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VIRIDIS LOCI

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Vademecum for sustainable urban green planning

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Result type: Methodologies / guidelines – Methodological framework for implementation

Vademecum for sustainable urban green planning

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1. Project description

The Viridis Loci (VL) project aims to provide specialised VET training/transfer of skills in the correct management of green areas and parks in municipalities to public technicians and private subjects who are interested in dealing with an advanced professional management of urban nature in three European islands: Sardinia, the Balearic Islands and Madeira. The Czech Republic will contribute to the development of the project as one European country where 'the culture of well managed green areas in cities as providers of ecosystem and social services for the whole community' is deeply rooted, considering the role and the presence of Czech's partner too.

The project partners come from four European countries, Italy, Spain, Portugal and the Czech Republic. The Italian partners are ANCI Sardegna (project leader), Fito-consult and ATM Consulting; the Spanish partner is FELIB (Federation of municipalities of the Balearic Islands); the Portuguese partner is AREAM (Regional Agency of Energy and Environment of the Autonomous Region of Madeira). The Czech partner is ABA International (a 'non profit' international education association and certification body).

The consortium presented this project for three main reasons:

1) Environmental sustainability and the fight against climate change: it emphasises the role of well-managed green areas/parks within cities and municipalities in general as providers of ecosystem services (benefits that people obtain from nature, e.g.,, climate regulation, CO2 capture, air quality improvement, cultural values, public health and biodiversity conservation).

2) Increase Inclusion. The project will operate in three island contexts in southern Europe, which due to their geography, tend to be isolated and at a permanent economic disadvantage compared to other regions of the continent

3) Overcoming the knowledge gap with the use of ICT technologies to impart a highly technological and innovative working methodology.

The project will operate in three island contexts in southern Europe, which due to their geography, tend to be isolated and at a permanent economic disadvantage compared to other regions of the continent. Islands tend to lag behind in economic terms and innovation processes negatively impact the communities residing on the islands. Unemployment rates in the three islands are high with dramatic peaks among young people and in all cases higher than the respective national averages: Sardinia (18% - youth unemployment around 45%), Balearic Islands (youth unemployment 17% - around 40%) and Madeira (10% - 50.5% youth unemployment).

2. Aims of the document

The “Vademecum for sustainable urban green planning” is a key result within the Viridis Loci project offering. Indeed, the following document aims at:

- introducing new concepts and skills, targeting the stakeholders active in urban and territorial planning;
- proposing digital solutions capable of quantifying the environmental benefits (namely, ecosystem services) offered by urban vegetation;
- improving awareness among the stakeholders regarding the benefits of urban vegetation and nature-based solutions.

This will lead to a more aware urban planning and maintenance and therefore to an increase of the sustainability in urban areas.

The Vademecum directly replies to a growing need, as it appears clear engaging with stakeholders and citizens, interested in new and innovative methodologies to evaluate and assess urban vegetation, including digital ones. The document is to be seen as a compass to navigate through novel concepts and as a starting point to learn about latest digital solutions that can be applied at urban level. Nevertheless, for the ones particularly interested in applying the exposed methodologies, it might be useful to further explore relevant literature (see Appendix) and to keep in mind that each environment has its own specific characteristics, and therefore, calibration and validation in specific environments might be needed as well.

Overall, the need for proposing a Vademecum capable of picturing a new approach to assess, manage and plan urban green vegetation comes from the increasing importance and complexity that today urban green infrastructures cover. Indeed, it is clear that they improve the quality of life of urban inhabitants and to reach Agenda 2030 goals, including environmental, social and economic sustainability.

Due to this increased importance and to a growing sensibility between citizens too, in the last years, many development projects at city-level had to consider the environmental and socio-cultural role of the urban green areas under a renovated light. This because "urban regeneration" became a priority. However, today, there are no accepted frameworks to assess and evaluate the value of the urban vegetation and the ecosystem services provided. This results into projects that often do not bring tangible improvements of urban environments, or, in best scenario, improvements that can not be quantified.

Indeed, currently available evaluation frameworks offer qualitative and subjective results, with numbers and a possible economic value depending on a limited set of indicators, often derived from other scientific branches and adapted to urban ecosystems.

