A Multidimensional Assessment of Ecosystem Services: From Grey to Green Infrastructure

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Abstract. The notion of Ecosystem Services (ESs) is constantly increasing in interest given their provision of multidimensional values (environmental, social, economic, etc.). Nowadays ESs are at the center of green cities policies tackling the challenges of sustainability. More than 55% of the population is already living in urban areas, and this number is still rising. Within this context, challenges for sustainable development considering a circular economy perspective will be more concentrated in cities and in particular urban green spaces where strategies could be more effective for achieving sustainable urban development goals, such as improving public health, preserving biodiversity, reinforcing social cohesion, supporting the economy, providing opportunities for recreation, and helping in adapting to climate change. More specifically, the role of urban green spaces is testified by many green infrastructures policies proposed by different cities around the world. Rooftops, abandoned infrastructures and downgraded areas are some of the places that can be reused for creating new natural and green spaces within cities. Given these premises, the present paper aims to investigate the role of green areas in urban context in improving the overall quality of the space and in providing multidimensional benefits. The innovation of the present paper regards the integration of cost-based and value-based methods for the assessment of ESs. Starting from a real case study located in the city of Milan, the article illustrates the potential of combining the valuation of biophysical and economic values.

Keywords: Integrated assessment · Multidimensional values · Urban regeneration

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1 Introduction

Climate change is severely challenging cities and urban areas. Instead of safe place from disasters, cities become the cause of possible risks [1, 2]. According to the definition provided by [3] the term disaster risk is both related to climatic (e.g. flood, sea level rise, etc.) and non-climatic hazard (e.g. earthquake, volcanic eruption, etc.) and the concept of risk reduction. This requires a systemic view and efforts to face and manage factors which cause the before mentioned issues. Within this context the urbanization has tightened many of these hazards and accelerated others. Nowadays 55% of the population lives in an urban area, and the percentage is expected to increase to 68% by 2050 [4, 5]. Moreover, considering the definition of risk reduction provided by [6], it is clear how it directly involves the population and affect communities. Several factors and characteristics of cities themselves strongly influence the climate change, starting from the urban fabrics morphology, the high population density, the high emissions and the constant processes of changes [1]. Adaptation to the existing hazards and the possible future ones could be the answer to address all the several risk factors. Among the different strategies, cities Authorities are increasing the attention on planning sustainable and resilient environments and the 17 Sustainable Development Goal (SDGs) adopted by all United Nations Members States in 2015 underlines this trend [7]. A potential role in this context can be engaged by green measures, nature-based solutions (NBS) and green infrastructures (GUI) which gained more attention in recent years given their effectiveness in impacts mitigation of climate change and the sustainability promotion [8]. In fact, compared to the monofunctional grey infrastructures, GUI are multifunctional ecological systems which create multi-purposes spaces and generate multiple benefits and values [9].

These strategies and their relative benefits can be better understood with the introduction of the concept of Ecosystem Services (ESs) which have been defined as benefits humans gain from ecosystem action [10–12]. The study of ESs has grown in importance over the years, especially thanks to the contribution provided by the Millennium Ecosystem Assessment (MA) [11], which clustered them in four main categories (i.e. provisioning services, supporting services, cultural services, regulating services) and given their provision of multidimensional values (environmental, social, economic, etc.). Within a circular economy perspective, challenges for sustainable development will be more concentrated in cities and in particular in urban green spaces where strategies could be more effective for achieving SDGs and obtaining both direct benefits and indirect co-benefits. In fact, evidence of positive externalities provided by the application of green strategies and the presence of GUI have been deeply discussed by several scholars and classified by [13] in *i)* Physical benefits, e.g. CO_2 reduction, thermal comfort and energy use reduction, and *ii)* Psychological and social benefits, e.g. health and restorative benefits, social and individual coping capacities and education. This classification underlines the need of a holistic approach aimed to plan new urban development projects and evaluate their impacts considering the contribution of systemic solutions [14–16].

