The Benefit Transfer Method for the Economic Evaluation of Urban Forests

Francesco Sica[1(✉)] and Antonio Nesticò[2]

[1] Department of Architecture and Design, Sapienza University of Rome, Rome, Italy
francesco.sica@uniroma1.it
[2] Department of Civil Engineering, University of Salerno, Fisciano, SA, Italy
anestico@unisa.it

Abstract. The communities' interest in urban forestry is growing, recently also in order to face the COVID-19 pandemic crisis. Although the multiple benefits (ecosystem services) that forestry provides in cities are recognized by the international community, the issue of economic evaluation of each service in the context of urban renewal processes is still little debated.

This paper describes the Benefit Transfer Method (BTM) as a framework for estimating the total economic value of urban forests. This is done with the aim of outlining an economic model to support decision-making processes. The model is tested on a set of Italian cities. Research perspectives are in the conclusions.

Keywords: Economic evaluation · Ecosystem services · Benefit transfer method

1 Introduction

In the last decades of the twentieth century, contemporary cities are often characterized by uncontrolled urbanization, high air pollution, strong population growth with negative effects on the urban quality levels [1]. Thus, the need to put in place initiatives aimed at defending and preserving the urban ecosystem [2]. These are Nature-Based Solutions (NBS) projects with which to create healthy public spaces for people's well-being [3].

NBS include: *i*) the use and enhancement of existing natural elements (urban forestry); *ii*) the implementation of technologically innovative projects such as green walls or roofs on buildings [4–6]. NBS produce multiple benefits (ecosystem services) with which to mitigate the effects of anthropogenic actions on nature, contribute to the psycho-physical well-being of the population, and promote economic growth [7–9]. In support of NBS, the *Food and Agricultural Organization* (FAO) of the United Nations (UN) and the *Arbor Day Foundation* created the *Tree Cities of the World* program in 2018. This identifies forestry as a key action strategy for eco-sustainable urban development.

Although it is recognized that urban forests contribute significantly to the sustainable development of cities, public decision-makers do not often pay attention to forestry projects. This is due to *i*) the interest in preferring actions with immediate financial

This contribution is to be attributed in equal parts to the two authors

O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12954, pp. 39–49, 2021.
https://doi.org/10.1007/978-3-030-86979-3_3

returns; *ii*) the difficulty in including the economic value of the environmental and social effects of forestry in the economic evaluation of territorial and urban projects [10].

According to the relevant literature, the methods traditionally used for the economic valuation of ecosystem services connected to urban forestry are classified into *stated* and *revealed* preference valuation methods [11–13]. Through *stated* preference methods, the economic value of ecosystem goods and services is expressed in terms of the *Willingness-To-Pay* (WTP) of the community to conserve and/or implement the urban forest [13, 14]. *Revealed* preference methods, on the other hand, are based on the capture of economic prices of economic goods related directly, and not, to the environmental asset. The latter category includes the hedonic price method, commonly used to estimate the market value of the natural components through the marginal prices that determine mercantile valuations.

In addition to stated and revealed preference valuation methods, another assessment strategy is that of the *Benefit Transfer Method* (BTM). With the BTM, the economic values already declared in scientific studies for environmental goods and services can be used as a reference for further analyses conducted in territorial contexts with dissimilar characteristics [15]. The BTM is based on meta-analytical statistical methods in which variables representing the socio-economic and environmental aspects of the place under investigation are included [16]. Research shows that geographic referencing is vital for transferring values for spatially defined goods since location dictates value and this typically decays over increasing distance [17]. In the case of urban forest, the proximity to populations, their density, income levels are crucial drivers of the value provided by the forestation.

2 Work Aim

In relation to the above introductory framework, the research objective is to define an analytical function for estimating the total economic value of urban forests. This function is constructed according to the *Benefit Transfer Method* (BTM) principles.

In the following, *Sect.* 3 (*Materials and Method*) illustrates the set of bibliographical references from which the analysis variables are derived. An explanation on the statistical method based on the *Benefit Transfer Method* is provided. This for the construction of the meta-analytical regression function used to define the economic value of urban forests in the cities. *Section* 4 (*Result*) describes the value function derived from the meta-analysis conducted in literature. The same value function is then applied to a case study. Finally, *Sect.* 5 (*Conclusion*) reports conclusions and research perspectives.

3 Materials and Methods

The Benefit Transfer Method starts from the results of economic analyses relating to areas comparable with the territorial context of study. The method is divided into three steps:

1. literature analysis in which environmental, economic and social data of interest related to territorial contexts similar to the study area are reported (*literature search*);

2. identification and definition of the variables to be used in the statistical model at the base of the Benefit Transfer Method (*meta-analysis variables*);
3. construction of the regression function for estimating the economic, social and environmental value of the analysis asset (*meta-regression model*).

