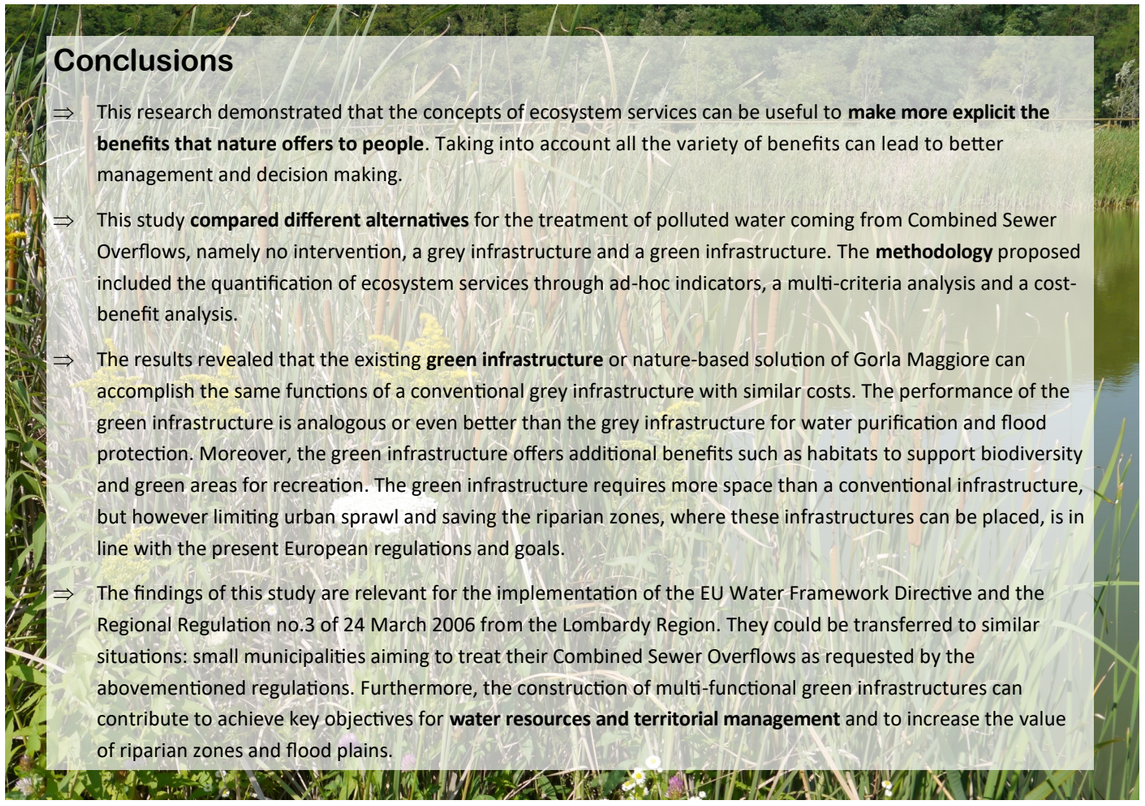

Conclusions

⇒ This research demonstrated that the concepts of ecosystem services can be useful to **make more explicit the benefits that nature offers to people**. Taking into account all the variety of benefits can lead to better management and decision making.

⇒ This study **compared different alternatives** for the treatment of polluted water coming from Combined Sewer Overflows, namely no intervention, a grey infrastructure and a green infrastructure. The **methodology** proposed included the quantification of ecosystem services through ad-hoc indicators, a multi-criteria analysis and a cost-benefit analysis.

⇒ The results revealed that the existing **green infrastructure** or nature-based solution of Gorla Maggiore can accomplish the same functions of a conventional grey infrastructure with similar costs. The performance of the green infrastructure is analogous or even better than the grey infrastructure for water purification and flood protection. Moreover, the green infrastructure offers additional benefits such as habitats to support biodiversity and green areas for recreation. The green infrastructure requires more space than a conventional infrastructure, but however limiting urban sprawl and saving the riparian zones, where these infrastructures can be placed, is in line with the present European regulations and goals.