Given these premises, the purpose of the present paper is to propose a multidimensional and multi-methodological approach aimed to assess the ecosystem values provided by the transformation of a grey infrastructure into a green infrastructure. Both cost-based and value-based approaches will be applied in order to have an overall scenario of costs and benefits generated by the urban intervention. The case study considers

the regeneration of an existing overpass located in the southeast area of the city of Milan (Italy). The methodology proposes the comparative assessment of the state of the art scenario (T0) and the regeneration scenario (T1). The study wants to underline the role of the evaluation within design process and its support in understanding positive and negative externalities produced by the projects. This is in line with the concept of Complex Social Value provided by [17] proposing a more comprehensive perspective of the Total Economic Value [18] by including the intrinsic value.

The paper is divided into five sections. After a brief introduction of the topic the methodological approach is described (Sect. 2) and applied (Sect. 4) to the case study (Sect. 3). Discussion of the results, conclusions and future perspectives are presented in the last section (Sect. 5).

2 Methodological Approach

Given the complexity of the decision-making process for supporting the regeneration of an underused grey infrastructure and the multiple values involved, the methodology has been structured by considering both cost-based and value-based approaches. Figure 1 presents a flowchart aimed at explaining how the approaches proposed have been developed and which are the results.

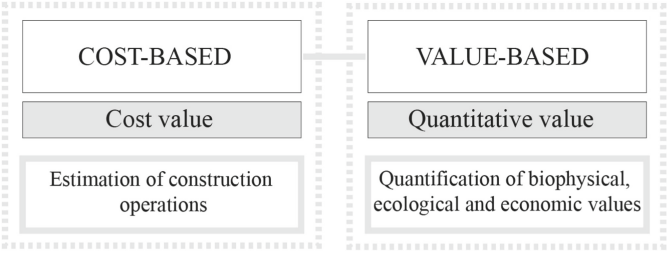

Fig. 1. Methodological approach flowchart

A detailed cost estimation has been performed in order to support the first phase of the analysis detecting all the construction costs of the project. In particular, the cost value has been developed by classifying the intervention according to the Work Breakdown Structure (WBS) which makes possible to divide it namely in: 1. Group of technological units, 2. Technological units, 3. Group of technical elements, 4. Technical elements and 5. Cost items. Following this classification, each work part of the project is described and detailed to assess the Cost items (the last element of the hierarchical frame). For this step, it was used the Regional Price List, which represent the reference tool for the preliminary quantification of planning and public works. Within this source it is also possible to find information about the percentage influence of materials, manpower, leasing and equipment. For all working activities, it was consulted the section related to the completed works to estimate the finished work.

For what concerns the value-based approach, and in detail the quantitative evaluation, the existing tool Simulsoil has been applied. Simulsoil is a free software able to

support the planning process through the analysis and evaluation of eight ESs [19]. In detail, the provision of ESs is evaluated by considering changes in land-use of at least two alternatives in order to estimate the differences among the two. Usually, the state-of-art is compared with a new project to understand if and how much the changes proposed and designed provide benefits. Simulsoil allows to assess the values of the following ESs: Habitat Quality (HQ), Carbon Sequestration (CS), Water Yield (WY), Sediment Retention (SR), Nutrient Retention (NR), Crop Production (CPR), Crop Pollination (CPO) and Timber Production (TP)[1]. According to this analysis, it is possible to highlight the sensitivity of a territory in relation to ESs variation as well as to quantify the overall cost of a transformation on the existing Natural Capital. Even if the economic valuation cannot be used as an exact measure of gains or losses of Natural Capital and as a direct value for the determination of compensation measures, it provides for an additional and easy way to show the effects of plans and projects. Moreover, it is able to support the *ex-ante* phase assessment of a transformation by involving different stakeholders, helping their comprehension and participation to the entire decision-making process, as well as the enrichment of a more comprehensive view of the relevant aspects in land-use planning and promotion of sustainable and resilient actions [20]. The results obtained from Simulsoil are given graphically by spatial maps for each ES and schematically by a final comparative table that quantitatively reports the biophysical and economic values of all scenarios [20]. Among the ESs analyzed: Habitat Quality (HQ) considers if the land-use proposed minimize or preserve the biodiversity, Carbon Sequestration (CS) quantifies the level of carbon stored by the territorial ecosystem, Water Yield (WY) analyzes the property of the land to absorb water and returned to the aquifer, Sediment Retention (SR) maps the eroded soil, Nutrient Retention (NR) takes into consideration the quantity of pollutant flowing into the water, Crop Production (CPR) evaluates the effective agricultural production provided, Crop Pollination (CPO) deals with the contribution of bees to agricultural production, Timber Production (TP) is referred to the fiber supply. As mentioned before, these ESs are both evaluated under a biophysical point of view and in economic terms. For what concerns the economic evaluation, the software assigns a unit price (e.g. avoided social cost) to the ESs with absolute biophysical values, while for the ESs expressed by an index, the economic estimation is developed by simulating a market and asking for the willingness to pay for the use of the good.