The 3 steps are described below in relation to urban forestry projects.

3.1 Literature Analysis

The analysis of current literature allows to select 13 scientific papers that have as reference Key-Words (KW): (KW1) «*urban forest*», (KW2) «*ecosystem services*», (KW3) «*Willingness-To-Pay*». We make the choice to assume data from the 13 papers as elements of the study meta-sample. Table 1 lists the 13 papers studied.

3.2 Meta-analysis Variables

The economic values of urban forests, expressed in terms of Willingness-To-Pay (WTP), are from the papers in Table 1. In addition to the information on WTP, the drivers that most influence the value of WTP according to each contribution are derived. These are socio-economic variables and morphological-environmental parameters.

Among the socio-economic variables found most frequently in the 13 analysis papers are GDP per capita and population density. Forestry parameters include the canopy cover and the ecosystem services. Ecosystem services are classified into four categories: Provisioning, Regulating, Cultural, and Supporting services [18, 19]. These categories are coded as dummy variables, i.e., variables that assume: unit value when the urban forest provides the i-*th* ecosystem service; zero value otherwise.

Table 2 summarizes the variables, of dependent and non-dependent type, examined for the construction of the meta-analytic value function. The mean value of each variable, calculated from the data collected from the 13 papers, is in the last column (*Mean*) of Table 2.

3.3 Meta-regression Model

Based on the variables in Table 2, the meta analytic function for estimating the economic value of urban forests is constructed.

Two methodological approaches are commonly used for constructing meta-regression models: the least squares method and the multilevel one [17, 20, 21]. The latter is employed for the meta-analytic function at the basis of the present work.

The *Multi-Level Method* (MLM) makes allowances for the variance and heteroscedasticity of the analysis variables [17]. Through the MLM the variance of the error term at each explanatory variable is estimated. This ensures, on the one hand, that the standard errors of the parameters of interest are more accurately calculated; on the other hand, that the coefficients linking the independent variables to the dependent variable are more accurately quantified [20–23].

In the present case, the dependent variable y_i gives the annual monetary value per hectare of the i-*th* urban forest in the investigation area. The explanatory and dummy

Table 1. Overview of valuation studies.

	Document title	Year	Source
1	Public preferences and willingness to pay for invasive forest pest prevention programs in urban areas	2020	Forests
2	Social valuation of regulating and cultural ecosystem services of Arroceros Forest Park: A man-made forest in the city of Manila, Philippines	2019	Journal of Urban Management
3	Economic valuation of the calden (Prosopis caldenia Burkart) forest in the south of Córdoba, Argentina [Valoraci n econ mica del bosque de cald n (Prosopis caldenia Burkart) en el sur de Cordoba	2018	Revista Chapingo, Serie Ciencias Forestales y del Ambiente
4	Value orientation and payment for ecosystem services: Perceived detrimental consequences lead to willingness-to-pay for ecosystem services	2018	Journal of Environmental Management
5	Effect of different personal histories on valuation for forest ecosystem services in urban areas: A case study of Mt. Rokko, Kobe, Japan	2017	Urban Forestry and Urban Greening
6	Atlanta households' willingness to increase urban forests to mitigate climate change	2017	Urban Forestry and Urban Greening
7	Willingness-to-pay for recreation services of urban ecosystem and its value assessment: A case study in the Wenjiang District of Chengdu City, China	2017	Shengtai Xuebao/ Acta Ecologica Sinica
8	Linking Forest to Faucets in a Distant Municipal Area: Public Support for Forest Restoration and Water Security in Albuquerque, New Mexico	2017	Water Economics and Policy

(*continued*)

Table 1. (*continued*)

	Document title	Year	Source
9	Land use influence on raw surface water quality and treatment costs for drinking supply in São Paulo State (Brazil)	2016	Ecological Engineering
10	Willingness to pay for maintenance of a nature conservation area: A case of Mount Wilhelm, Papua New Guinea	2016	Asian Social Science
11	Individual aesthetic differences evaluation of Yan'an urban forests in the loess plateau China	2014	International Journal of Multimedia and Ubiquitous Engineering
12	Scope for introducing payments for ecosystem services as a strategy to reduce deforestation in the Kilombero wetlands catchment area	2014	Forest Policy and Economics
13	Estimating non-use values of Anzali wetland using contingent valuation method	2010	Journal of Environmental Studies

variables used in the proposed model are processed in vector terms. The vector X_i^S includes the socio-economic characteristics of the reference urban context (*GDP per capita, population density*) and the morphological parameters of the urban forest to be evaluated from an economic point of view (*Canopy Cover*). The vector X_i^{ESS} Involves the dummy values of eco-system services related to forestry.

