Valuing Nature: Experimenting the GiVal Toolkit for the Economic Evaluation of Nature-Based Solutions in Milan

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Abstract. Urban environments are particularly affected by climate change impacts, such as Urban Heat Island (UHI), which leads to tangible consequences for the well-being and health of citizens. In this context, several national and international policies promote the implementation of Nature-Based Solutions (NBS) in urban contexts to provide a sustainable strategy for climate change mitigation and adaptation. However, the integration of these solutions into strategic urban planning remains a challenge, particularly due to the difficulty of evaluating their economic value. This study investigates the suitability of the Green Infrastructure Valuation toolkit (GiVal) as a preliminary tool for the economic assessment of NBS in urban environments. The tool has been applied for the economic evaluation of a reforestation project in the city of Milan, aligned with key goals of the city's Climate and Air Plan. Based on the Benefit Transfer method, the GiVal tool estimates the economic value of a wide range of benefits. The proposed application underlines both the strengths and the criticalities of the GiVal tool. According to the obtained results and the recognised strengths and criticalities, it can be addressed that this tool is an effective preliminary evaluation framework which enables the identification of the benefits provided by the analysed NBS.

Keywords: Economic evaluation · Nature-Based Solution (NBS) · Total Economic Value (TEV)

1 Introduction

The climate change phenomenon is exposing societies to many stresses and risks [1, 2]. Urban environments are particularly vulnerable to climate change effects, as both the direct and indirect impacts affect social, economic, and environmental aspects [3–5]. One of the main impacting phenomena is represented by the Urban Heat Island (UHI), which leads to tangible consequences for the well-being and health of citizens [3]. In

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this context, Nature-Based Solutions (NBS) are proposed as strategic interventions to foster sustainable and resilient urban development [6], as well as to implement operative mitigation and adaptation strategies by maximising the interactions between natural and built environments [7–10]. Therefore, the implementation of NBS in the urban context, such as urban forestry and Sustainable Urban Drainage Systems (SUDS) can offer multiple benefits, including reduced flood risk, improved water quality, better air quality, and the mitigation of UHI effects [11].

Within this premise, the introduction of NBS in urban contexts is supported by different policies, ranging from the international level with the European Green Deal and the Sustainable Development Goals (SDGs), to the national level with the Italian Recovery and Resilience Plan (PNRR). These policies frame NBS as effective urban regeneration strategies, owing to their ability to simultaneously provide a range of environmental, social, and economic benefits [12].

Despite the abovementioned supporting policies and the general interest in the concept of NBS, the strategic planning and the operative implementation of NBS in urban context are not emerging as priorities in urban action to tackle climate and multidimensional challenges. This condition is mainly due to difficulties in evaluating the benefits of these solutions in monetary terms [13], as well as in estimating implementation and maintenance costs [9, 14]. The estimation of costs and benefits associated with NBS interventions is a critical issue for their integration into strategic urban planning processes. According to this state-of-the-art, this research is mainly based on this research question Q_1 "*How can the benefits of Nature-Based Solutions (NBS) in urban areas be effectively evaluated in monetary terms to inform and support strategic planning processes?*". In thi:s framework, the present research explores and tests the Green Infrastructure Valuation toolkit (GiVal) for developing the ex-ante evaluation of the generated economic value of NBS interventions in the urban context, thus addressing its suitability in supporting decision-making in the early stages of urban planning.

This tool has been applied to assess the economic value of an urban reforestation project in the city of Milan, designed to mitigate the UHI effect. Some adjustments have been made to the input data (Sect. 3) to enable a context-specific assessment as much as possible and to consider the difference in the currency. The proposed application permits to recognize of both the strengths and criticalities of the GiVal tool in assessing the economic value of NBS in urban environments.

The present paper is structured as follows. Section 2 is dedicated to the introduction of the concept of NBS and to the description of the economic evaluation of natural capital to address its main methodological background. This section also lists the most relevant tools developed for the economic evaluation of natural resources and Green Infrastructure (GI). Section 3 contains the description of the application of the GiVal toolkit to the considered case study, also underlying the adjustments made. Section 4 critically discusses and analyses the obtained results, focusing on both the strengths and criticalities of the adopted tools. Section 5 summarises the contents of the proposed study and discusses the possible implementation of the GiVal toolkit.

2 Nature-Based Solution and Economic Evaluation of Natural Capital

2.1 Nature-Based Solution Definition

The concept of Nature-Based Solution (NBS) is an umbrella term which has been introduced in 2008 [15]. Since the first introduction, several definitions of NBS have been proposed in both academic and political contexts. One of the most shared definitions is that provided by the European Commission [16], which describes NBS as "*solutions inspired and supported by nature that are cost-effective, provide environmental, social, and economic benefits, and enhance resilience. These solutions introduce more diverse nature and natural processes into cities, landscapes, and seascapes through locally adapted, resource-efficient, and systemic interventions*". Given the variety of existing definitions, this research adopts the one previously mentioned, as it emphasizes the multidimensional and multifunctional nature of NBS. Accordingly, the study aims to evaluate the economic benefits of NBS from a holistic perspective.