Since the unit of measure is specific for each ES the biophysical results cannot be aggregated while the economic ones can be combined in order to have an overall evaluation of the value provided by the projects. This consideration is strategic since the methodological approach proposed aims at integrating both cost and benefits of the same project providing an additional information about the sustainability of the project under a multidimensional point of view.

3 Case Study

The case study under analysis is located in the southeast area of the city of Milan (Italy), in the neighborhood called Corvetto (Fig. 2). Here, in 2018, the municipality established the

[1] http://www.sam4cp.eu/Simulsoil/.

demolish of the viale Lucania overpass due to its underused. In contrast, a regeneration project has been proposed with the aim to maintain the artifact and give the community an open public space, characterized by cycle and pedestrian paths, equipped services and green spaces. The project objective is mainly to realize a new "green landscape" for the city able to increase the environmental quality of the area, but also to produce other benefits both for the community, such as well-being and health, and for the image of the area. The project is the result of an in-depth investigation of the main pros and cons of the context, supported by the development of a SWOT analysis which has been structured considering the following steps:

1. Definition of the objective of the analysis;
2. Analysis of the context by considering infrastructural, environmental, settlement and socio-economic aspects;
3. Development of the SWOT matrix for each aspect analyzed;
4. Definition of a set of strategies considering the results of the previous analysis and the objective to be achieved.

In particular, the project strategies derive from the main opportunities highlighted in the SWOT analysis as well as the reduction of the weaknesses and the control of the threats.

The main strategies developed consider: 1. the implementation of cycle-pedestrian paths by reducing the road size and the amount of car traffic; 2. new trees planting to reduce no-permeable surfaces, 3. the heat-island effect, the presence of pollutants in the air and the summer shade; 4. new public spaces for recreation and commercial activities; 5. people engagement in the regeneration project by increasing the safety perception; 6. the involvement of different age groups and 7. the organization of evening events.

This study wants to highlight the opportunity of the regeneration project in contrast to the demolition by the assessment of the two alternative proposals both in terms of economic benefits and ecosystem ones. On one hand, scenario T0 considers the state-of-art of the area with the presence of the overpass that is planned to be demolished. According to this demolition, the costs connected to this activity are estimated. On the other hand, scenario T1 refers to the regeneration project and the costs of intervention for this transformation (Fig. 3).



Fig. 2. Location of the project area



Fig. 3. T0 (image on the top) and T1 (image above)

4 Application

Following the methodological approach proposed, the first step regards the quantification of the costs of the overpass demolition and the ones connected with the regeneration interventions (T1).

Firstly, the costs connected with the overpass demolition has been estimated, including the 17 vertical concrete supports, and aggregates disposal. After the calculation of the volume (6326 cm + 1189 cm) and aggregates weight (2400 kg/cm), it was considered a parametric cost of 151.78 €/cm for the demolition, and 1.9 €/ton for the disposal activity, as reported in the Lombardy Regional Price List of public works 2020 (Volume 1.1, respectively 1C.01.030.0040 and 1C.27.050.0100.d). The overall cost for this intervention is equal to 1,483,350 €, i.e. about 299 €/sqm.

Secondly, for T1, it has been estimated the construction costs of the linear park project section through a WBS in order to clearly state the costs for this intervention.

