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Measuring the green efficiency in the settlements structure

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Misurare l'efficienza del verde nella struttura degli insediamenti

sommario

Table of contents/*Sommario*

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Measure the performance of urban green materials. Two models to support the implementation urban planning.

Valentina Adinolfi, Isidoro Fasolino

Abstract

The objective of this paper is to compare two models aimed at measuring the various functions and relative prestations of greenery in the urban planning of settlements at a detailed scale. The Ecosystem Services based model is aimed at assessing the performance of plant species based on the ability of the soil cover to provide Ecosystem Services, SEs. Through the attribution of scores to the SEs and with a multi-criteria calculation method, a summary performance evaluation is obtained, weighted according to the areas involved, or disaggregated by single indicators or by groups of them. A comparison between different scenarios allows you to make more conscious technical choices in relation to the design needs.

The Green features based model measures the level of efficiency in detailed design, of a multi-criteria type, through the use of indicators, measures the performance offered by urban green, based on its physical, phenological characteristics, etc. The value of the indicators is measured with respect to a Global Goal of environmental improvement, divided into Intermediate Goals, obtained through the grouping of Specific Goals.

For both models, by comparing the scenarios, it is possible to evaluate the choice of the optimal use of urban green, also with reference to the specific objectives of the implementation urban project. The limits and potentials of two models are presented and some lines of research development are outlined.

Keywords:
Land use, planning, ecology

Misurare le prestazioni degli urban green materials.
Due modelli a supporto dell'attuazione del progetto urbanistico.

L'obiettivo di questo lavoro è confrontare due modelli volti a misurare a scala di dettaglio le diverse funzioni e le relative prestazioni del verde nella pianificazione urbanistica degli insediamenti urbani. Il modello basato sui servizi ecosistemici ha lo scopo di valutare le prestazioni delle specie vegetali in base alla capacità della copertura del suolo di fornire gli ecosystem services, SE. Attraverso l'attribuzione di punteggi e con una metodologia di calcolo multicriteriale, si ottiene una valutazione sintetica della performance, ponderata per le aree interessate, oppure disaggregata per singoli indicatori o per gruppi di essi. Il confronto tra diversi scenari consente di effettuare scelte tecniche più consapevoli in relazione alle esigenze progettuali.

Il modello Green features based misura il livello di efficienza nella progettazione esecutiva, di tipo multicriterio, attraverso l'utilizzo di indicatori, misura le prestazioni offerte dal verde urbano, in base alle sue caratteristiche fisiche, fenologiche, ecc. Il valore degli indicatori è misurato rispetto ad un Obiettivo Globale di miglioramento ambientale, articolato in Obiettivi Intermedi, ottenuti attraverso il raggruppamento di Obiettivi Specifici.

Per entrambi i modelli, confrontando gli scenari, è possibile valutare la scelta dell'uso ottimale del verde urbano, anche con riferimento agli obiettivi specifici del progetto urbano operativo. Vengono presentati i limiti e le potenzialità dei due modelli e delineate alcune linee di sviluppo della ricerca.

Parole Chiave:
Usi del suolo, pianificazione, ecologia

Measure the performance of urban green materials. Two models to support the implementation urban planning.

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1. Introduction

The integration between natural environmental processes and urban processes is envisaged as an opportunity to create new forms of interaction between the anthropic and biological dimensions of the environment. By now the connection between urban planning, ecology and landscape is known, verifying the results produced and evaluating their effects, the role played by greenery within the urban environment is still marginal.

Urban green is an element of the built environment capable of promoting urban development aimed at improving life in the city. This capacity affects different components of the urban environment, such as landscape, atmosphere, water environment, soil and subsoil, ecosystems and biodiversity, public health, noise.

The purpose of this contribution is to measure the performance of green areas through the definition of a set of objectives in the use of the green itself, which has been reached with the creation of two models. The specific objectives are identified in the Green Features Based model (GFB), while the Ecosystem Services Based (ESB) model sees its application during a research phase where the identification of the indicators was not yet completed.