2.2 Economic Evaluation of Natural Capital

Economic evaluation refers to the assignment of monetary values to non-market assets, goods and services. Non-marketed goods and services are those that are not directly traded in the marketplace, such as natural resources, clean air, or neighbourhood amenities [17]. If a good or service contributes positively to human well-being, it holds economic value.

Over time, the economic evaluation of environmental goods has undergone significant theoretical development, leading to the formulation of the Total Economic Value (TEV) concept [18]. According to Pearce and Turner (1990) [19], the TEV consists of two principal components represented by the use and non-use values (Fig. 1).

Specifically, the use value refers to three main components:

1. Direct use value is related to the benefits derived from tangible goods that can be consumed, harvested, or directly experienced;
2. Indirect use value refers to the benefits provided by Ecosystem Services (ES) and natural functions that support human well-being;
3. Option value can be considered as a particular type of use value that reflects the importance of preserving the possibility of utilising certain resources or services in the future.

Non-use can also be divided into two components:

1. Bequest value, which reflects the importance of preserving the natural capital and ecosystems for the benefit of future generations;
2. Existing value refers to the satisfaction or moral benefit individuals derive simply from knowing that a natural asset or ecosystem exists, regardless of any intention to use it.

Different evaluation techniques are available for estimating the TEV. These methods can be divided into two main categories (Fig. 1), the Revealed Preference (RP) and the Stated Preference (SP) [17, 19, 20].

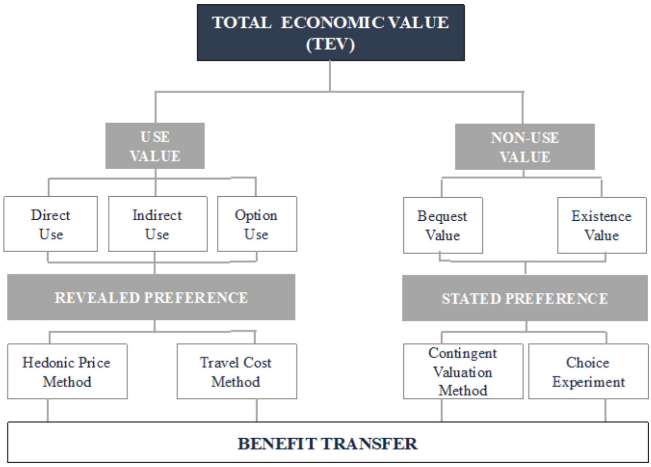

Fig. 1. Total Economic Value components and evaluation methodologies (elaboration from Pearce et al., 2002).

The RP methods derive economic values from choices and behaviours observed in related markets. These methods assume that people's preferences are indirectly revealed through their market decisions. The most widely used RP techniques are the Hedonic Price (HP) method and the Travel Cost Method (TCM). The HP is based on the measurement of the change in the value of an asset caused by an environmental characteristic in labour or property markets. Accordingly, amenity and disamenity can be derived from the difference in the value of a property, which corresponds to the Willingness to Pay (WTP) for the improvement of a given environmental quality. Assuming that environmental characteristics are reflected in property prices, it is possible to isolate the value of these individual characteristics, but this depends on the amount of data available on property prices, which must be adequate for the level of detail desired [21]. The TCM estimates value based on the travel expenses (including time and money) incurred by individuals to access natural sites, such as parks, forests, or lakes. These costs reflect the demand and value people place on these experiences [22]. The RP methods are mainly used for estimating the use value.

On the other hand, SP methods use hypothetical market scenarios to directly elicit individuals' WTP for specific environmental improvements or to avoid degradation. These approaches are especially useful for capturing non-use values that cannot be directly observed through actual market behavior [23]. The main techniques within this category include the Contingent Valuation Method (CVM) and the Choice Experiment (CE). The CVM uses structured surveys to directly ask individuals how much they would be WTP for a defined improvement in environmental quality or to avoid a particular form of degradation. As noted in the literature, it is the most commonly applied method for estimating non-use values [24]. On the other hand, the CE presents respondents with a series of hypothetical alternatives, each described by different attributes and levels. By analysing the choices individuals make, researchers can estimate the marginal value of individual ecosystem attributes and the trade-offs people are willing to accept [25].

As shown in Fig. 1, the results derived from SP and RP are often used to implement the Benefit Transfer (BT) method [26]. The BT is an economic valuation method that applies monetary estimates, like WTP, from one context (evaluation area) to another (the policy site) using statistical and econometric methods [27]. It is commonly used in ex-ante evaluation and policy analysis when time or resources prevent new primary valuation studies [27]. BT is typically divided into two approaches: (1) point transfer, which applies a single estimate directly or with simple adjustments, and (2) function transfer, which uses statistical models derived from multiple studies [28, 29]. The point transfer is the simplest approach, but it requires strong similarity between sites to be reliable. On the other hand, the function transfer is often based on meta-analysis, offering thus greater flexibility by generating valuation functions that consider variations in site characteristics and methodological factors. In general, the function transfer process involves the definition of the valuation objective, compiling and screening relevant studies, extracting key variables, building a meta-regression model, and applying the resulting function to the policy site. This approach enhances the robustness and generalizability of economic valuation in support of environmental and policy decision-making [30, 31].