It is important to highlight that some costs, strictly related to the construction sites activities (e.g. security), are not listed in the table of costs but considered as a percentage of the overall intervention. Considering the hierarchical classification explained in Sect. 2, the project has been further described and the total cost for the realization of the linear park amounts to € 981,873.05 with a unit cost of the work equal to 178.83 €/sqm.

Once the first phase of the methodological approach has been assessed, the two scenarios (T0 and T1) are compared by considering the amount of ESs provided. For this stage, the existing tool, Simulsoil, was applied for assessing the eight ESs.

The two alternatives (T0 and T1) were designed in a georeferenced CAD environment, then imported in QGIS 2.18.28. The CAD and QGIS procedures were useful for the following analysis with Simulsoil. Both for the T0 and T1 scenarios, the polygons had specific layers corresponding to the different land-uses. The land-uses must be associated with the Corine Land Cover classification used by Simulsoil to calculate the biophysical values. Based on a set of algorithms associated with the land-uses, Simulsoil provides output data in raster maps with a resolution level of 20 × 20 meters per pixel.

As it is possible to see in Fig. 4, scenario T0 represents the business-as-usual scenario (BAU), i.e. the current state of the art of the area, while T1 shows the regeneration proposal. In particular, T0 is essentially characterized by a road network land cover, with only a small piece of green areas and some trees and bushes. Conversely, in T1, the road network land cover is strongly reduced due to the realization of recreational green areas on the overpass and in the north portion of the area. Moreover, additional trees are planted in the entire project area.

The output data provided by Simulsoil on the two scenarios analyzed are reported in Table 1 and showed in Fig. 5. It is important to underline that in Fig. 5, only the ESs with values higher than 0 are reported in maps. The reason why many ESs have obtained a zero value is connected with the specific land-use in the area. However, the output data of the other ESs provide interesting considerations on the difference between the two scenarios. The increase of CS, HQ and TP in T1 can be explained by the great amount of new green spaces and vegetation considered in the regeneration project. Moreover, T1 strongly reduces the fragmentation of (non-agricultural) green areas compared to T0. According to a consolidated rule in ecology, the concentration of green spaces, in fact, provides better environmental performances, as well as more interaction between habitat sources, the creation of corridors and the reduction of threats [21]. The new land uses provided by the intervention project certainly helps in the increase of these ESs values compared to the current state of the area, even if more potentialities are faced with social and cultural values generated by the regeneration scenario.

Moreover, since the economic results represent only an indication of the overall ESs performance, they are converted in a final incremental percentage of the increase of T1 over T0, as it is possible to see in the last row of Table 1.

According to the results of this research, the regeneration project is beneficial in terms of ESs provision, but it is also preferable from a merely financial perspective since the overall costs of the overpass demolition activities are higher than the ones of the project proposed. The comparative Table 2 shows how the differences in the performance of both alternatives in terms of economic values of ESs and of the financial ones. Even if

the monetary savings are limited - as shown in the last row of Table 2 -, there are a lot of biophysical and environmental benefits provided by T1 (about 50% more than T0).

