Ecosystem Service Evaluation for Landscape Design: The Project of a Rural Peri-Urban Park as a Node of the Local Green Infrastructure

Marco Allocco[1], Davide Murgese[2], Giorgio Quaglio[3], Emma Salizzoni [4]

[1]*SEACoop, allocco@seacoop.com*
[2]*SEACoop, murgese@seacoop.com*
[3]*SEACoop, quaglio@seacoop.com*
[4]*Politecnico di Torino, DIST, emma.salizzoni@polito.it*

Abstract: Green Infrastructure (GI) multifunctionality – namely the capacity to deliver a wide range of Ecosystem Services (ES) – is one of the main GI planning principles. It is for this reason that the integration between GI and ES concepts and approaches is increasingly tested. This paper presents the outcomes of an applied research that took up the challenge of implementing GI at the local level through the landscape design of a peri-urban rural park (Chieri, Italy) conceived as a GI node. The park's project was based on the evaluation of ES, that allowed to highlight the ES performance of alternative design choices and to support the GI design towards multifunctionality. Eventually, Payment for Ecosystem Services (PES) schemes were defined in order to foster the implementation of the park's project. The research, thus: (i) puts in action a multiscalar approach, translating at the local level, through landscape design, GI planning indications; (ii) promotes GI multifunctionality based on a "place-based" vision, that is through the assessment of local features, highlighting the actual area's potential to provide ES and the existing ES trade-offs; (iii) identifies PES as a tool for increasing the effectiveness of GI implementation.

Keywords: Ecosystem Services; Green Infrastructure; landscape design; peri-urban park.

Introduction

The integration of Ecosystem Service (ES) evaluation – namely both ES biophysical assessment and economic valuation (Häyhä and Franzese, 2014, Mavsar and Varela, 2014) – into spatial planning policies is today widely promoted. This integration is generally assumed to be a crucial step to address territorial transformations towards sustainable development, since the ES concept effectively connects environmental, social and economic issues (Braat and de Groot, 2012). Several recent studies addressed the question of how to operationalize ES evaluation for spatial planning and landscape planning in particular (see, among the others, Gómez-Baggethun and Barton, 2013, Von Haaren *et al*. 2016, Tammi *et al*. 2017, Hian *et al*. 2018, Lam and Conwey, 2018). To date, this is a still open and experimental issue (Lerouge *et al.* 2017).

In the last decade, the relationship between ES and landscape design has been increasingly investigated too. After the publication of the Millennium Ecosystem Assessment Report (MEA, 2005), the ES paradigm started to fertilise landscape design science (Nassauer and Opdam, 2008, Termorshuizen and Opdam, 2009). An increasing number of studies proposed ES as a conceptual framework for landscape design, to address it towards multifunctionality objectives, that is the capacity of providing at the same time environmental, social and economic benefits (Lovell and Johnston, 2009). Performance indicators for designed landscapes based on the delivery of ES were defined (Windhager *et al*. 2010, Sustainable Sites Initiative 2015).

It is precisely this capacity of the ES concept to support *multifunctionality* that makes it a central element in the Green Infrastructure (GI) paradigm as well. Multifunctionality is actually one of the main GI planning principles (together with "connectivity", "multi-functionality", "integration", "multi-scale approach" and "multi-object approach", Hansen and Pauleit, 2014). GI has been defined as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (EC COM(2013)249). The integration between GI and ES concepts and approaches is thus increasingly studied and tested (Arcidiano *et al*. 2016, Marino *et al.* 2019). It is worth underlying that multifunctionality should not be seen as a straightforward and simplistic result of GI promotion, but as a "place-based" vision, based on the local assessment of GI environmental, social, cultural, economic and institutional context (Madureira and Andresen, 2014). This, in turn, entails the need of meeting another GI principle, that is a multi-scale approach able to link different spatial scales. The construction of an effective link between the planning and design levels is still an open issue in landscape planning policies and ecological network policies (Voghera and La Riccia, 2018).

