	608.00	593.00	730.00	554.00
pH		7.25	7.30	7.52	7.53
Temperature	°C	6.40	12.50	15.40	20.00
Alcalinity T	mg/L CaCO3	176.00	186.00	246.00	254.00

* Calculated concentrations

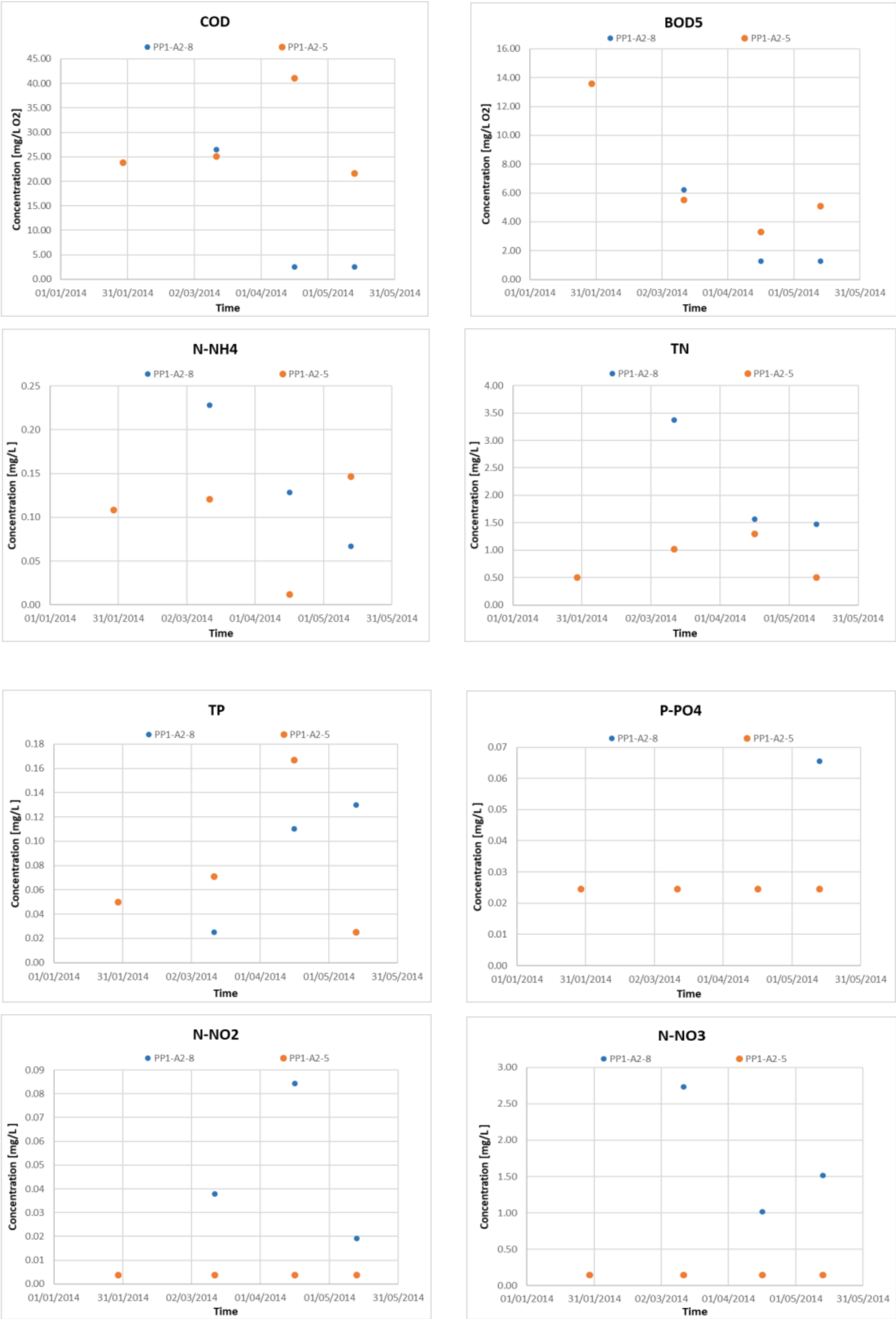


Figure 50. Graphic representation of the concentrations of the main pollutants monitored in the station PP1-A2-8 (influent) and PP1-A2-5 (effluent)

Linear Park of Marina di Latina

The PP2-2 sampling station is located in the Colmata Canal, near the uptake of the system, while the station PP2-1 is located in the Mastro Pietro Canal, near the discharge of the system. The concentration of pollutants recorded in the inlet and outlet section of the system are shown in **Table 42** and **Table 43**.