Both Revealed Preference (RP) and Stated Preference (SP) methods have their respective strengths and limitations. RP methods are grounded in actual observed behavior, providing robust estimates of use values, but their application is often constrained by the availability and quality of market data. In contrast, SP methods offer greater flexibility and can capture a broader spectrum of values, including non-use values, but they may be subject to biases due to the hypothetical nature of survey responses.

Therefore, the choice of method should be context-dependent, taking into account the specific type of ES being evaluated, the availability of relevant data, and the overarching policy or management objectives [32].

2.3 Available Toolkit for the Economic Evaluation of Natural Capital in an Urban Context

The methodologies proposed by the appraisal discipline for the economic evaluation of the benefits of green solutions and natural capital are increasingly supported by several tools proposed by European projects and various research institutions. These tools are designed to quantify in monetary terms the benefits of GI. They also support Cost-Benefit Analysis (CBA), policy formulation, and stakeholder engagement, ultimately making the evaluation process more accessible and actionable for planners, decision-makers, and practitioners. Table 1 presents an overview of some of the most widely used tools for the economic evaluation of GI and NBS. They are described according to the purpose, the evaluation methodology and the evaluation output. As illustrated by Table 1, many of these tools are designed to translate ecological outcomes into monetary terms, facilitating their integration into economic decision-making.

This research selected the GiVal tool among others for two main reasons. Firstly, it adopts the BT as its basic methodological approach, which permits the estimated values to be adapted and applied to different contexts with appropriate adjustments. Secondly, the GiVal tool provides an evaluation output of the Net Present Value (NPV), enabling the quantification of the benefits of the NBS intervention in monetary terms. Therefore,

Table 1. List of the most relevant tools for the economic evaluation of GI and NBS in urban contexts.

Tool	Developer	Purpose	Evaluation methodology	Evaluation output
Economic evaluation of GI investment through discounted benefits	Natural Economy Northwest	Support economic appraisal of GI investments by local authorities and planners	Benefit transfer from empirical literature and UK government sources	Economic evaluation of GI investment through the Net Present Value (NPV)
InVEST	Natural Capital Project	Model and map ES under different land-use scenarios	Biophysical models with optional economic valuation via market prices, avoided cost, or BT	Spatial maps and quantitative estimation of services like carbon storage, urban cooling, etc. Monetary values only for some selected models
i-Tree	U.S. Forest Service	Quantify urban forest benefits for planning and management	Biophysical modeling and economic valuation via market/avoided cost	Monetary estimation for air pollution removal, carbon sequestration, and energy savings
BEST	CIRIA (UK)	Estimate benefits of SuDS and other GI interventions	Multi-criteria analysis with economic proxies and unit values from literature	Monetary valuation of flood mitigation, water quality, amenity, health and biodiversity

it permits to response to the main research question Q_1, as it provides strategic insights into the feasibility of the intervention to strategically support the urban planning process.

3 Application

3.1 Case Study

As declared in Sect. 1, this research aims to address the suitability of the GiVal tool for estimating the economic value of urban forestation for the city of Milan. The objective is to evaluate its capacity to provide a preliminary economic assessment that can support the early-stage planning and definition of this type of intervention.

The case study under evaluation focuses on the proposal of the implementation of NBS as a suitable strategy for revitalising vacant green spaces [11], as well as a

suitable intervention for UHI mitigation. Specifically, the case study refers to the urban forestation intervention project aimed at regenerating the neglected green area located in Via dei Canzi, in the city of Milan (Fig. 2). This intervention aligns with the strategic objectives of the Climate and Air Plan of the city of Milan [33]. This plan proposes and suggests several actions to implement urban regeneration, mitigation and adaptation strategies through the integration of NBS or GI in the context of the city of Milan, as specifically underlined by objectives 4.2 "Urban cooling and reduction of the heat island phenomenon" and objective 4.3 "Milan, sponge city".

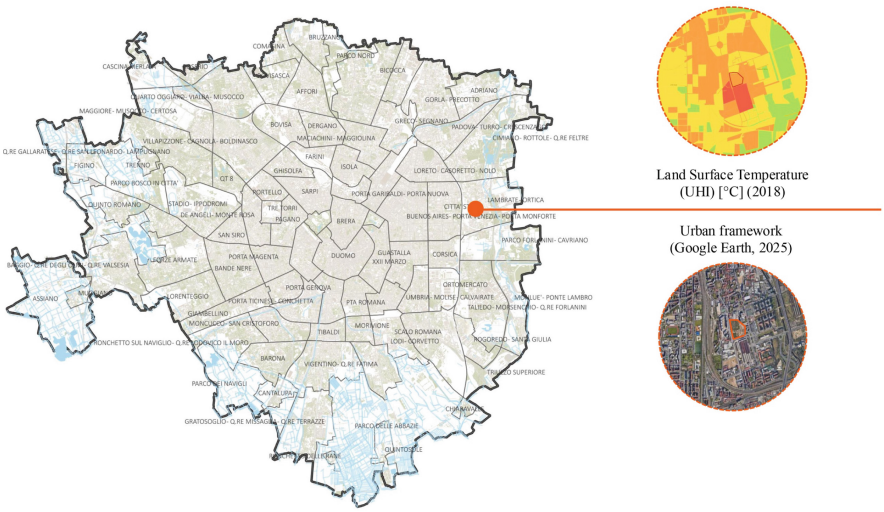

Fig. 2. Territorial framework of the intervention area with a specific focus on UHI.