This paper presents the outcomes of an applied research that took up the challenge of implementing GI at the local level, through the landscape planning and design of a peri-urban rural park that was conceived as a GI node. The park's project was based on the evaluation of ES at the local scale. ES evaluation (biophysical assessment and economic valuation) was developed both for the area's current state and for three different design scenarios, allowing to highlight the ES performance of alternative design choices and supporting the GI design towards multifunctionality. Eventually, PES schemes were implemented in order to foster the actual implementation of the park's project.

Territorial and Institutional Context

The project area, known as *Fontaneto*, is a rural area of 100 ha close to the city of Chieri (Turin, Italy). It is a residual peri-urban zone, surrounded by residential and industrial buildings and transport infrastructures. The area, which is crossed by two minor watercourses (Rio Tepice and Rio del Vallo), is mainly characterized by an intensive agricultural activity (cereal and forage crops), that has non-negligible impacts on the nearby residential areas, due to the use of chemical plant protection products and fertilizers. Despite some punctual restoration projects developed by the Municipality, today *Fontaneto* presents a general low environmental and landscape quality. The area is mainly private and highly fragmented (439 cadastral parcels and 175 owners).

This area has been identified in the Chieri Local Ecological Network[1] as a part of a "*cuneo verde*" (green wedge). Green wedges are areas with a high density of zones with relevant ecological functionality. These areas act as important ecological corridors that penetrate the urban and peri-urban context. *Fontaneto*, in particular, is situated in the northern part of a green wedge (Figure 1) and it is a crucial transitional zone between the city and the surrounding rural landscape. In green wedges, interventions to increase ecological performance are needed in order to improve the quality and connectivity of the overall network. A Plan ("*Biciplan",* closely connected to the Ecological Network Plan) aimed at improving the soft mobility network in Chieri highlighted the need for integration of bicycle pathways in the city and in the *Fontaneto* area as well.

[1] "Local ecological network and Biciplan of Chieri" (2016) is a study developed by Politecnico di Torino – DIST (research group: Angioletta Voghera, Luca Staricco, Stefania Guarini, Gabriella Negrini, Luigi La Riccia), on behalf of Chieri Municipality.