Table 42. Chemical analysis results for the PP2-2 station (influent stream)

		29/01/2014	12/03/2014	16/04/2014	13/05/2014
COD	mg/l O2	24.9	12	12	9.6
BOD5	mg/l O2	13.3	1.25	4.3	1.25
NH4	mg/l NH4	0.332	0.434	0.475	0.015
N-NH4*	mg/l N-NH4	0.258	0.338	0.370	0.012
T.N.	mg/l N	3.96	4.19	6.3	5.6
P	mg/l P	0.025	0.067	0.347	0.393
PO4	mg/l PO4	0.075	0.075	0.84	1.07
P-PO4*	mg/l P-PO4	0.02	0.02	0.27	0.35
NO2	mg/l NO2	0.437	0.512	0.65	0.11
N-NO2*	mg/l N-NO2	0.133	0.156	0.198	0.033
NO3	mg/l NO3	14	15.7	22.3	14.2
N-NO3*	mg/l N-NO3	3.16	3.55	5.04	3.21
Cl	mg/l	418	426	547	81.2
E. Coli	CFU/100 mL	4800	1400	4000	1800
Streptococchi f.	CFU/100 mL	3400	520	400	98
100-DO	%sat	41.8	42.6	41.7	36.1

* Calculated concentrations

Table 43. Chemical analysis results for the PP2-1 station (effluent stream)

		29/01/2014	12/03/2014	16/04/2014	13/05/2014
COD	mg/l O2	7.3	10.5	25	2.5
BOD5	mg/l O2	4.4	4	7	1.25
NH4	mg/l NH4	0.342	0.197	0.335	0.55
N-NH4*	mg/l N-NH4	0.266	0.153	0.261	0.428
T.N.	mg/l N	5.37	5.5	1.72	3.47
P	mg/l P	0.025	0.025	0.142	0.196
PO4	mg/l PO4	0.075	0.075	0.075	0.421
P-PO4*	mg/l P-PO4	0.02	0.02	0.02	0.14
NO2	mg/l NO2	0.226	0.22	0.1797	0.126
N-NO2*	mg/l N-NO2	0.069	0.067	0.055	0.038
NO3	mg/l NO3	21.6	21.5	2.35	14
N-NO3*	mg/l N-NO3	4.88	4.86	0.53	3.16
Cl	mg/l	90.7	116.1	124.7	77.5
E. Coli	CFU/100 mL	98	68	120	100
Streptococchi f.	CFU/100 mL	51	15	12	180
100-DO	%sat	17.6	88.1	48.6	8.2