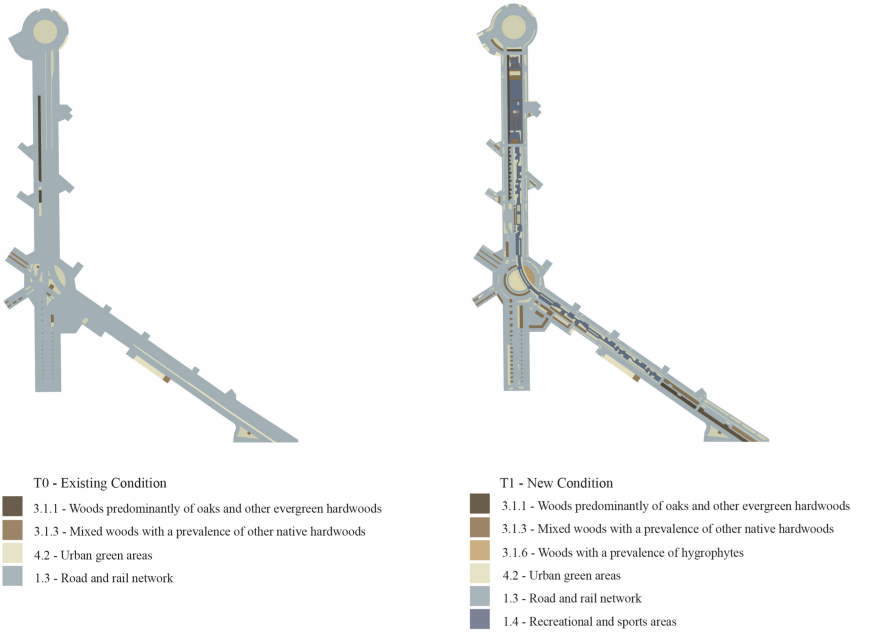

Fig. 4. Land-uses assignment for T0 and T1 according to the Corine Land Cover classification

Table 1. Comparison of the ES values of the two transformation scenarios (T0 and T1) in biophysical (bio) and economic (econ) terms

Code	ES Name	u.m	T0 (bio)	T1 (bio)	u.m	T0 (econ)	T1 (econ)
CS	Carbon sequestration	ton	356.38	496.42	€	35,637.89	49,641.81
CPO	Crop pollination	0–1	0	0	€	0	0
HQ	Habitat quality	0–1	0.30	0.41	€	2,690.20	3,632.04
NR	Nutrient retention	ton	0	0	€	0	0
SDR	Sediment retention	ton	0	0	€	0	0
WY	Water supply	0–1	0	0	€	0	0
CPR	Crop production	€	0	0	€	0	0
TP	Timber production	€	10,570.64	19,355.08	€	10,570.64	19,355.08
Total						48,898.73	72,628.93
Incremental %						**48.53**	

Table 2. Differences between T0 and T1 according to the integrated framework in biophysical (bio) and economic (econ) terms

ES Name	u.m	T0 (bio)	T1 (bio)	u.m	T0 (econ)	T1 (econ)	Delta (T1- T0)
Carbon sequestration	ton	356.38	496.42	€	35,637.89	49,641.81	**14,003.92**
Habitat quality	0–1	0.30	0.41	€	2,690.20	3,632.04	**941.84**
Timber production	€	10,570.64	19,355.08	€	10,570.64	19,355.08	**8,784.44**
Total (econ)				€	**48,898.73**	**72,628.93**	**23,730.20**
Incremental %				%			**+48.53%**
Costs				€	−1,483,350	−981,873	**501.48**
Incremental %				%			**+0.034%**

5 Discussion and Conclusions

The paper presents the application of an integrated framework for the multidimensional assessment of a strategic project, that considers both financial and extra-economic aspects. This analysis has underlined the advantages of combining cost-based and value-based approaches in order to highlight both tangible and intangible benefits produced by the regeneration project of viale Lucania overpass in Milan (Italy).

On one hand, the application has shown how Simulsoil is a simple but very effective tool that clearly shows the relationship between urban morphology and land-use. More specifically, it helps to design and define projects capable of maximizing the provision of the benefits for man and its related environment by assessing ESs in different scenarios. This tool can be used by various professionals to rapidly assess, in an *ex-ante* phase, the ES generated in land-use scenarios and support the Strategic Environmental Assessment (SEA) that is a mandatory activity in urban planning. The integration of ES assessment, management tools and SEA makes possible to improve the sustainability of land use planning process [22, 23]. The spatial output data given by Simulsoil make the output very intuitive by all the stakeholders involved in the decision-making process, also with the conversion of biophysical performances in an economic dimension.

Then, the estimation of intervention and demolition costs can support a direct interaction with the Public Administration and its bodies in order to guide them in an efficient allocation of their resources, which are often limited and scarce. In fact, according to the results of this research, the regeneration project is not only beneficial in terms of ESs provision, but it is also preferable in a merely financial perspective since the overall costs of the overpass demolition activities are higher than the ones of the project proposed.

These results are in line with the concept of adaptation to which cities should aim to mitigate the effects of climate change and meet sustainable goals.