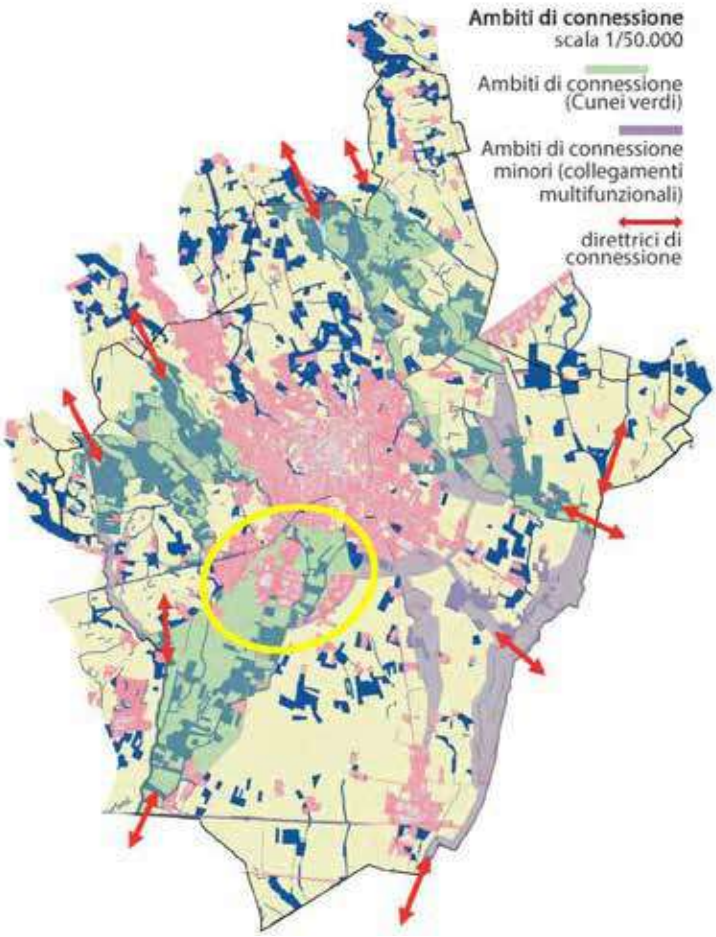

Figure 1. The *Fontaneto* area in the context of the Chieri Local Ecological Network (Source: *Variante strutturale n. 15 del Piano Regolatore Generale Comunale*. Urban areas are highlighted in pink, green wedges are highlighted in light green, the *Fontaneto* area is circled in yellow).

On the wave of these studies, and of a more general Municipality's effort to develop policies that reduce soil consumption, in 2019 Chieri Municipality approved a modification of its local urban plan (*Variante strutturale n. 15 del Piano Regolatore Generale Comunale*). According to this modification – that was supported by the LIFE+ project SAM4CP (http://www.sam4cp.eu/en/) and explicitly aimed at maintaining and enhancing ES provided by soil – some areas of *Fontaneto* that were previously classified as industrial zones and golf courses have been converted in rural areas. The Municipality aims to create in *Fontaneto* a rural-recreational park that could act as a crucial node of the local GI (here intended as the combination of the local ecological and mobility networks above-mentioned), in which sustainable agricultural areas, natural areas, and recreational areas coexist and, in the meanwhile, a more sustainable relationship between the dense city and its peri-urban rural context is promoted.

The research here presented – developed by SEACoop, in collaboration with Politecnico di Torino, on behalf of Città Metropolitana di Torino (December 2017 - July 2018) and the Chieri Municipality (October 2018 - today) – meant to support the area's transformation by developing a design vision based on *Fontaneto* environmental and landscape enhancement. To this aim, the concept of ES has been assumed as an operational paradigm to address the area's design towards the requested multifunctionality and to envisage a peri-urban park capable of delivering provisioning, regulating and cultural ES. Evaluation has been thus conceived not only as a knowledge tool but as an operational tool, able to sustain and address landscape design choices.

Ecosystem Service Evaluation for *Fontaneto* Landscape Design: Methodological Framework and Outcomes

Evaluation was carried on in relation to nine ES (Table 1). Starting from the ES classification framework provided by the Common International Classification of Ecosystem Services (CICES, V5.1, 2018, cices.eu), ES were selected according to their representativeness of the main ES classes – Provisioning, Regulation and Maintenance, and Cultural ES – and the primary functions that are currently performed by the area and envisaged by the project. In order to evaluate ES, both biophysical and economic indicators were used. Because of the site-scale of the evaluation, indicators, when possible, relied on empirical and in-situ collected data (e.g. water quality is based on the analysis of extracted soil samples, Habitat maintenance on local avifauna observation, Agriculture production on a survey of local agriculture land uses).

Ecosystem Services		Biophysical indicator	Structure	Economic indicator	Structure	Economic valuation method
PROVISIONING	Agricultural production	Amount of agricultural products	ql/ha/year	Value of agricultural products	€/ha/year	Market price
	Wood production	Volume of extracted wood	m^3/ha/year	Value of extracted wood	€/ha/year	Market price
	Groundwater	Volume of water extracted for irrigation use	m^3/ha/year	Value of water extracted for irrigation use	€/ha/year	Market price
REGULATION AND MAINTENANCE	Hydrogeological protection	Surface of vegetation areas acting for prevention of riverbanks erosion	ha	Value of the protective function played by riparian vegetation	€/ha/year	Replacement cost
	Habitat maintenance	Surface of areas able to maintain nursery populations and habitats	ha	Value of the ecosystem capacity to maintain nursery populations and habitats	€/ha/year	Avoided cost and Benefit transfer
	Water quality	Amount of nitrogen absorbed by soil	g/m^3/year	Value of the water purification function played by soil	€/ha/year	Replacement cost
	Climate regulation	Amount of carbon absorbed by soil	t/ha/year	Value of carbon absorbed by soil	€/ha/year	Market price
CULTURAL	Recreation	Number of visits	Visits/year	WTP/visits	€/ha/year	Benefit transfer
	Aesthetic values	Number of visitors	Visitors/year	WTP/visitors	€/ha/year	Benefit transfer

Table 1. Biophysical and economic indicators for the evaluation of Ecosystem Services.