* Calculated concentrations

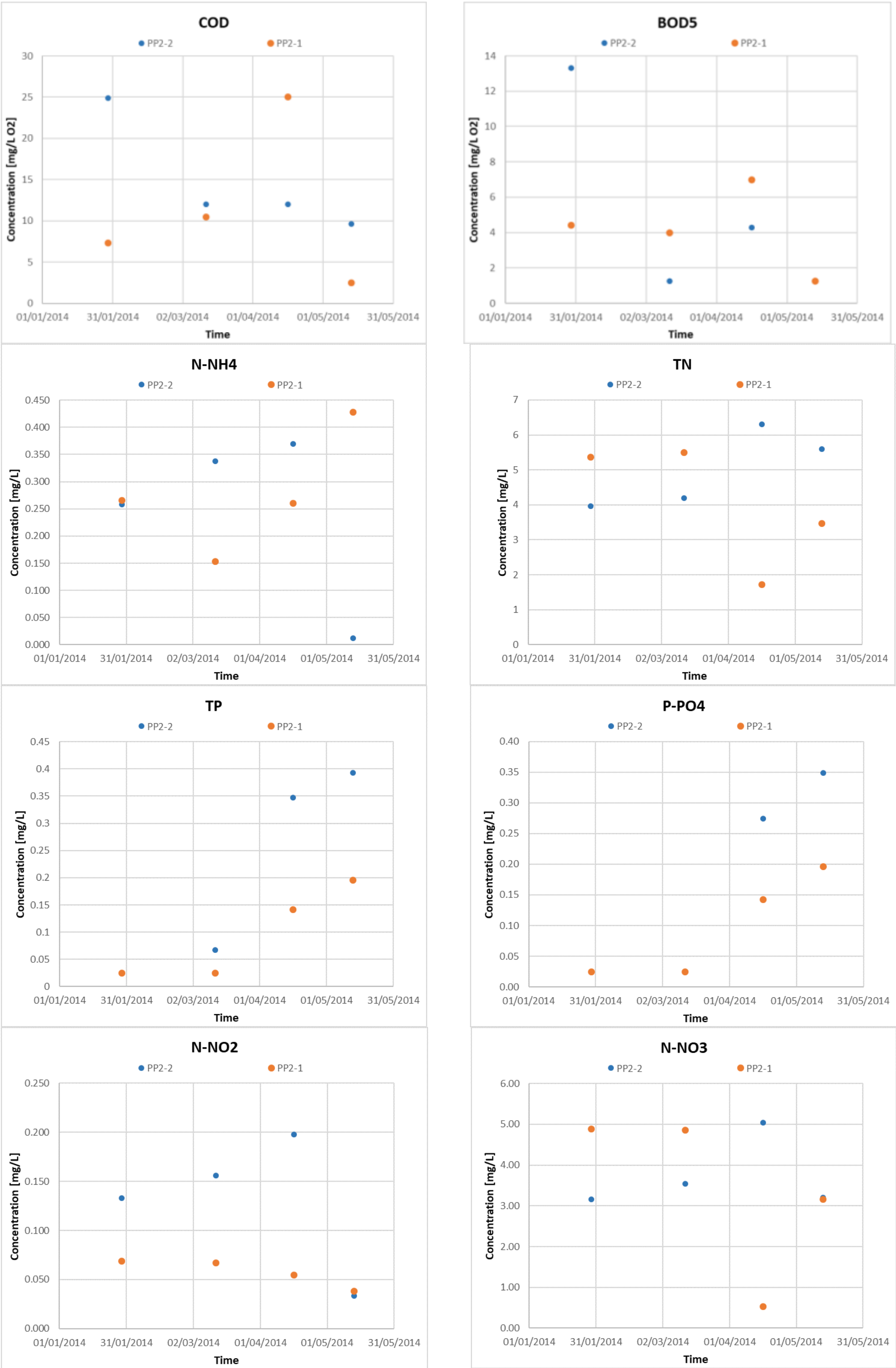


Figure 51. Graphic representation of the concentrations of the main pollutants monitored in the station PP2-2 (influent stream) and PP2-1 (effluent stream)

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 44. 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 45. 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 wetlands 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) which derive 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.