In this perspective, urban forestation is recognised as a combined intervention, according to the fact that it can mitigate emissions through increasing carbon storage [11], as well as adapting the urban environment to the growing impacts of heat waves, reducing local average temperatures and the heat island effect [34]. The designed intervention proposed for Via dei Canzi directly supports these two objectives. The area was selected due to its high degree of soil sealing and limited vegetation cover, conditions that significantly improve the UHI effects. By increasing permeable surfaces and vegetation, the intervention contributes to the targets of climate neutrality by 2050 and urban cooling by 2030, as established in the Climate and Air Plan.

3.2 The GiVal Toolkit

The GiVal toolkit [35] has been developed to support preliminary project appraisal by identifying the potential impacts of both proposed GI interventions and existing green assets. It provides a structured framework for the economic evaluation of GI projects, such as urban reforestation, by estimating a broad range of environmental, social, and economic benefits.

It supports the development of indicative Cost-Benefit Analysis (CBA) by integrating monetised, quantitative, and qualitative impacts, and it permits the estimation of the TEV through the BT method.

In detail, it evaluates eleven benefit categories, each grounded in ES functions and linked to policy objectives:

- Climate change adaptation and mitigation;
- Water and flood management;
- Place and communities;
- Health and wellbeing;
- Land and property values;
- Investment;
- Labor productivity;
- Tourism;
- Recreation and leisure;
- Biodiversity;
- Land management.

Each benefit is supported by a logic model that considers the connection between the GI intervention and its expected outputs and outcomes, using value transfer methods and evidence from case studies and empirical research. The tool is mainly based on two key case studies that inform its valuation parameters. The first is the study by Garrod and colleagues, 2003 [36], which provides average values for forestry and woodland benefits. The second reference is the work commissioned by the Department for Communities and Local Government (DCLG), which offers insights into the scale of external, non-use benefits that GI can deliver [37].

The Excel-based calculator provided by the toolkit includes multiple interlinked worksheets that guide users through the valuation process and help consolidate the results into a structured economic appraisal. Here are described the spreadsheets mainly related to the project description and the project evaluation:

- Project Data Sheet. It is the sheet used to fill in the baseline information about the project. It includes details such as the type and size of the GI intervention, land use characteristics, site location, population density, and assumptions about visitor numbers. These parameters are directly connected to the benefit calculation tools to provide an evaluation fitted to the details of the project;
- Cost-Benefit Analysis (CBA) Sheet. This sheet combines the results from the different benefit modules and compares the total value of the benefits with the project's capital and operational costs. However, it has to be specified that the capital and the operational costs of the project are not calculated with the support of this tool, they have to be estimated separately and filled in;
- Summary of Economic Value. This sheet presents all monetised benefits by benefit category, in discounted present value terms over the defined appraisal period.

3.3 Applying the GiVal Toolkit for the Economic Evaluation of Urban Reforestation Intervention in the City of Milan

Before describing the application and the adjustment made, it is necessary to underline that the GiVal toolkit has been selected among the other proposed tools (Table 1) according to the fact that is based on the BT method, which makes it possible to use estimated values derived from similar case studies (Sect. 2). As well, it permits to respond to the main research question Q_1 (Sect. 1).

The preliminary steps implemented for the GiVal tool application for the economic evaluation of the urban forestation intervention in the city of Milan concerns firstly the identification of the benefits to consider following intervention objectives, and secondly, the arrangement of some input data contained in the values library to ensure the evaluation context-based as much as possible and to consider the difference in the currency.

First, the relevant benefits have been identified. In this context, the tourism spreadsheet has not been considered, as the necessary information is not available at the current stage of project development. Similarly, the spreadsheets related to the labour productivity and land management benefits have not been considered, according to the fact that these benefits are calculated based on the number of employees and site maintenance. Therefore, this calculation sheet has not been filled and considered for the evaluation according to the fact because the input data are too detailed and specific for the current stage of project development.

Secondly, it is essential to note that the economic values established in the Excel-based calculator to assess the benefits are expressed in pounds sterling [£]. Moreover, the monetary values refer to different years (e.g., 2006, 2007, 2012, and 2018) than the valuation year. For this reason, all the amounts have been first converted from pounds sterling [£] to euros [€] using the exchange rates provided by the Bank of Italy for the respective reference years.[1] Subsequently, the amounts in euros were adjusted to 2024 values using the appropriate updating coefficients. According to these adjustments, the performed calculation have been made directly in euros [€].