⇒ The findings of this study are relevant for the implementation of the EU Water Framework Directive and the Regional Regulation no.3 of 24 March 2006 from the Lombardy Region. They could be transferred to similar situations: small municipalities aiming to treat their Combined Sewer Overflows as requested by the abovementioned regulations. Furthermore, the construction of multi-functional green infrastructures can contribute to achieve key objectives for **water resources and territorial management** and to increase the value of riparian zones and flood plains.

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OpenNESS
Operationalisation of Natural Capital and Ecosystem Services

Nature-based solutions to improve water quality:
The Gorla Maggiore water park

A nature-based solution to treat Combined Sewer Overflows

There is a significant amount of pollution being discharged by **Combined Sewer Overflows (CSOs)** into surface water bodies all across Europe. During heavy rain events, the excess flow of mixed sewage and rainwater cannot be treated in the normal wastewater treatment plants. Thus, part of this water flow, with the associated waste and toxic materials, is discharged directly into rivers and lakes from CSO. In the Italian Lombardy Region, which is one of the most populated and industrialised regions in Europe, there are thousands of CSOs that contribute to increase the pollution of natural water bodies. These water bodies frequently do not reach the *Good Ecological Status* required by the EU Water Framework Directive, partly due to the effect of CSOs.

The two possible solutions to **reduce the pollution** coming from CSOs are upstream control, which avoids rainwater to flow into the sewer system, or downstream control, which treats the CSO. The typical infrastructure used in the second option is an underground storage tank that accumulates the most polluted water and pumps it back to the wastewater treatment plant after the rain events. An alternative to this grey infrastructure is to construct a green infrastructure or *nature-based solution* that stores and treats the polluted water on-site through phytodepuration or natural purification processes.

The first example of this kind of green infrastructure in Italy is the **Gorla Maggiore water park** that was inaugurated in March 2013. Gorla Maggiore is a municipality with 5,000 inhabitants located in the Province of Varese (Lombardy Region). The water park covers a green recreational area adjacent to the Olona River and includes a set of constructed wetlands (the phytodepuration system) that treats the CSO. The EU research project OpenNESS (http://www.openness-project.eu/) selected the Gorla Maggiore water park as a case study due to its innovative characteristics.

Objectives of the case study

⇒ Assess and value the **ecosystem services** provided by the green infrastructure, i.e. the benefits that people get from the nature-based solution

⇒ Compare the **performance** of the green infrastructure (water park) with other alternative options

⇒ Evaluate the usefulness of the ecosystem services' and green solutions' concepts for **water resource management**

Ecosystem services analysed

Regulating services	Water purification
	Flood protection
	Biodiversity support
Cultural services	Recreation
Provisioning services	Wood production

The alternatives under study

0) The previous situation ("*doing nothing*"): a poplar plantation
1) The standard solution (*grey infrastructure*): an underground first-flush tank and an open-air dry retention pond
2) The nature-based solution (*green infrastructure*): the phytodepuration system and a wet retention pond

Quantification of ecosystem services

The three alternatives were evaluated on the basis of the ecosystem services provided by each of them (that is, the **benefits they offer to humans**) and their investment and management costs.

The quantification of ecosystem services was based on scientific models, field data collection, and statistical and spatial analyses, as follows:

⇒ Reduce water pollution: water flow monitoring on site, measures of pollutants' concentration before and after the infrastructure (for alternative 2) and estimates of depuration efficiency (for alternative 1)
⇒ Reduce flood risk: hydraulic model
⇒ Availability of natural habitats: field observations, expert opinion and landscape analysis
⇒ Availability and use of green recreational areas: questionnaire addressed to the citizens of Gorla Maggiore and analysis of accessibility to the site
⇒ Value of wood production: analysis and estimation of the market value
⇒ Minimization of costs: analysis of the actual construction and management costs

(Detailed information about the quantification methods and results can be found in the publications listed at the end of this document).