The ESB model considers the intervention space as a unicum, in which the built environment and the vegetated one develop at the same time. The green, as soil not artificially covered, is able to provide ecosystem services (SEs) with both direct and indirect benefits for humans, taking into account that the transformations of the soil involve the definitive loss of these numerous SEs.

The effectiveness and efficiency of green areas in producing benefits depend on various factors, such as the choice of plant species suitable for the environment, their adequate biodiversity, the correct design of the different types, and finally, the adoption of adequate techniques of planting and maintenance (Fasolino et al., 2020; Fasolino et al., 2020). At present, the scientific literature is lacking with respect to the definition of models or methods aimed at measuring the performance of urban green spaces in overall terms for a settlement. In fact, there is no attempt to measure the performance of urban green spaces through a holistic approach.

The second model, GFB, measures the efficiency level of urban green areas in detailed design: through a multi-criteria procedure and, through the use of indicators, it quantifies the performance offered by urban green, based on its physical and phenological characteristics. In the model, the value of the indicators is measured with respect to a Global Goal (GG) of green efficiency, divided into Intermediate Goals (IGs) obtained through the grouping of certain indicators aimed at measuring the performance of green spaces with respect to Specific Goals (SGs).

Finally, the two methodological proposals for the optimal use of greenery in the urban organization of the settlements are compared to highlight their limits and potential and trace some lines of research development.

2. Materials and methods

The urban project must be understood as an unavoidable hinge of the relationship between urban planning and the environment and as such must be equipped with appropriate tools and techniques. Green plays a fundamental role for the effective functioning of cities, from the point of view of environmental, energy, ecological and social parameters, offering its contribution in improving the quality of life of the present and future population (Dessì et al., 2018).

Different approaches to assessing the SEs provided by different land covers can be found in the literature. Some of them are based on matrices that, based on the opinion of experts (such as physical geographers, forest scientists and environmental engineers), associate each land cover class with a score related to the level of performance offered by each SE (Costanza et al., 1997; de Groot, 2010; Burkhard et al., 2012; Rodriguez et al., 2015; Santolini et a., 2015).

Among the global action programs, the 2030 Agenda defines Goal 11 of the Sustainable Development Goals, plans to make cities and human settlements "inclusive, safe, long-lasting and sustainable." (UN, 2015).

Trees, green areas and ecosystems more generally perform countless beneficial functions for public health and urban quality, through the related Ecosystem Services (Bolund et al., 1999; Chiesura, 2007; Chiesura et al., 2008; MATTM, 2018; Ezechieli, 2005; Silli et al., 2014, Williams, 2016).

The classification commonly adopted to differentiate the functions of urban greenery refers to the following 6 classes (Bovo et al., 1998): ecological-environmental function, which substantially contributes to mitigating the effects of deterioration and the impacts produced by the presence of buildings and anthropogenic activities; protective function, it provides an important protection and effect of the territory in degraded or sensitive areas (river banks, embankments, landslide hazard areas, etc.); hygienic-sanitary function that contributes, in the vicinity of healthcare buildings, to the creation of a support environment for the convalescence of patients, due to the presence of aromatic and balsamic essences, for the mitigating effect of the microclimate, as well as for the beneficial psychological effect produced by the enjoyment of a "well-tended green area" (Kaplan, 2001); social and recreational function that allows you to meet recreational and social needs, making the city more liveable and to the size of its inhabitants; cultural, didactic and scientific function constitutes an element of great importance both from the cultural point of view, favoring knowledge and respect for the environment, through the direct experience of nature, and teaching especially when the green is inserted in school structures and finally aesthetic-architectural function capable of improving the urban landscape and making the stay in the city more pleasant.

To act in the direction of settlement quality and sustainability, it is necessary to identify indicators that can measure these specific capabilities of green materials in urban planning (Toccolini, 2012).