Thirdly, some of the input data, both from the values library spreadsheet and other sources used to describe the project context, have been tuned to ensure the assessment reflects the specific characteristics of the intervention.

These adjustments were necessary because several default values in the tool are based on data from the UK context. Specifically, the made changes are described as follows:

- Average household energy consumption (electricity) for cooling. The calcolator originally included an input value in kWh/year based on average UK data. This value has been replaced to better reflect the Italian context, using data provided by ENEA.[2] A value of 2000 kWh/year was entered, representing an average between the estimated consumption of new buildings (1000–1500 kWh/year) and older buildings (2000–2500 kWh/year);
- Average household energy consumption (gas) for heating. As in the previous case, the value originally included in the spreadsheet referred to average consumption in

[1] https://tassidicambio.bancaditalia.it/terzevalute-wf-ui-web/converter

[2] Energy Efficiency Unit Department, Rapporto Annuale sull'Efficienza Energetica 2024

the UK. This input was replaced with data from ENEA, reflecting the Italian context. The updated value entered is 10,700 kWh/year;
- Commercial electricity price. The original value was replaced with the average electricity price in Italy, set at 0.17 €/kWh according to ARERA[3];
- In the climate spreadsheet, the values for the percentage of buildings with air-conditioned [%] and the yearly air conditioning use [Hrs/yr] have been modified to better reflect the application context. The percentage has been set at 50%, and the yearly usage has been set at 540 h/year based on data provided by ENEA;
- In the water spreadsheet, the value for annual rainfall was updated, with 125.25 mm/year as provided by ENEA. This estimate reflects the seasonal distribution of rainfall, which is generally heavier during the winter months;

In the property spreadsheet, the input for the average property price has been based on the average market value in the OMI zone where the project area is located. Specifically, the OMI zone is the "D13 - Lambrate, Rubattino, Rombon". In this context, the valuation referred to civil residential properties in standard condition has been considered, with market values ranging from 2,900 €/m^2 to €4,000 €/m^2. Therefore, the average value equal to 3,450 €/m^2 has been estimated and used for the evaluation.

4 Discussion of Results

This section describes and critically analyses the results obtained by applying the GiVal toolkit for the economic evaluation of the forestation intervention in the city of Milan.

First of all, it is necessary to underline that the tool sets a discount rate of 3.5% and the Excel-calculator sheet is organised to set a a time horizon of 50 years at least.

Both values have been considered appropriate for this assessment. The 50-year period aligns with the typical life cycle of forestation projects within the necessary and required ordinary and extraordinary maintenance costs [38]. As well, the discount rate equal to 3.5% complies with European guidelines for the evaluation of GI [39].

Based on the project data, the values provided in the toolkit's library, and the adjustments made to specific inputs (Sect. 3), the GiVal toolkit estimates an NPV for the benefits equal to € 409,245.

This amount reflects benefits related to climate change adaptation and mitigation, water management and flood alleviation, place and community enhancement, health and well-being, land and property value improvements, and recreation.As described before (Sect. 3), the benefits associated with labour productivity, land management, and tourism have not been included in this calculation, as the relevant data are not available at this stage of the project.

Moreover, the benefits related to biodiversity have been estimated as 0 € (Table 2). This is because, in the toolkit, the biodiversity-related benefits are calculated only for the areas specifically designated for nature and wildlife conservation. Considering that the NBS intervention under evaluation is an urban forestation intervention, this typology of intervention is not engaged in the category considered by the tool for the evaluation of biodiversity benefits. This aspect critically underlines the difficulty of considering the specific characteristics of NBS intervention in the urban context.

[3] Autorità di Regolazione per Energia Reti e Ambiente, 2025

Table 2. Economic benefits of urban forestation intervention evaluated with the GiVal toolkit.

Benefit	**Economic value [€]**
Climate Change adaptation and mitigation	17,878
Water management and flood alleviation	162
Place and communities	30,974
Health and well-being	203,910
Land and property values	7,396
Labor productivity	0
Tourism	0
Recreation and leisure	148,925
Biodiversity	0
Land management	0
TOT	**409,245**

Table 2 summarises the monetary contribution of each of the benefits considered, as reported in the "Summary of Economic Value" spreadsheet.

The evaluation provided by the tool, which estimates the monetary value of each benefit separately, is particularly useful for understanding which dimensions are most enhanced by the proposed NBS intervention. This perspective can also support ex-ante comparison and monitoring, helping to assess whether the project is moving in the right direction from the early stages.

Concerning costs, the tool does not provide any information or input data for estimating the implementation and maintenance expenses of the intervention. However, these are essential for properly developing the Cost-Benefit Analysis (CBA) and calculating the NPV, which requires both discounted costs and benefits. The costs have to be estimated separately and manually entered into the calculation tool.

In this case, the implementation and ordinary maintenance costs have been assessed in another study proposed by Torrieri and colleagues (2025) [40]. Therefore, the costs estimated through the Prezziario della Regione Lombardia have been implemented in the CBA spreadsheet.