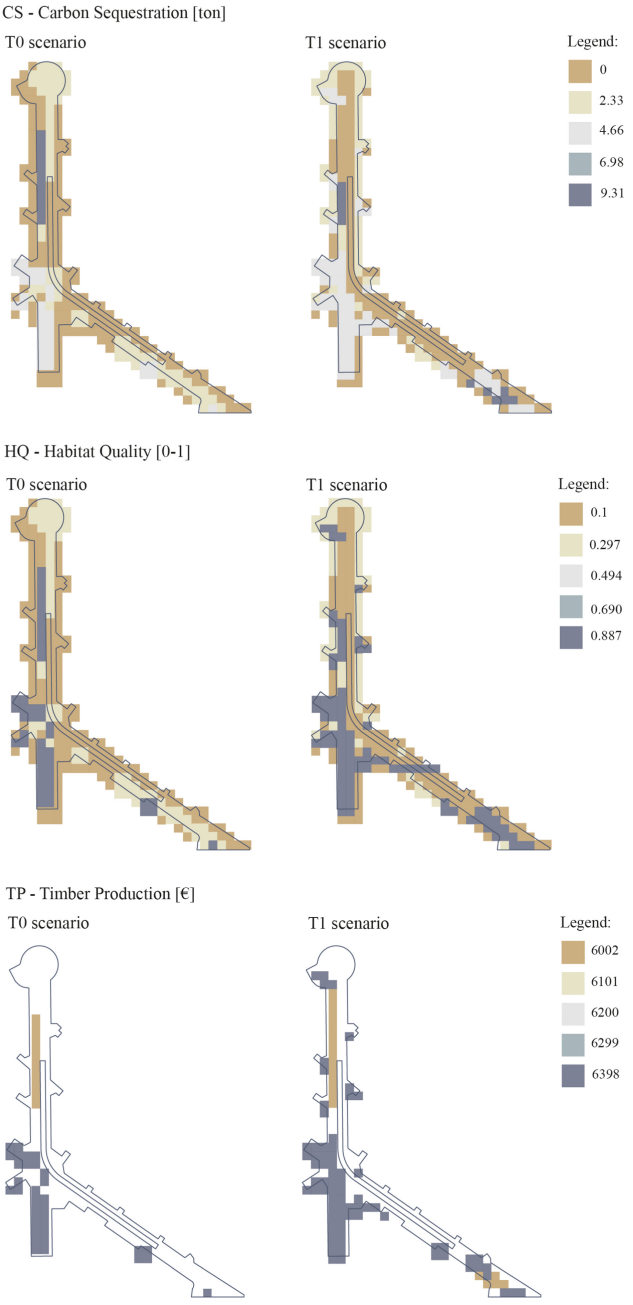

Fig. 5. ES quantification and spatial representation for the two transformation scenarios (T0 and T1)

Some limits, instead, can be highlighted, in particular concerning the Simulsoil tool. Future implementations of the present work will regard the adoption of more sophisticated tools for the ESs assessment, such as InVest or iTree, in order to consider all the different benefits of T1over T0. Moreover, the economic values obtained from Simulsoil can be connected with the estimated costs in an integrated approach, for example by using the Cost-Benefits Analysis. Another perspective that should be explored is related to the consideration of more intangible values [24], in particular socio-cultural ones, that are strongly relevant for the specific recreational use of the area and to have an overall view of the positive externalities produced by the regeneration project. In this perspective, multicriteria decision analysis (MCDA) can be a powerful method to assess all the different ESs values and give a comprehensive evaluation of the strategies under analysis and the multiple dimensions involved (i.e. well-being, ecological, tangin and economic aspect). Moreover, MCDA makes possible to include the distribution of gains and losses across beneficiaries of ESs [25]. This perspective is also in line with the recent trends of the ESs assessed literature, as testified by [26].

Finally, it can be of particular interest to propose the combination of the results of the previous analysis (costs estimation and Simulsoil quantifications) with the MCDA performances in order to have an overall index. For example the composite model for assessment approach (COSIMA) proposed by [27] could be tested. This proposal can be highly effective for a discussion with public bodies, and in particular the city of Milan, for supporting the project. In fact, the combined approach is able to clearly show how the project, in contrast to the overpass demolition, is an opportunity for the neighborhood to improve the community well-being, the environmental quality of the area and the economic externalities generated by the regeneration.

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