The scientific literature relating to the use of indicators provides two fundamental examples that can provide useful support for the development of the proposed models.

An indicator aimed at measuring the ecological benefits of green surfaces is the well-known Biotope Area Factor (BAF) (Becker et al., 1990), measuring the overall permeability of a given coverage, it is particularly useful as it offers a flexible approach capable of reconcile densification and greening actions. The permeability of the territory can also be measured by the Reduction of the Building Impact (RIE) indicator (Bolzano Building Regulation) whose purpose is to mitigate the hydrological impacts of the context in which the new buildings are inserted, stimulating the creation of permeable surfaces.

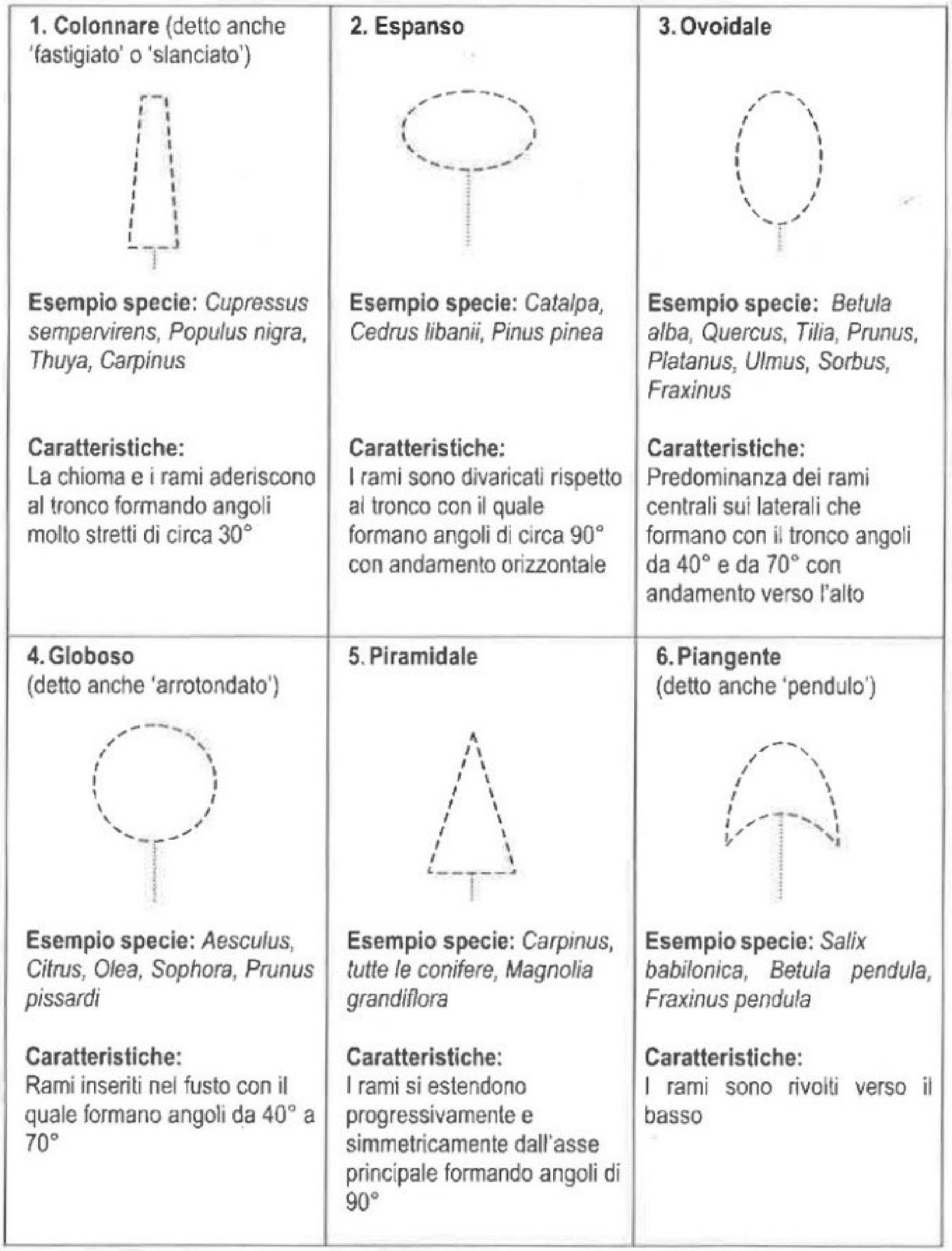
The urban green is chosen and arranged considering morphological, aesthetic, ecological, functional, as well as dispositive characteristics, due to possible interference, with respect to roads and buildings, for the safety of pedestrian and vehicular traffic (Chiesura, 2010).