Table 3 synthesises the estimated costs for the considered NBS intervention for urban forestation.

Table 3. Synthesis of estimation cost for forestation intervention (Torrieri et al., 2025).

	Cost [€]	**Source**
Implementation cost	563,056 €	Prezziario Regione Lombardia, 2023
Maintenance cost	150,759 €/year	Prezziario Regione Lombardia, 2023

The estimated costs have been entered into the CBA spreadsheet, and the discounted amount of costs has been calculated using a discount rate of 3.5%, using a 20-year time horizon consistent with the benefits evaluation. The time horizon has been set to 20 years, according to the fact that only ordinary maintenance costs.

Based on these inputs, the total amount of the discounted cost, considering both implementation and ordinary maintenance costs, amounts to € 2,360,080. Extraordinary maintenance costs have been excluded at this preliminary stage, as the Lombardy Region price list expresses extraordinary maintenance in €/tree, and at this preliminary stage of the project, the exact number of trees to be planted is not yet defined.

Table 4 summarises the estimated discounted amount for both benefits and costs and shows their combination for calculating the final NPV of the intervention.

Table 4. Synthesis of discounted costs and benefits and the estimated NPV.

	[€]
Discounted Benefits	409,245
Discounted Costs	–2,360,080
NPV	1,950,835

As can be observed, the final NPV is negative. It is also important to highlight that a relevant number of benefits have not been included in the evaluation due to the current state of development of the project. In particular, the benefits related to labour productivity, land management and tourism have not been considered, although their inclusion would likely lead to a significant increase in the total estimated benefits. Additionally, concerning the biodiversity benefits, the applied toolkit only accounts for those areas specifically designated for nature and wildlife conservation, limiting the estimation of these benefits in the urban context. It reveals that the model does not fully reflect the characteristics of urban-scale interventions.

Considering the GiVal toolkit as a support tool for project design in its early stages, the obtained results should suggest a downsizing of the intervention area (3.36 hectares), given the high implementation and maintenance costs of an urban forestation project and the limited economic value of the benefits compared to the initial investment.

However, in the context of public interventions that generate long-term benefits, such as NBS and urban forestation, the choice of the discount rate becomes particularly important. This is the rationale at the basis of the test carried out to address how the NPV changes with a lower discount rate. Specifically, the test explored the variation in NPV when applying a 2% discount rate. This discount rate has been chosen based on a 2006 study that advocated the use of a discount rate equal to 1.4% to evaluate the long-term costs and benefits of climate change mitigation actions [41].

Using the discount rate of 2%, an NPV of −1,592,431 € has been estimated. This result highlights and confirms that not estimating some benefits penalises in a significant manner the final NPV against a significant investment. Furthermore, a more structured and detailed sensitivity analysis is required to precisely determine which item among

discount rate, benefits and costs has the greatest impact on NPV. Also, the use of decreasing discount rates over time could be considered according to the long-term benefits concerning the implementation of urban forestation.

5 Conclusions

This research aims to answer the main research questions Q_1: "*How can the benefits of NBS in urban areas be effectively evaluated in monetary terms to inform and support strategic planning processes?*". Therefore, this application applies the GiVal toolkit to address its suitability for developing the preliminary economic evaluation of NBS in urban environments. The toolkit has been applied to estimate the economic value of an urban forestation intervention in Via dei Canzi, Milan, in alignment with the key objectives outlined in the City of Milan's Climate and Air Plan.

One of the main challenges in this field is the integration of environmental benefits into traditional CBA, a process that often requires expertise not easily accessible to many stakeholders [8]. The GiVal toolkit aims to bridge this gap by providing an accessible, evidence-based framework for estimating the potential benefits of GI interventions [35]. The proposed application permits underlining of both strengths and critical issues concerning the examined tool.

The most evident strength is that the GiVal tool offers a valuable initial insight into the spectrum of benefits provided by NBS and GI. It permits the identification of the different types of benefits related to the analysed NBS, ranging from leisure and recreation to less immediately tangible ones such as climate regulation, health and well-being, and property value increases. This categorisation supports the alignment of the intervention with the broader strategic goals of the local government. The second strength is represented by the robust methodological framework at the basis. By using the BT method [19], the toolkit enables a structured and methodologically consistent estimation of economic benefits even when context-specific valuation data is lacking. Moreover, the required input data are relatively easy to obtain from public or open-access databases, enabling context-based adjustments that enhance the reliability and applicability of the results (Sect. 3).

On the other hand, some criticalities have to be discussed. First of all, the default economic values within the toolkit are expressed in British pounds [£] and they are referred to periods which are different from the date of evaluation. Therefore, in the proposed application, all monetary values have been converted using exchange rates provided by the Bank of Italy and updated to 2024, to perform calculations in euros [€] and to be able to compare the benefits estimated by the tool with the costs estimated previously [40]. Moreover, it has to be underlined that these adjustments can introduce inconsistencies or errors without proper adjustments.