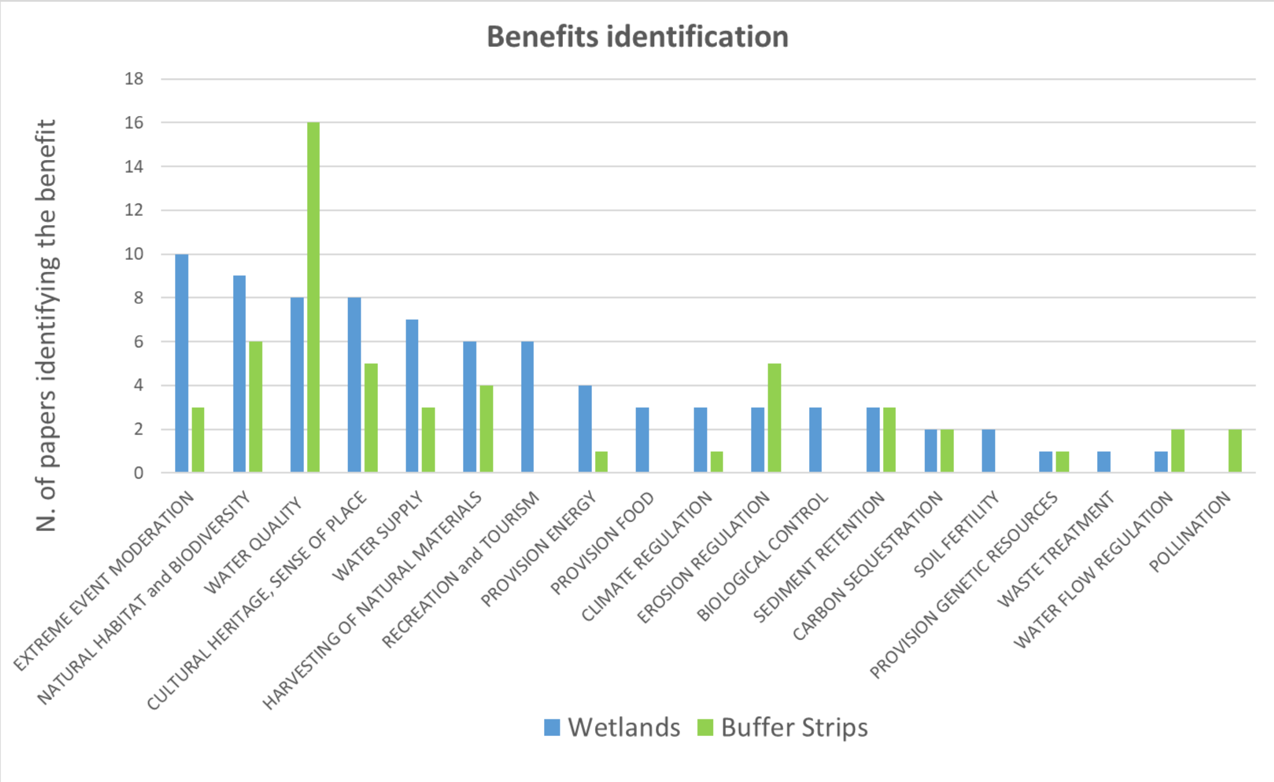


Figure 52. Identification of benefits from Wetlands and Buffer Strips implementation, through literature review.

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, it was 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 52**, 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 were filtered out to select the most appropriate ones in the context of the analysed case study. The selection was made through expert judgment and is based on the results of the analysis carried out 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 46. 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 (m^3/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 (tonsCo^2/ha)	↑
	FLOOD RISK	2.2.2.2	Increased water storage (buffer) capacity in m^3; reduced peak flows; ecosystem structure characteristics; Reduction of flood danger and prevented damage to infrastructure	↑
	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	↑

Category	Benefit	CICES 4.3	Example indicators	Effect
	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 a research was carried out on existing economic valuation so that to proceed with the Value Transfer.

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

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)

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. 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 [29]
- 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 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.