Objectives, criteria and indicators per alternative

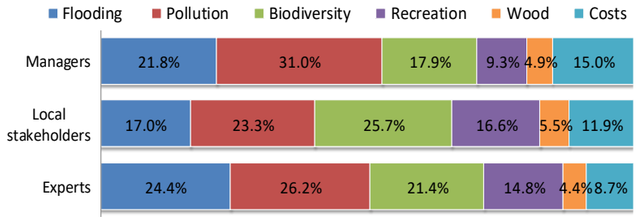
Objectives	Criteria	Indicators	Alternative 0	Alternative 1	Alternative 2
Flood control	Reduce flood risk	Peak flow reduction (%)	0	80	86
		Reduction of flooding downstream (m^3)	0	8 100	8 900
Improve water quality	Reduce water pollution	Load reduction of dissolved organic carbon (t/yr)	0	9.5	11.7
		Load reduction of nitrogen (t/yr)	0	0.2	0.4
Biodiversity support	Availability of natural habitats	Expert judgment about biodiversity	low	low	high
		Landscape diversity index	1.89	1.85	2
People recreation	Availability and use of green recreational areas	Number of visitors/users	very low	moderate	high
		Frequency of visits	very low	moderate	high
Production of market goods	Value of wood production	Estimated benefit from wood production (€)	ca. 21 420	0	0
Public costs	Minimization of costs	Total construction costs (€)	0	844 750	900 000
		Total maintenance costs per 20 yr (€)	0	27 824	29 590

Table 1

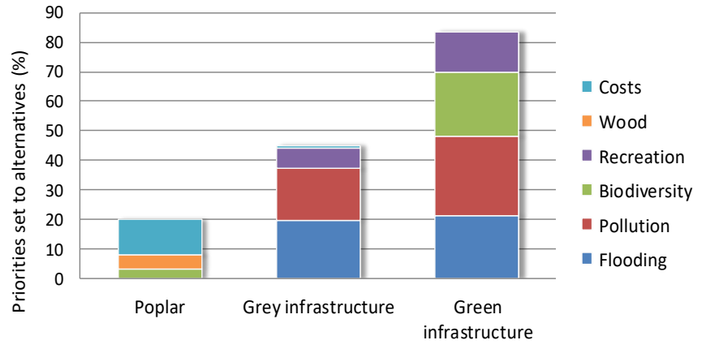
Multi-criteria analysis and valuation

Optimizing the benefits for society and the public costs are key **goals for a good water resources and territorial management**. For each objective identified in the case study there is an evaluation criteria and several indicators able to quantify those criteria (Table 1). Table 1 allows the comparison of the three alternatives in terms of multiple management objectives.

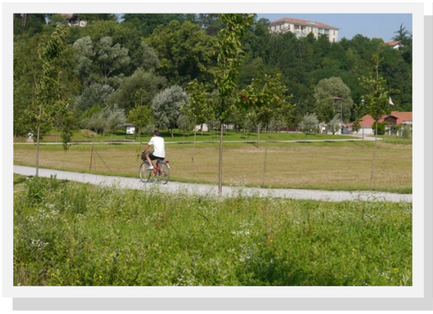
A multi-criteria analysis run in the case study integrated the quantification of costs and benefits under each alternative with the opinion of different stakeholders, in order to select the **optimal management option**.

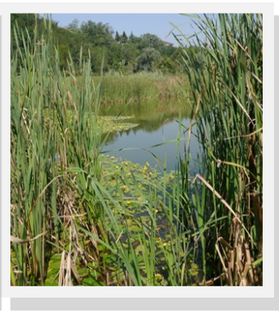


The **stakeholders** were represented by the Case Study Advisory Board and included members of public institutions at different levels (managers), the municipality and local associations (local stakeholders), and technical experts. The Advisory Board members defined the relative importance of each objective; each group of interest attributes a different weight to each objective (see upper figure).



The final **valuation of the three alternatives** following the multi-criteria analysis shows that the green infrastructure is the best possible option followed by far by the grey infrastructure and finally the poplar plantation (see figure to the left).





Economic valuation

The ecosystem services were also valued in monetary terms. A **questionnaire** was distributed among the residents of Gorla Maggiore to estimate the value they assign to each of the three alternatives and their use of the different infrastructures. The results were analyzed with econometric models.

The analysis shows that local citizens are **willing to pay** around three times more for a green infrastructure than for a grey one, and much more if it is surrounded by a recreational park. On average, the willingness-to-pay per household and per year for the existing water park is around 28 euro.

Based on these results, the **cost-benefit analysis** of the different projects reveals that after a timespan of 20 years the cost and benefits of the green infrastructure can be balanced, while for the other alternatives the economic balance is still negative.