However, the main criticality concerns the absence of cost estimation support, within the lack of a module for preliminary estimating implementation, maintenance, and operational costs [8]. As a result, the tool cannot be used to perform a full CBA unless users provide costs estimated externally.

Furthermore, this tool is not able to properly consider the specific features and benefits provided by NBS implemented in urban contexts. As underlined in Sect. 4, the tool

only considers those areas specifically designated for nature and wildlife conservation for estimating the biodiversity benefits. In this sense, the NBS referred to the urban forestation cannot be considered for this estimation, thus limiting the estimation of these specific benefits in urban contexts.

The GiVal toolkit has been designed as a support tool for project design in its early stages for the preliminary identification and evaluation of the benefits of NBS interventions. However, considering that this tool evaluates long-term benefits, the issue of the choice of discount rate is fundamental [41], as the possibility of using a decreasing rate over time, given the wide period of benefits. Therefore, considering the peculiarities of the application described in this paper, the development of an in-depth sensitivity analysis is considered fundamental in the future phases of the research to understand which aspects among the discount rate, costs and benefits influence mostly the NPV. This analysis is even more necessary given the lack of estimating some benefits as NBS implemented on an urban scale (Sect. 4).

Moreover, some future research should be addressed to implement and integrate cost estimation modules (implementation and operational costs) in the GiVal toolkit to better support the early-stage planning of NBS in an urban context within a comprehensive perspective of costs and benefits [42, 43].

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References

1. Carter, T.R., Benzie, M., Campiglio, E., et al.: A conceptual framework for cross-border impacts of climate change. Glob. Environ. Chang. **69**, 102307 (2021). https://doi.org/10.1016/j.gloenvcha.2021.102307
2. Olivieri, F., Sassenou, L.-N., Olivieri, L.: Potential of nature-based solutions to diminish urban heat island effects and improve outdoor thermal comfort in summer: case study of Matadero Madrid. Sustainability. **16**, 2778 (2024). https://doi.org/10.3390/su16072778
3. Romanello, M., van Daalen, K., Anto, J.M., et al.: Tracking progress on health and climate change in Europe. Lancet Public Health. **6**, e858–e865 (2021). https://doi.org/10.1016/S2468-2667(21)00207-3
4. Faivre, N., Fritz, M., Freitas, T., et al.: Nature-based solutions in the EU: Innovating with nature to address social, economic and environmental challenges. Environ. Res. **159**, 509–518 (2017). https://doi.org/10.1016/j.envres.2017.08.032
5. Gómez Martín, E., Máñez Costa, M., Egerer, S., Schneider, U.A.: Assessing the long-term effectiveness of nature-based solutions under different climate change scenarios. Sci. Total Environ. **794**, 148515 (2021). https://doi.org/10.1016/j.scitotenv.2021.148515
6. Raymond, C.M., Frantzeskaki, N., Kabisch, N., et al.: A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environ. Sci. Policy. **77**, 15–24 (2017). https://doi.org/10.1016/j.envsci.2017.07.008
7. Cohen-Shacham, E., Andrade, A., Dalton, J., et al.: Core principles for successfully implementing and upscaling Nature-based Solutions. Environ. Sci. Policy. **98**, 20–29 (2019). https://doi.org/10.1016/j.envsci.2019.04.014