The point elements are usually isolated trees or shrubs, mainly in the case of monumental specimens. The linear configuration includes the use of hedges, rows or combinations of green materials arranged in sequence. The massive configuration indicates groups of trees, groups of shrubs or a combination of trees and shrubs in order to form a compact plant mass. Green surfaces include lawns, green walls and green roofs.

In the urban environment, the fundamental factor for the choice of species and for the planting of trees is represented by the size of the plant itself and the space it needs for its development.

Tree plants are classified on the basis of dimensional requirements according to the height they reach at full maturity: first size trees (over 20 m), second size trees (between 10 m and 20 m), third size trees (do not exceed 10 m).

Based on the characteristics of the foliar apparatus, the essences are divided into broad-leaved and conifers: the former are broad-leaved species while the latter are characterized by needle-shaped or flake-shaped leaves. The shape and density of the crown are fundamental parameters for the choice of the species. For the different species, some recurring types of posture are identified: columnar (also called fastigiato or slender), expanded, ovoid, globose, pyramidal (or conical in the case of shrubs) and weeping (Ezechieli, 2005).



1. Colonnare (detto anche 'fastigiato' o 'slanciato')	**2. Espanso**	**3. Ovoidale**
Esempio specie: *Cupressus sempervirens, Populus nigra, Thuya, Carpinus*	**Esempio specie:** *Catalpa, Cedrus libanii, Pinus pinea*	**Esempio specie:** *Betula alba, Quercus, Tilia, Prunus, Platanus, Ulmus, Sorbus, Fraxinus*
Caratteristiche: La chioma e i rami aderiscono al tronco formando angoli molto stretti di circa 30°	**Caratteristiche:** I rami sono divaricati rispetto al tronco con il quale formano angoli di circa 90° con andamento orizzontale	**Caratteristiche:** Predominanza dei rami centrali sui laterali che formano con il tronco angoli da 40° e da 70° con andamento verso l'alto
4. Globoso (detto anche 'arrotondato')	**5. Piramidale**	**6. Piangente** (detto anche 'pendulo')
Esempio specie: *Aesculus, Citrus, Olea, Sophora, Prunus pissardi*	**Esempio specie:** *Carpinus, tutte le conifere, Magnolia grandiflora*	**Esempio specie:** *Salix babilonica, Betula pendula, Fraxinus pendula*
Caratteristiche: Rami inseriti nel fusto con il quale formano angoli da 40° a 70°	**Caratteristiche:** I rami si estendono progressivamente e simmetricamente dall'asse principale formando angoli di 90°	**Caratteristiche:** I rami sono rivolti verso il basso

Fig. 1 – Types of posture.
Source: Ezechieli, 2005.

Fig. 2 – Types of posture
Source: Image produced as part of the research activity

From the survey of the technical-scientific literature, of case studies of green design and from the opinion of experts, the LAI, Leaf Area Index or Leaf Surface Index, is identified as an important biophysical parameter for the study and characterization of terrestrial ecosystems, defined as "the total leaf surface that intercepts the light energy expressed in relation to the underlying soil area" (Watson, 1947; Asner, 2003).

$$LAI = \text{Total leaf surface } (m^2)/\text{Soil area} (m^2)$$

For example, in the case of broad-leaved species, in the calculation of the LAI, the sum of the surfaces, projected onto the ground, of the upper page of all the leaves of a tree is considered; in the case of conifer species, with needle-like leaves, the area of the exposed surface is considered.