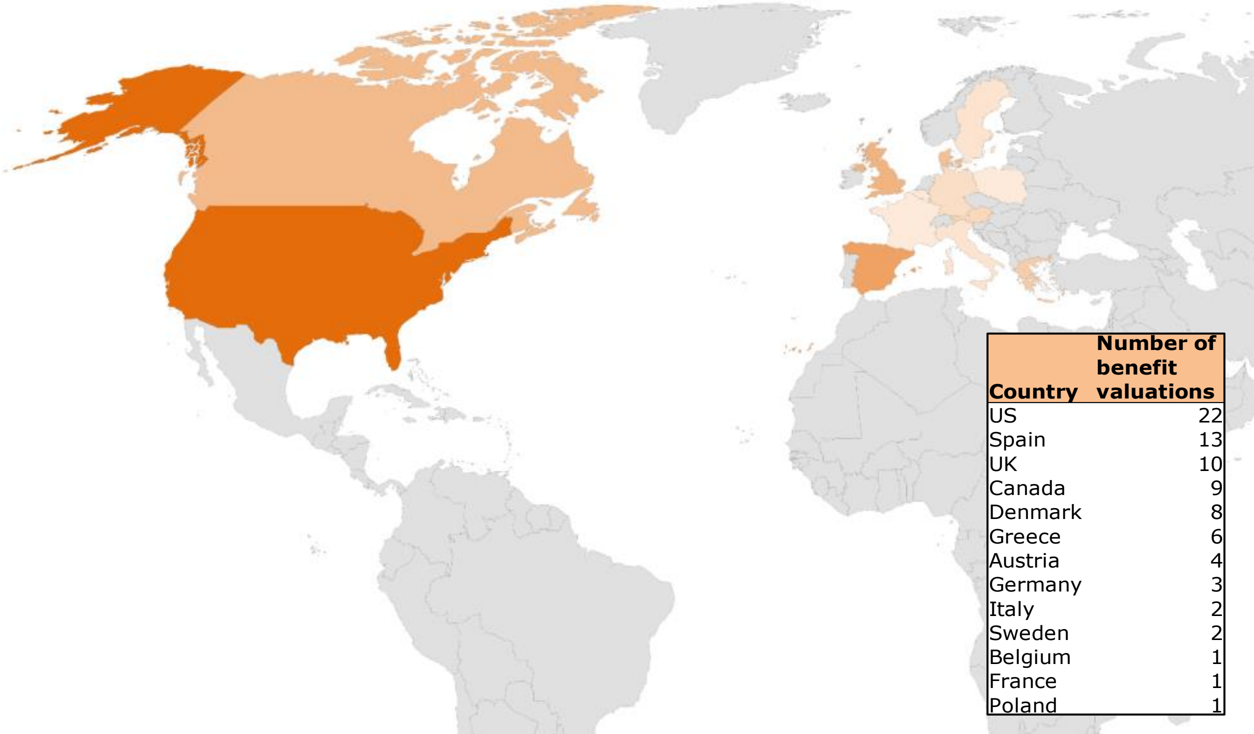
The benefit valuations have been originally computed in the period from 1980 to 2018. However, not all the values have been extracted from the original research computing them. Indeed, it was not always possible to track down the original study; many values are reported from a more recent research, referencing 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). The map below (**Figure 53**) 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.

[29] 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.

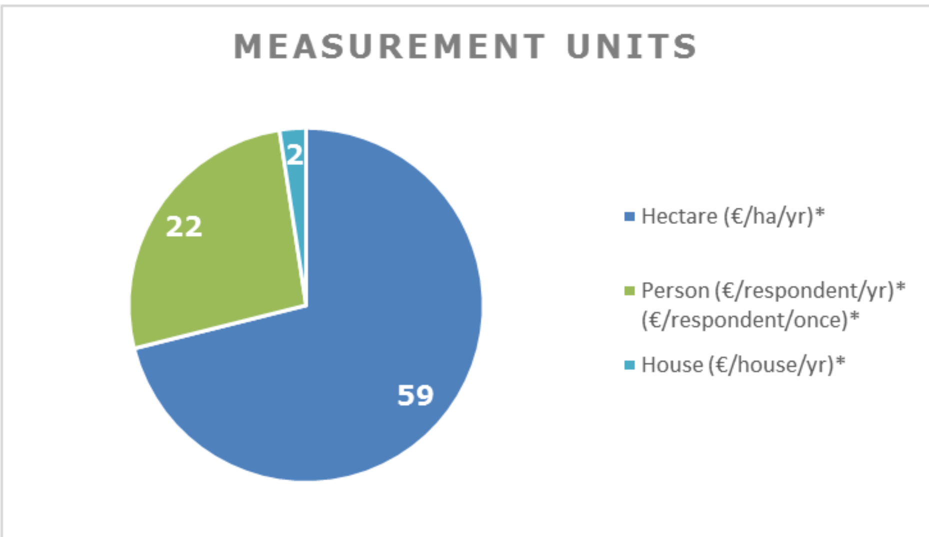
ECONOMIC VALUATION OF BENEFITS, PER COUNTRY



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 53. 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 this information.



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

Figure 54. Most common measurement units in study sites economic valuations.