Each variable in Table 2 is log-transformed. This allows us to define the linear relationship between the dependent and independent variables ensuring a nearly constant degree of elasticity between factors.

The meta-analytic expression assumes the algebraic connotation of the type:

$$y_i = \alpha + \beta_i^S X_i^S + \gamma_i^{ESS} X_i^{ESS} + \mu_i \tag{1}$$

where the term μ_i represents the regression function error.

In logarithmic terms the meta-analytic expression is written:

$$y_i = e^{\alpha + \beta_i^S \ln(X_i^S) + \gamma_i^{ESS} \ln(X_i^{ESS}) + \mu_i} \tag{2}$$

4 Benefit Transfer Function for Urban Forests

The results of the meta-analysis conducted from the items in Table 1 are in Table 3. This reports the regression coefficients for each variable. The estimated coefficients express

Table 2. Variables set.

Variable	Description	Measurement Unit	Mean
Dependent Variable			
Willingness-To-Pay (WTP)	The value of urban forest in US dollars per hectare per year	\$/(ha·year)	1,689
Socio-economic and forest variables			
Canopy Cover (CC)	Size of the urban forest in ha	ha	1,465
Gross Domestic Product (GDP) per capita	GDP per capita in US dollars	\$	23,130
Population Density (PD)	Population density in number of people per square kilometer	inhab/sqkm	410
Ecosystem Services			
Provisioning (Pro)	1 = ecosystem service is provisioning of food, resources, 0 = otherwise	[0,1]	0.497
Regulating (Reg)	1 = ecosystem service is local climate regulation, 0 = otherwise		0.442
Cultural (Cul)	1 = ecosystem service is preservation of cultural heritage, 0 = otherwise		0.517
Supporting (Supp)	1 = ecosystem service is biodiversity preservation, 0 = otherwise		0.673

the percentage change in the dependent variable (annual $ value of urban forest per hectare) as a function of the percentage point change in the i-*th* explicative variable.

The results obtained illustrate that:

– The regression constant has a significant numerical value. It expresses the economic value of one hectare of urban forest per year provided that the explanatory variables are equal to the mean values (canopy cover = ln (1,465), PIL = ln (23.130) in USD, population density = ln (410) people per square kilometer);
– The coefficient relative to Canopy Cover (CC) is negative and statistically significant. This indicates that larger urban forests have a lower unit economic value than smaller forests, showing decreasing marginal appreciation in relation to the natural area size;
– The income, expressed by Gross Domestic Product (GDP) per capita, is positively and statistically significantly associated with the economic value of the urban forest

Table 3. Meta-regressions results.

Variable	Regression coefficient	
Constant	7.654	(***)
Socio-economic and forest variables		
Canopy Cover (CC)	−1.023	(***)
Gross Domestic Product (GDP) per capita	1.652	(***)
Population Density (PD)	0.356	(*)
Ecosystem Services		
Provisioning (Pro)	−0.319	
Regulating (Reg)	−0.475	
Cultural (Cul)	1.236	(**)
Supporting (Supp)	−0.360	

per hectare. This represents the scenario in which city dwellers with above-average incomes value nature more markedly;

– The population density is positively associated with the dependent variable. This means that in urban areas with higher population density the value per hectare of nature is higher than in areas with lower population density;
– With regard to eco-systemic services, low coefficient values were found for provisioning (Pro), regulating (Reg) and supporting (Sup) services. This is in contrast to services related to the aesthetics and conservation (Cul) of cultural heritage.

Based on the coefficients in Table 3, (2) is written as follows:

$$Value\,of\,urbanforest_i = e^{7.654-1.023[\ln(CC)-\ln(1.465)]+1.652[\ln(GDP)-\ln(23.130)]+0.356[\ln(PD)-\ln(410)]_i} \quad (3)$$

4.1 Application of the Transfer Function to a Case-Study

Function (3) is applied for the economic evaluation of urban forests in the cities of Milan, Rome, Naples and Catania. Information on canopy cover and the socio-economic system of the context in which the investigated urban forests are located is from European Urban Nature Atlas database (https://naturvation.eu/atlas; last accessed on 07/05/2021).

Milan, Rome, Naples and Catania have significantly different values of per capita income, population density and canopy cover. The size of the canopy cover in the selected cases varies between 1ha and 27ha.