It is an index that is related to the qualitative efficiency of the plant, such as shading, absorption and storage of CO_2, absorption of pollutants (dust and particulates), mitigation of the heat island and interception of precipitation (Novak, 1996).

However, there is an overall lack of indicators capable of measuring the performance of greenery with respect to the objectives selected in the context of this research.

3. Methodologies

3.1. ESB-Ecosystem services based model

Through the ESB model, the functions of the various categories of green materials and land cover are quantified, capable of providing benefits produced on the urban settlement by identifying the indicators capable of measuring the performance associated with the aforementioned functions.

Indicators are distinguished according to their greater or lesser importance for land use; standard (permeability, shading, microclimate mitigation, pollutant mitigation) and additive (windbreak effect, noise mitigation, visual screening, biodiversity, ecological corridor, spatial de-limitation).

Performance indicators are calculated by weighing the SEs scores provided by the different types of land cover for the respective areas and relating them to the total area.

The value measuring the performance of each indicator is obtained by summing up the products of the scores for the respective areas and dividing the result by the total area in order to weight the contribution of the individual cover. Through the grouping of some functions, two intermediate indicators have been constructed, between the individual ones and the synthetic one: Heat Island Mitigation (including permeability, shading and microclimate mitigation) and Environmental Wealth (biodiversity and corridor ecological).

Starting from the study of the literature, the first step in the construction of a matrix of scores is to select the land covers referring to the urban environment.

The next step sees the normalization of the scores provided by the matrices present in the literature, bringing the performance indices within a range of values between 0 and 5. Scores between 0 and 5 can be described as follows: 0 no ability; 1 low capacity; 2 relevant capacity; 3 medium capacity; 4 high capacity; 5 very high capacity.

The ultimate aim is therefore to obtain a matrix that allows to assign a score to each land cover based on the SEs provided by urban greenery. The scores assigned to the items in the matrix are attributed both by drawing on literature and manuals, but also based on the opinion of experts (agronomists, naturalists, botanists, environmental engineers).