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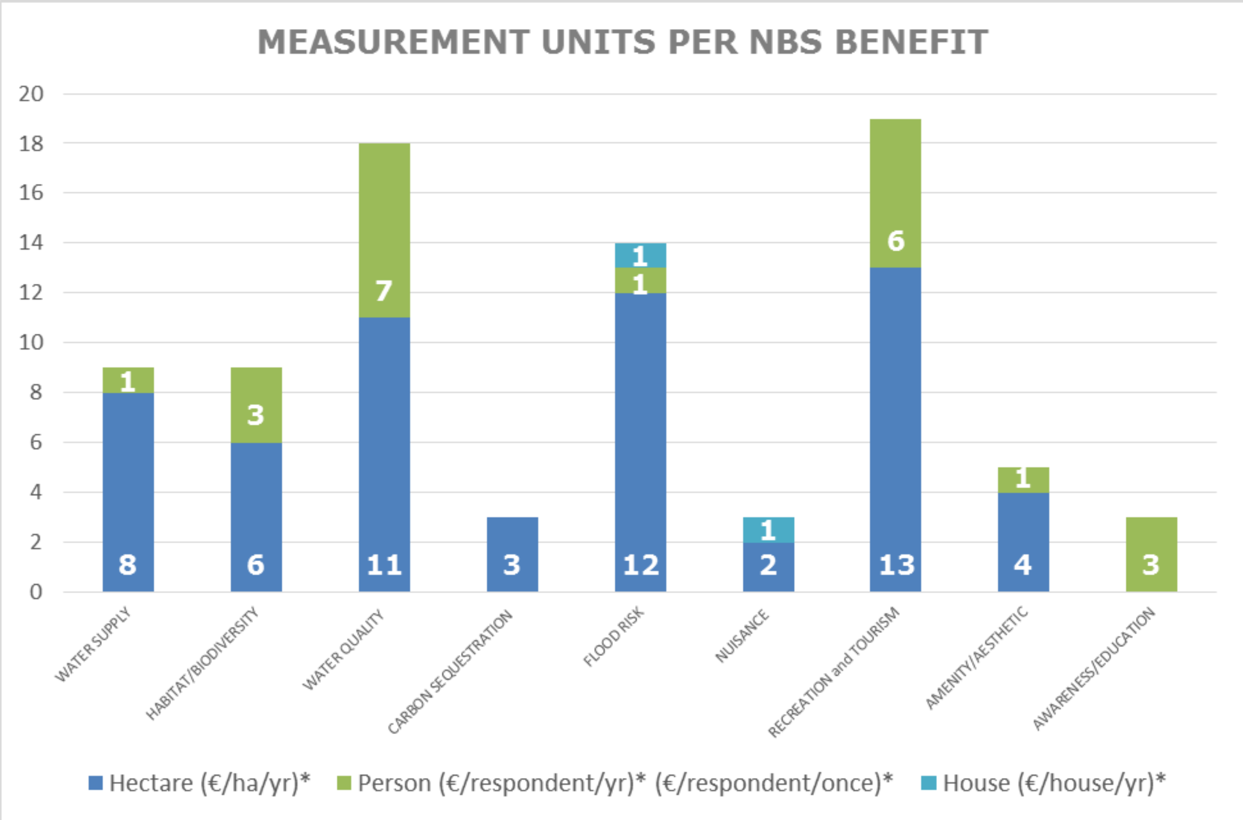

*€ or any currency used in the study site economic valuations.

Figure 55. 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 realized a list of example indicators suitable for determining provision of NBS benefits, listed in **Table 46**.

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[30], 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.

[30] 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)