To make evaluation an effective tool to sustain the landscape design choices, ES evaluation has been developed as tightly connected to the design phase.

Firstly, we evaluated the baseline, namely the current provision of ES in the *Fontaneto* area. Through the application of indicators, we defined, for each ES, per unit (ha) and per year biophysical and economic values, and we applied them to the different land-uses in the area that contribute to specific ES production.

We then defined a Masterplan for *Fontaneto* aimed at improving the delivery of ES in the area and at meeting the Municipality's request for a multifunctional park where rural, naturalistic and recreational areas can coexist. The Masterplan entails three main types of landscape design interventions: (i) interventions explicitly aimed at improving the area's environmental quality, such as cultivation changes from cereals to oil and protein crops to grant a more sustainable agriculture, creation of a wetland to improve local biodiversity, and planting of riparian vegetation for hydrogeological protection; (ii) interventions to improve the area's landscape quality (here meant in terms of scenic-perceptive values), such a planting of vegetation for the mitigation of the visual impact of buildings situated inside and nearby the area; (iii) interventions to improve the area's recreational potential, such as the creation of recreational areas and tree-lined bicycle paths.

With regard to interventions, we envisaged three different implementation scenarios: (i) in the first one (the optimum scenario) all the interventions are carried on; (ii) in the second one (the medium scenario), some landscape elements aimed at improving the area's environmental quality (e.g. wetland and riparian vegetation) and the recreational potential are not implemented; in the third one (the worst scenario) only tree-lined bicycle paths are implemented. For each scenario we evaluated the overall ES provided, applying indicators to the new envisaged land-uses. The comparison between the scenarios and the baseline, and among the three scenarios (Table 2), gives interesting insights to support the definition of the final project for the rural-recreational park.

Ecosystem Services		**Scenario 1 (optimum scenario) €/year**	**Scenario 2 (optimum scenario) €/year**	**Scenario 3 (worst scenario) €/year**	**Baseline €/year**
PROVISIONING	Agricultural production	95,105.18	96,586.88	99,620.18	101,724.37
	Wood production	139.24	119.41	87.02	87.96
	Groundwater	45.81	47.22	46.81	45.55
REGULATION AND MAINTENANCE	Hydrogeological protection	18,866.34	17,630.23	17,630.23	17,325.31
	Habitat maintenance	6,109.17	6,092.92	5,839.81	5,810.30
	Water quality	24,282.36	24,246.16	24,028.07	9,297.66
	Climate regulation	89,008.39	90,412.60	89,642.13	60,698.30
CULTURAL	Recreation	50,585.83	37,846.65	25,969.91	19,273.92
	Aesthetic values	47,886.39	27,841.64	5,283.75	1,869.97
TEV		332,028.71	300,823.71	268,147.90	216,133.34

Table 2 Evaluation outcomes: baseline and scenarios.

The TEV of ES delivered by each scenario is higher than the baseline. The envisaged interventions thus improve significantly the value of ES provided by the area, even if we consider the worst scenario. Concerning the three scenarios, the values of ES differ consistently among them. In most cases, ES values grow from the worst to the optimum scenario (only Groundwater and Climate regulation present non-linear dynamics). Agriculture production is the only ES whose values decrease from the worst to the optimum scenario. This negative dynamic is due to the conversion of a part of the current agricultural areas to different functions (e.g. recreational functions, through bicycle paths, or environmental functions, through riparian vegetation). This trend of values catches the trade-off phenomena that can occur among ES: maximizing the delivery of all ES simultaneously is often difficult, if not impossible (Torkelboom *et al*. 2018). This is particularly true for provisioning ES (such as agriculture production) whose dynamic is usually inversely proportional to regulating and cultural ES (Braat and ten Brink, 2008). In *Fontaneto* this relationship is clear and poses issues regarding social acceptation and feasibility of the project.