3.2. GFB model - Green features based

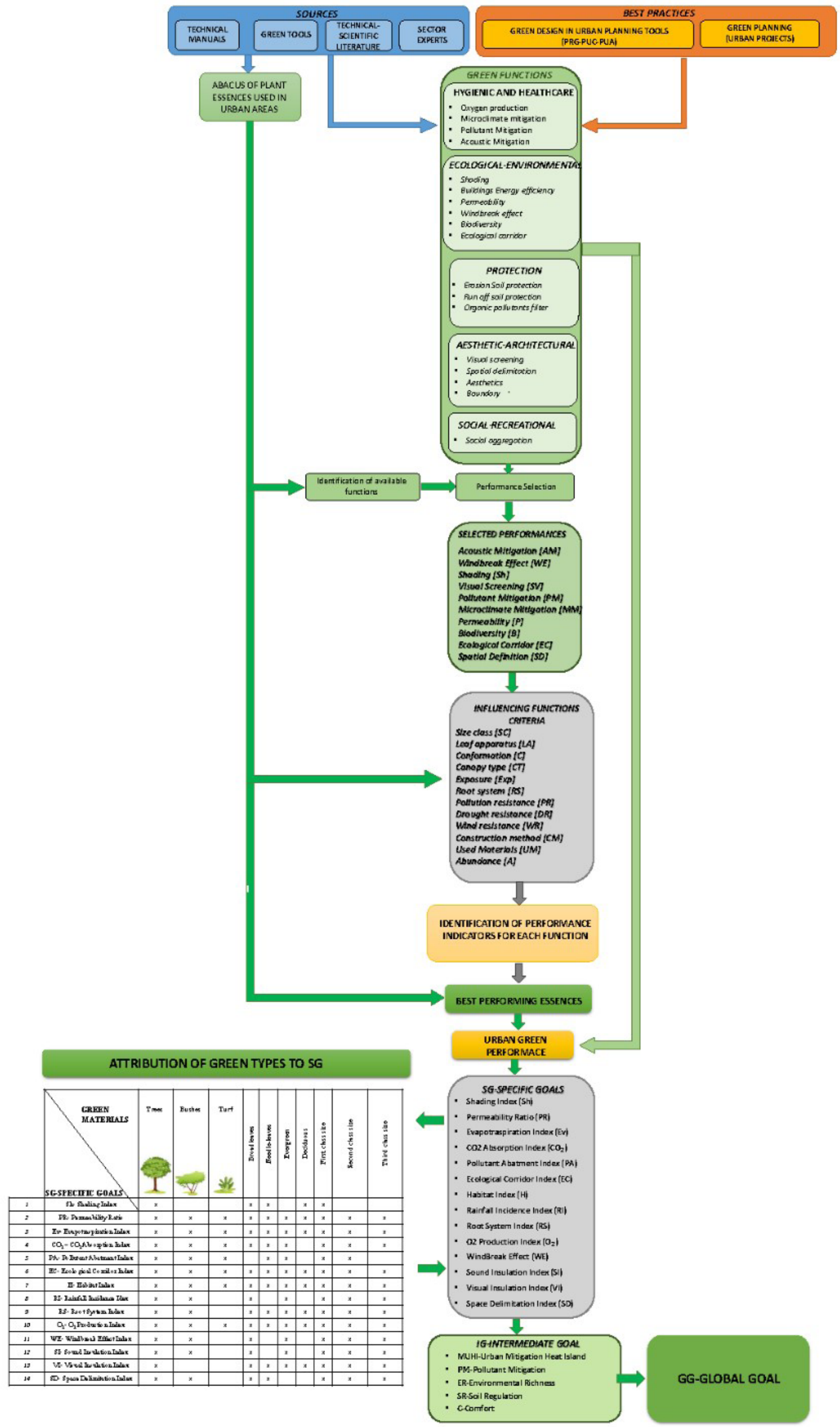
The GFB method, characterized by a level of research focused on the characteristics of the individual plant species, uses the support of experts, thus proceeding to the determination of a first general abacus of plant essences, to the identification of the services that can be provided by green materials, to their simplified quantification based on specific criteria. This leads to an abacus of the performance of green materials, which identifies the properties necessary to characterize each essence by virtue of their use in an urban setting for a specific function.

In order to define a methodology capable of quantifying the effects produced by the use of greenery, the following phases are carried out: definition of specific, intermediate and global efficiency goals; identification of functions and corresponding performance indicators; standardization of scores and weighting of performance indicators and finally the quantification of specific, intermediate and global goals.

The calculation of SGs in the presented model is done by means of geometries, which in turn are dictated by constraints and planning requirements. In particular, one cannot disregard the partitioning of the land area according to the proportioning, which in turn derives from the urban load and the functions envisaged in the area of intervention.

To understand how to achieve a high level of efficiency in the use of urban green areas

Fig. 3 – Methodology flowchart.
Source: Image produced as part of the research activity.



in detailed urban planning, it is necessary to define Intermediate Goals (IGs) of green efficiency, from which the Global Goal (GG) of efficiency is obtained, which can be achieved thanks to to particular performances offered by urban green spaces, quantifiable through the use of Specific Goals (objectives) (SGs).

Five IGs are identified, obtained on the basis of a convergence criterium, by grouping the IGs as follows:

Mitigation Urban Heat Island (MUHI), as the sum of Sh, PR, and Ev; Pollutant Mitigation (PM), as the sum of CO_2 and PA, Environmental Richness (ER), as the sum of EC and H, Soil Regulation (SR)as sum of RI e RS, and Comfort (C), as sum of O_2,WB,SI,VI and SD, identified with the analysis of scientific literature and expert opinions.