Table 4 reports the values estimated by means of the proposed value function. Formula (3) returns the annual economic values per hectare of urban forest in relation to the socio-economic characteristics of the locality concerned.

Based on the results of Table 4, the *Ticinello Agrarian Park* of the Milan city records a total economic value per year of $121,625.49 higher than that of the urban forests of

Table 4. Meta-regressions result on urban forests in Italian cities.

	Milan	Rome	Naples	Catania
	Ticinello Agrarian Park	*Flaminio Park*	*Capodimonte Urban Park*	*Cibali Forest*
Socio-economic and forest variables				
Canopy Cover (CC) [ha]	35	27	10	20
Gross Domestic Product (GDP) per capita [$]	31,761	26,215	21,222	19,000
Population Density (PD) [inhab/sqKm]	16,947.74	2,030.12	26,398.74	1,585.32
Economic value per ha per year	$3,475.01	$1,479.48	$1,996.98	$816.57
Total economic value per year	$121,625.49	$39,945.99	$19,969.80	$16,331.37

Rome, Naples and Catania cities. The significant valuation of Milan's natural area from an economic point of view is certainly commensurate with the high values of GDP per capita and population density of the city, as well as the canopy cover of the urban forest. The implementation of (3) also provides a unit economic value of particular significance for the *Capodimonte* park in Naples city (1,996.98 $/ha·y). The numerical data obtained is due to the high population density of the study city context (26,398.74 inhab/sqKm), the highest among those of the four cities examined.

5 Conclusions

The urban forest provides multiple benefits to citizens. Valuation methods for estimating the economic value of ecosystem services are used in multiple case studies in the literature. The application of the *Benefit Transfer Method* is common. This method associates the economic values of urban forests in similar areas with the spatial context of analysis. The value transfer is adjusted by multi-level regression functions [24–27].

In this paper, a meta-analysis of the total economic value of urban forestry is conducted based on recent literature references. From the selected works information on the Willingness-To-Pay of the community to implement and/or preserve urban forests on the territory is found. The research allows to identify the variables that influence the urban forestry economic value: per capita income, housing density, canopy cover, eco-system services.

The meta-analysis conducted on the 13 papers shows the economic value of the urban forest is related to: the size of the natural area through the coefficient -1.023; income per capita and population density through the coefficients $+ 1.652$ and $+0.356$ respectively. In addition, the economic value of the urban forest depends on the ecosystem services that it is able to generate. The results in Table 3 provide correlation coefficients for recreational, regulatory (local climate control, noise reduction, and flood regulation), biodiversity, and habitat services. Significant correlation occurs with respect to cultural services.

The value transfer function makes it possible to derive in quantitative terms the interdependencies between the economic value of forestation and both the socio-economic characteristics of the territory and the ecosystem characteristics of the environmental resource under analysis.

The statistical relationship proposed for the estimation of the total economic value of urban forests (see paragraph 4) is tested on the cities of Milan, Rome, Naples and Catania. In particular, 4 natural areas are examined, one for each of the cities considered. The economic results obtained explain that the total economic value of the i-*th* forest is significantly dependent on canopy cover, GDP per capita and population density. The values obtained also suggest the existence of a proportional relationship between the total economic value and the production of ecosystem services.

Limits of the methodological approach are both in the selection of studied works, both in the parameters of multi-level regression function proposed.

Opportunities of future research developments by the proposed work consist in the definition of a quick evaluation method to assess the total economic value of nature-based elements in urban contexts as that of the urban forests in the cities.

References

1. Eurostat: Urban Europe — statistics on cities, towns and suburbs. Cat. No: KS-01–16–691-EN-N (2016). https://doi.org/10.2785/91120
2. Raymond, C.M., et al.: An impact evaluation framework to support planning and evaluation of nature-based solutions projects. report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom. 82p (2017)
3. Coscia, C., Lazzari, G., Rubino, I.: Values, memory, and the role of exploratory methods for policy-design processes and the sustainable redevelopment of waterfront contexts: the case of Officine Piaggio. Sustainability - Special Issue "Real Estate Economics, Management and Investments **10**(9), 2989, 1–22 (2018). https://doi.org/10.3390/su10092989
4. Elmqvist, T., et al.: Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment, p. 755. Springer, Cham (2013). https://doi.org/10.1007/978-94-007-7088-1
5. Sutton, P.C., Costanza, R.: Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. Ecol. Econ. **41**(3), 509–527 (2002)
6. Nesshöver, C., et al.: The science, policy and practice of nature-based solutions: an interdisciplinary perspective. Sci. Total Environ. **579**, 1215–1227 (2017)
7. Guarini, M.R., Nesticò, A., Morano, P., Sica, F.: A multicriteria economic analysis model for urban forestry projects. In International Symposium on New Metropolitan Perspectives, pp. 564–571. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-92099-3_63
8. Nesticò, A., Guarini, M.R., Morano, P., Sica, F.: An economic analysis algorithm for urban forestry projects. Sustainability **11**(2), 314 (2019). https://doi.org/10.3390/su11020314