Potentialities and Challenges of Payments of Ecosystem Services as a Tool for Supporting Green Infrastructure Implementation

PES can be defined as incentive mechanisms to promote the provision of ES. More specifically PES are "voluntary transactions where a well-defined ES (or a land-use likely to secure that service) is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provider, if and only if the ES provider secures ES provision (conditionality)" (Wunder, 2005, p. 3).

This theoretical scheme proves to be significantly more complex when applied in reality (Muradian *et al.* 2010). Every PES is necessarily a site-specific solution. This is even truer in Italy, where there is not a legal framework for ES (the legislative decree which should have regulated PES in accordance with the principles laid out by Section 70(1) of Law 221/2015, art. 70.1, is still to be enacted). Moreover, a strong tradition of "command and control" planning tools and a widespread land property fragmentation do not favour the implementation of PES in our country, that are less common[2] compared to other European contexts (Maztdorf *et al*. 2014). PES are currently a technical testing ground for environmental and landscape policies in Italy.

However, despite these challenges we think that PES could represent a valuable tool for implementing in *Fontaneto* the landscape interventions described above, and, more generally, for fostering the actual implementation of GI. Thanks to the main features that should characterize PES – i.e. conditionality, additionality and permanence (DEFRA, 2013) – this tool could improve the effectiveness of the design action by: (i) granting a real and long-term provisioning of ES, (ii) fostering local actor "responsibilisation", and (iii) contributing to solving potential social conflicts linked to ES trade-offs. In *Fontaneto* PES could be used to incentive farmers to provide cultural and regulating ES, through giving up portions of arable land for creating bicycle paths, or planting and maintaining riparian and mitigation vegetation.

We thus identified possible "buyers" of ES in *Fontaneto*: the Municipality itself, other public institutions (such as the Local Health Authority), private actors that are already committed with the Municipality to pay for landscape-environmental compensations (e.g. local companies) or that could be interested in sponsoring PES. Concerning the ES "provider side", farmers have been identified as the main potential ES providers in the area. However, due to the high fragmentation of the land properties, an Association of owners has been identified as the most suitable actor to be involved in a PES scheme that could assure a consistent management of the area.

Conclusions

This applied research aimed to link ES and GI concepts and approaches. We think that the *Fontaneto* project can be considered a valuable experience of GI implementation because of the following reasons:

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[2] Beyond some interesting, punctual experimentation (see for instance Marino 2017).

- it puts in action a *multiscalar approach*, translating at the local level, through landscape design, planning indications concerning the local ecological and recreational network;
- it promotes *multifunctionality*, by considering the provisioning of different ES as a key criterion for the Park's design. Multifunctionality is not a "simplistic result" of the GI concept, but it is based on a "place-based" vision. The assessment of the local features highlighted the actual area's potential to provide ES and the existing ES trade-offs;
- it identifies *PES* as a tool for increasing the *effectiveness* of GI implementation. A path for activating PES schemes between the Municipality and some locale farmers has already been started. The Municipality has recently dedicated a part of the 2019 annual budget to finance PES on private rural areas. Moreover, the Municipality is currently working on the hypothesis of decreasing the rental price of public rural areas in order to incentive farmers to deliver certain ES. Several operational aspects still need to be stated (e.g. constitution of landowner association, drafting of PES contracts, definition of the monitoring processes), but the process for the activation of PES schemes in *Fontaneto* can already be seen as an innovative and experimental practice in the national framework of landscape policies.

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