Each objective is a function of specific performances of green materials, quantifiable by appropriately chosen indicators, as they can be controlled from an urban planning point of view.

The evaluation of the global efficiency indicator (GG) takes place through the set of values of the Intermediate goals (IGs), each obtained from the sum of the respective values of the Specific Goals (SGs), which define it, appropriately weighted.

The urban basis is represented by the project plan, drawn on the basis of a functional subdivision deriving from the calculation of proportioning for the intervention area.

Starting from this project plan, for each land area it is possible to calculate the SGs indicators by initially evaluating the basic parameters: permeable surface; semi-permeable surface; number of trees (divided according to the size class); number of shrubs; number of hedges (specifying their thickness and total length); number of rows of trees with the respective planting spacing; number of rows of shrubs with the respective planting spacing; number of mixed rows, with respective planting layout and the perimeter of the lot.

4. Application

4.1. ESB-Ecosystem services based model

The ESB method was applied to the a specific zone of the urban plan of the Municipality of Fisciano.

The total area of 49,549 m2 is partly occupied by the transformed lots and to a greater extent by uncultivated land and cultivated vineyards, orchards and citrus groves; the transformed lots are for residential and commercial use.

The performance indices are then calculated, both standard (permeability, shading, mitigation of the microclimate, mitigation of pollutants) and additional ones (windbreak effect, acoustic mitigation, visual shielding, biodiversity, ecological corridor, delimitation of spaces), weighing the scores of the SEs provided from the different types of land coverings for the respective areas and relating them to the total area.

In other words, each index was obtained by summing the products of the scores for the respective areas and dividing the result by the total area, in such a way as to weigh the contribution of the single coverage.

By examining the performance indices for each scenario, it emerges that the standard component of these indices has the greatest impact on the performance provided by the green.

Among the standard performance indices, the ones that show the greatest increase according to the scenarios and that, therefore, have the most influence on the performance provided by green materials, are the mitigation of the microclimate and the mitigation of pollutants. On the contrary, what has a minor impact on performance turns out to be shading.

Fig. 4 – Optimum scenario processing result. Source: Image produced as part of the research activity.

4.2. GFB-Green features based model

The GFB method is applied to the same area as the first method, so as to emphasise the comparison between the two methodologies.

The application of the model to the case study, preceded by a phase of proportioning the same, is divided into the following phases:

- representation of scenario 0: the actual state is reported;
- assessment of scenario 0: the contribution of the green of a scenario is assessed in which the arrangement and choice of the type of green materials is of an ordinary type

Fig. 5 – Optimum scenario processing result. Source: Image produced as part of the research activity.

in the implementation planning practice;

- scenario 1 project: a new scenario is planned in which, with the same function and covered area, the green materials are carefully chosen and arranged with the criteria and purposes previously described;
- assessment of scenario 1: the contribution of the green of the new scenario is assessed;

Through the evaluation of the performance indicators and the quality goals, the differences between the scenarios are examined and evaluated.

These parameters allow the calculation of the performance indicators and, following the standardization and possibly weighing operations, the calculation of the Intermediate Goals, (IGs), obtained by grouping the individual performance indicators, (SGs), and, subsequently, of the global target indicator (GG).

The GG, IGs and SGs indicators allow you to evaluate the actual contribution of greenery and compare different urban green projects, in order to obtain an efficient planning that makes the most of the functions that green materials are able to provide, maximizing their performance. The model provides the definition of two Scenarios, 0 and 1, from the comparison of which it is possible to verify how the optimal Scenario 1 presents an increase in efficiency.

This emerges more by analyzing the values of the IGs in which there is approximately a doubling of many of the parameters, which therefore leads to an increase in the value of the Global Goal GG.

5. Discussions and conclusions

The study proposes a comparison between the two models which aim to define a methodology to be used in the design choices of implementation urban planning, at the scale of the settlement towards the conscious use of green materials and towards the full exploitation of their performance.