9. Guarini, M.R., Morano, P., Sica, F.: Eco-system services and integrated urban planning. a multi-criteria assessment framework for ecosystem urban forestry projects. In Values and Functions for Future Cities, pp. 201–216. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-23786-8_11
10. Naumann, S., et al.: Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe. Final report to the European Commission. Ecologic Institute, Berlin, Germany and Environmental Change Institute, Oxford University Centre for the Environment, Oxford, UK (2011)
11. Dobrovolskienė, N., et al.: Developing a composite sustainability index for real estate projects using multiple criteria decision making. Oper. Res. Int. Journal **19**(3), 617–635 (2017). https://doi.org/10.1007/s12351-017-0365-y
12. Fregonara, E., Coscia, C.: Multi criteria analyses, life cycle approaches and delphi method: A methodological proposal to assess design scenarios | Analisi multi criteria, approcci life cycle e delphi method: Una proposta metodologica per valutare scenari di progetto. Valori e Valutazioni **23**, 107–117 (2019)
13. Champ, P.A., Boyle, K.J., Brown, T.C. (eds.): A Primer on Nonmarket Valuation. TENGR, vol. 13. Springer, Dordrecht (2017). https://doi.org/10.1007/978-94-007-7104-8
14. Nesticò, A., Endreny, T., Guarini, M.R., Sica, F., Anelli, D.: Real estate values, tree cover, and per-capita income: an evaluation of the interdependencies in Buffalo City (NY). In: Gervasi, O., et al. (eds.) ICCSA 2020, vol. 12251, pp. 913–926. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58808-3_65
15. Bergstrom, J.C., Taylor, L.O.: Using meta-analysis for benefits transfer: Theory and practice. Ecol. Econ. **60**(2), 351–360 (2006)
16. Johnston, R.J., Rolfe, J., Rosenberger, R.S., Brouwer, R. (eds.): Benefit Transfer of Environmental and Resource Values. TENGR, vol. 14. Springer, Dordrecht (2015). https://doi.org/10.1007/978-94-017-9930-0
17. Bateman, I.J., Jones, A.P.: Contrasting conventional with multi-level modeling approaches to meta-analysis: expectation consistency in U.K. Woodland Recreation Values. Land Econ. **79**(2), 235–258 (2003)
18. Millennium ecosystem assessment, M. E. A.: Ecosystems and Human Well-Being, vol. 5. Island Press, Washington, DC (2005)
19. TEEB: The economics of ecosystems and biodiversity: ecological and economic foundations. Kumar P. (ed). Earthscan, London and Washington.Tu, G., Abildtrup, J., Garcia, S. (2016)
20. Brander, L.M., Koetse, M.J.: The value of urban open space: meta-analyses of contingent valuation and hedonic pricing results. J. Environ. Manage. **92**(10), 2763–2773 (2011)
21. Schmidt, F.L., Hunter, J.E.: Methods of meta-analysis corrected error and bias in research findings. J. Am. Statist. Assoc. **20**(7) (2004). https://doi.org/10.2307/2289738
22. Zhou, P., Ang, B.W., Poh, K.L.: A mathematical programming approach to constructing composite indicators. Ecol. Econ. **62**(2), 291–297 (2007)
23. Sardi, A., Sorano, E., Cantino, V., Garengo, P.: Big data and performance measurement research: trends, evolution and future opportunities. Measur. Busin. Excell. (2020)
24. Podvezko, V.: The comparative analysis of MCDA methods SAW and COPRAS. Eng. Econ. **22**(2), 134–146 (2011)
25. Ferreira, F.A., Santos, S.P.: Comparing trade-off adjustments in credit risk analysis of mortgage loans using AHP, Delphi and MACBETH. Int. J. Strateg. Prop. Manag. **20**(1), 44–63 (2016)

26. Cerreta, M., Mazzarella, C., Spiezia, M., Tramontano, M.R.: Regenerativescapes: incremental evaluation for the regeneration of unresolved territories in East Naples. Sustainability **12**(17), 6975 (2020)
27. Morano, P., Tajani, F., Di Liddo, F., Amoruso, P.: The public role for the effectiveness of the territorial enhancement initiatives: a case study on the redevelopment of a building in disuse in an Italian small town. Buildings **11**(3), 1–22 (2021)