8. Dumitru, A., Garcia, I., Zorita, S., et al.: Approaches to monitoring and evaluation strategy development. In: Evaluating the Impact of Nature-based Solutions. A Handbook for Practitioners. EU Publications Office (2021)
9. European Commission: Nature-based Solutions: State of the Art in EU-Funded Projects. Publications Office of the European Union (2020)
10. Rossitti, M., Torrieri, F.: Circular economy as 'catalyst' for resilience in inner areas. Sustain. Mediterr. Constr., 64–67 (2021)
11. Masiero, M., Biasin, A., Amato, G., et al.: Urban forests and green areas as nature-based solutions for brownfield redevelopment: a case study from Brescia Municipal Area (Italy). Forests. **13**, 444 (2022). https://doi.org/10.3390/f13030444
12. Wickenberg, B., McCormick, K., Olsson, J.A.: Advancing the implementation of nature-based solutions in cities: a review of frameworks. Environ. Sci. Policy. **125**, 44–53 (2021). https://doi.org/10.1016/j.envsci.2021.08.016
13. Oppio, A., Caprioli, C., Dell'Ovo, M., Bottero, M.: Assessing ecosystem services through a multimethodological approach based on multicriteria analysis and cost-benefits analysis: a case study in Turin (Italy). J. Clean. Prod. **472**, 143472 (2024). https://doi.org/10.1016/j.jclepro.2024.143472
14. Sowińska-Świerkosz, B., García, J.: What are nature-based solutions (NBS)? Setting core ideas for concept clarification. Nat. Based Solut. **2**, 100009 (2022). https://doi.org/10.1016/j.nbsj.2022.100009
15. Tarantino, G., Bottero, M.C., Datola, G., Arco, E.: Implementation of Nature-Based Solutions (Nbs) for Urban Heat Island (Uhi) Mitigation Restoration of Green Brownfields in the City of Milan (2024)
16. European Environment Agency: Nature-based Solutions in Europe: Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction (2021)
17. Pearce, D., Ozdemiroglu, E., Bateman, I.J., et al.: Economic Valuation with Stated Preference Techniques. Edward Elgar Publishing (2002)
18. Roscelli, R.: Manuale di estimo. Valutazioni economiche ed esercizio della professione. UTET Università (2014)
19. Pearce, D.W., Turner, R.K.: Economics of Natural Resources and the Environment. Johns Hopkins University Press (1990)
20. Freeman, A.M., Herriges, J.A., Kling, C.L.: The Measurement of Environmental and Resource Values: Theory and Methods. Taylor & Francis (2014)
21. Croci, E., Lucchitta, B., Penati, T.: Valuing ecosystem services at the urban level: a critical review. Sustainability. **13**, 1–16 (2021). https://doi.org/10.3390/su13031129
22. Clawson, M., Knetsch, J.L.: Economics of outdoor recreation. In: Resources for the Future. Wiley (1966)
23. Bateman, I.J., Carson, R.T., Day, B., et al.: Economic Valuation with Stated Preference Techniques. Edward Elgar Publishing (2002)
24. Mitchell, R.C.: Using Surveys to Value Public Goods, pp. 7–9 (2013). https://doi.org/10.4324/9781315060569
25. Louviere, J.J., Hensher, D.A., Swait, J.D., Adamowicz, W.: Combining sources of preference data. In: Stated Choice Methods, pp. 227–251. Cambridge University Press (2000)
26. Wilson, M.A., Hoehn, J.P.: Valuing environmental goods and services using benefit transfer: the state-of-the art and science. Ecol. Econ. **60**, 335–342 (2006). https://doi.org/10.1016/j.ecolecon.2006.08.015
27. Zhou, J., Wu, J., Gong, Y.: Valuing wetland ecosystem services based on benefit transfer: a meta-analysis of China wetland studies. J. Clean. Prod. **276**, 122988 (2020). https://doi.org/10.1016/j.jclepro.2020.122988

28. Stanley, T.D., Jarrell, S.B.: Meta-regression analysis: a quantitative method of literature surveys. J. Econ. Surv. **3**, 161–170 (1989). https://doi.org/10.1111/j.1467-6419.1989.tb00064.x
29. Boyle, K.J., Bergstrom, J.C.: Benefit transfer studies: myths, pragmatism, and idealism. Water Resour. Res. **28**, 657–663 (1992). https://doi.org/10.1029/91WR02591
30. Johnston, R., Rolfe, J., Rosenberger, R., Brouwer, R.: Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners, Springer, Berlin (2015)
31. Mehvar, A., Filatova, T., de Ruyter van Steveninck, E., et al.: Quantifying economic value of coastal ecosystem services: a review. J. Mar. Sci. Eng. **6**, 5 (2018). https://doi.org/10.3390/jmse6010005
32. Bateman, I., Mace, G., Fezzi, C., et al.: Economic analysis for ecosystem service assessments. Environ. Resour. Econ. **48**, 177–218 (2011)
33. Comune di Milano (2023) Piano AriaClima
34. Abhijith, K.V., Kumar, P., Gallagher, J., et al.: Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments—a review. Atmos. Environ. **162**, 71–86 (2017). https://doi.org/10.1016/j.atmosenv.2017.05.014
35. Ashton, R., Baker, R., Dean, J., et al.: Building natural value for sustainable economic development. In: The Green Infrastructure Valuation Toolkit User Guide, p. 83 (2011)
36. Willis, K., Garrod, G., Scarpa, R., et al.: The Social and Environmental Benefits of Forests in Great Britain. Centre for Research in Environmental Appraisal & Management (2003)
37. England, N., Heritage, E.: Valuing and Funding Green Infrastructure, pp. 1–16 (2016)
38. Bonsignori R, Senes G (2022) Soluzioni progettuali tipo di infrastrutture verdi per la gestione delle acque meteoriche
39. Commission E (2014) Guide to Cost-Benefit Analysis of Investment Projects
40. Torrieri, F., Datola, G., Dell'Ovo, M., et al.: Integrating spatial analysis, ecosystem services and cost analysis for nature-based solution (NBS) planning in the urban context. Aestimum. (in press)
41. Stern, L.N.: Stern Review: The Economics of Climate Change. United Kingdom (2006)
42. del Giudice, V., Passeri, A., Torrieri, F., de Paola, P.: Risk analysis within feasibility studies: an application to cost-benefit analysis for the construction of a new road. Appl. Mech. Mater. **651–653**, 1249–1254 (2014). https://doi.org/10.4028/www.scientific.net/AMM.651-653.1249
43. del Giudice, V., Passeri, A., de Paola, P., Torrieri, F.: Estimation of risk-return for real estate investments by applying Ellwood's model and real options analysis: an application to the residential real estate market of Naples. Appl. Mech. Mater. **651–653**, 1570–1575 (2014). https://doi.org/10.4028/www.scientific.net/AMM.651-653.1570