The objective of both methodologies is to provide support for the choices for the use of urban green in the implementation urban planning, which can be applied independently by the planner, but it is essential to make a premise for this study: the presented models have a different mode of application as they relate to two different moments of the research.

Faced with the application of both models, it is possible to arrive at a series of considerations.

The ESB model, relating to a first phase of research, allows to analyze and compare different projects, identifying the best design solutions in terms of efficiency in the use of green materials, according to the capacity of the ground cover to provide certain SEs. This model focuses on the SEs provided by the various soils, revealing itself to be a useful application tool capable of identifying the most performing design solutions in terms of efficient use of green materials in covering urban soils, which can be controlled by the urban planner. Despite this, the main criticality encountered is the passage of scale between the technical-scientific literature in which the applications concern natural or in any case extra-urban contexts on a large scale and, vice versa, the scope of application of this methodology, which is specifically urban and local.

In the future, an in-depth study is envisaged regarding the ecosystemic value of soils at the urban scale, as well as a direct involvement of experts, such as agronomists, botanists, naturalists, environmental engineers and landscape architects, in a multidisciplinary perspective.

It is therefore believed that this study can serve as a basis for further verifications and refinements, as well as a calibration to be obtained by applying to different case studies with different characteristics.

The GFB model, relating to a second phase of research, offers the possibility of a precise control of the performance of the green area, both in terms of land surfaces and individual, aggregated and overall functions; in particular with regard to both the individual specific SGs Goals and the Intermediate and Global Goal of the IGs and GG.

The value of the indicators is measured in relation to a Global Goal (GG) of green efficiency, broken down into Intermediate Goals (IGs), obtained by grouping together certain indicators aimed at measuring green performance in relation to Specific Goals

(SGs).

The Goals (SGs, IGs, GG), defined in the context of the GFB model, can also be assumed as goals of the ESB model in the development of research relating to the latter.

The comparison between different project Scenarios allows you to choose the one that maximizes the efficiency in the use of urban greenery, allowing you to make the most of its potential as it is based on the search for the best combination between the choice of greenery and the urban functions to be performed.

The main difference in the construction of the Scenarios is related to the type of approach followed: while Scenario 0 is supposed to be characterised by low performance values, linked to a traditional project development, the distribution in Scenario 1 is characterised by specific objectives, defined through the application of SGs: in fact, it is the model itself that is set up as a guide to the project.

The model lends itself to flexible use and can therefore be considered as a decision support for the designer. It represents, in fact, a reference for evaluating and improving certain aspects in the project. It is possible, in fact, to create a project Scenario and, through the model, intervene on the aspects that af-fect the value of the indicators at the various levels, from the most detailed to the global ones (SGs, IGs, and GG) and, therefore, a control tool to identify possible design errors.

Otherwise, a range of Scenarios can be created and, on the basis of the indicator values for the Global Goal (SGs, IGs, and GG), choose the optimal one, the one that performs best.

Despite the limitations mentioned, it is believed that the study could be the basis for a more flexible and calibrated methodology. In fact, the GFB model reveals a significant gap in the specific literature as it does not provide exhaustive technical indications, aimed at the design, evaluation and measurement of certain green performances, such as for example in relation to biodiversity, as regards the identification of ecological micro-corridors or urban micro-habitats in terms of minimum extension or efficiency parameters.

Furthermore, the methodology allows the comparison, as seen in the application, between project Scenarios of the same intervention area, but does not allow the quantitative comparison between urban projects on different areas.

In the perspectives there is the possibility of deepening the analysis of the technical-scientific literature to fill the deficit related to the identification of suitable indicators useful for measuring certain performances. Furthermore, it is necessary to verify the model with respect to some necessary approximations made, deepening the procedure for assigning weights in the multi-criteria analysis and, finally, strengthening and extending the interdisciplinary involvement for the purposes of refinement and validation of the model.

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