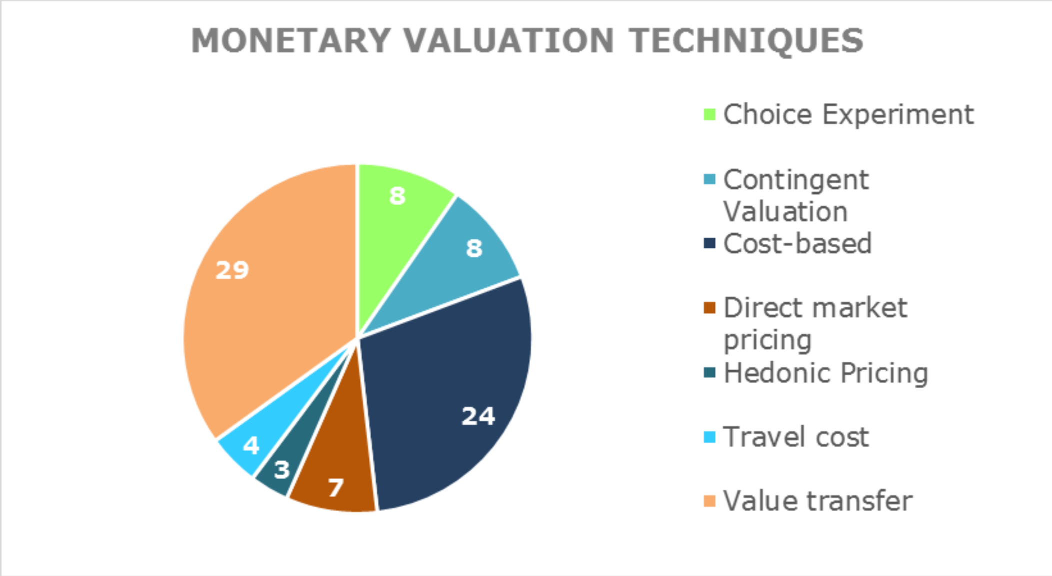

Figure 56. Most common monetary valuation techniques in study sites economic valuations.

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 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:	$OriginalValue^{SS}_{c\,y}$
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.	↓ $Value^{SS}_{c\,2018}$ ↓
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).	$Value^{SS}_{USD\,2018}$ ↓
iii	To control for the effect of income on the demand and value of ecosystem services, estimates have been	$Value^{PS}_{USD\,2018}$

	adjusted for the differences in Gross Domestic Product per capita based on Purchasing Power Parity (PPP) (WB, 2020) between study and policy site.	↓
iv	Values have finally been transformed into euro2018, using exchange rates (OECD, 2018).	$\boldsymbol{Value}_{\text{€ }\mathbf{2018}}^{\boldsymbol{PS}}$

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 **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 47. 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 - ecological, biophysical or other appropriate indicators as ES in the case of VT**.**	**Score: 0-1**	**0**=low reliability **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 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 below.

Table 49. Final transferred economic values for each NBS benefit.

	WETLANDS			BUFFER STRIPS		
	Value* - Confidence interval		Units	Value* - Confidence interval		Units
NATURAL HABITAT and BIODIVERSITY SUPPORT	448	498	€/ha/yr	29	36	€/ha/yr
WATER QUALITY	2959	9598	€/ha/yr	66	132	€/ha/yr
FLOOD RISK	10541	16139	€/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

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Final transferred economic values for each NBS benefit.

Original Reference	Year of value calculation	Where (socio-economic context)	Fitness to policy site (1 min – 5 max)	Monetary valuation technique	Economic value (latest available)	Units	Year of latest available update of the value
WETLAND – NATURAL HABITAT and BIODIVERSITY SUPPORT							
Folke, C. (1991)	1990	Sweden	4	Cost-based	10	USD/ha/yr	2007
Gren et al. (1995)	1993	UK	4	Value transfer	34	USD/ha/yr	2007
Dubgaard et al. (2002)	2000	Denmark	4	Value transfer	1207	DKK/ha/yr	2000
Meyerhoff and Dehnhardt, A. (2004)	2001	Germany	5	Contingent Valuation	12	€/repondent/yr	2001
Anielski and Wilson (2005)	2004	Canada	2	Value transfer	263	CAD/ha/yr	2002
Birol et al. (2006)	2005	Greece	4	Choice Experiment	13-17	€/respondent/one-off payment	2003
Brenner Guillermo (2007)	2007	Spain	5	Value transfer	279	USD/ha/yr	2004
Dias and Belcher (2015)	2011	Canada	3	Choice experiment	58	CAD/household/one-off payment	2011
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
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

Original Reference	Year of value calculation	Where (socio-economic context)	Fitness to policy site (1 min – 5 max)	Monetary valuation technique	Economic value (latest available)	Units	Year of latest available update of the value
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