Therefore, the need for a novel approach, with the characteristic of being quantitative. At its core, urban vegetation and ecosystem services quantification. Urban vegetation – encompassing all trees, shrubs, lawns, and other vegetation in cities –, if adequately managed, can play an important role to ensure a good quality of life and meet the challenges set by Agenda 2030, helping to reach several Sustainable Development Goals: indeed, in urban environments it can provide several ecosystem services, such as air purification, global climate regulation, temperature regulation, run-off mitigation as well as recreational opportunities, increasing aesthetic values. In a few words, urban vegetation can help make cities safer, healthier, wealthier and more attractive, with benefits grouped in social, communal, environmental and economic categories.

Although this central role, urban vegetation is not often considered a priority by decision-makers, so that budgetary resources are allocated to other areas, perceived as more important. Even worst, most of the time, it is just seen as a cost, even if studies showed that the benefits of urban trees outweigh the costs by ratios of between 1,37 and 3,09, with an estimated value of the provided ES of US $3,8 billion per year in the United States of America. Thus, despite years of researches and because urban environment differs from the natural one, urban vegetation lives in inhospitable conditions, so that its lifespan is limited – an urban tree lives on average between 19 to 28 years – impacting their ability to provide long-term benefits. Because of this, in the last years, many researchers have begun to develop strategies to enhance the impact of nature on human settlements, giving a primary scientific role – yet with many possibilities of growth – to urban nature, its implementation and its management, which is crucial to ensure the optimal contributions to the physiological, sociological and economic well-being of urban societies. Urban vegetation should be studied with an integrated, interdisciplinary, participatory and strategic approach to planning and managing its presence in and around cities. Therefore, being an interdisciplinary matter, urban vegetation planning and management is highly complex, having to deal with several topics, such as landscape ecology, arboriculture, urban planning and environmental sciences; meanwhile satisfying the different interests of the stakeholders – mainly, citizens, public authorities, researchers and the involved industries.

Today, these topics need for a strong research support to achieve a long-term development, which should address four major components:

1. the conservation, implementation and adaptation of natural areas within cities, in order to improve their fitness to the urban environment, therefore enhancing the provided ecosystem services;
2. the spatial configuration of the urban green areas: well-designed and planned systems can assure better conservation of biodiversity, linking rural and urban areas;
3. the management of the urban vegetation – an aspect that still needs to be deeply examined – developing local and tailored plans, thus being able to satisfy peculiar needs;
4. an improvement in decision-making processes needs to be more participated and transparent with quantitative data provided by reliable frameworks.

The following document wants to represent a first trials in this direction, showcasing a methodology and tools that can be implemented in urban contexts to reach a more aware level of management.

3. Ecosystem Services – definitions

Viridis Loci's partners are deeply rooted in stakeholders' views, and therefore the partners believe that it is needed to properly introduce and define the concept of Ecosystem Services.

The term Ecosystem Services (ES) was introduced in the early 1980s and then developed in the following decade, mainly thanks to the researches of Daily and Costanza. The latter conducted one of the first global estimation to calculate the overall value of the ES annually provided by Earth to humanity, with a resulting amount between 16,000 and 54,000 billion dollars. These studies led to further researches developed in limited fields, that were first integrated on an international scale thanks to the Millennium Ecosystem Assessment. Here, ES are defined as the benefits that humanity obtains, or can obtain, from ecosystems. Costanza proposed 17 types of ES, while MEA reduces them to 4 main categories, strongly underlining the close relationships – with different potentiality and intensity – between ES and human well-being in terms of security, essential material provision, health and social relations – all aspects fundamental to guarantee freedom in choices and actions. MEA analyses ES concept applying the idea of direct use value (to indicate benefits derived from the direct use, whose value can be obtained via surveys), or indirect (to indicate benefits derived from processes, thus not directly available, such as processes that lead to soil formation, water purification, pollination...). Moreover, MEA adds the declination of ES value in different individual and future levels (indicating the value we are willing to assign to the need for conservation and transmission to the next generations of natural resources, therefore not using a part of the available natural resources).

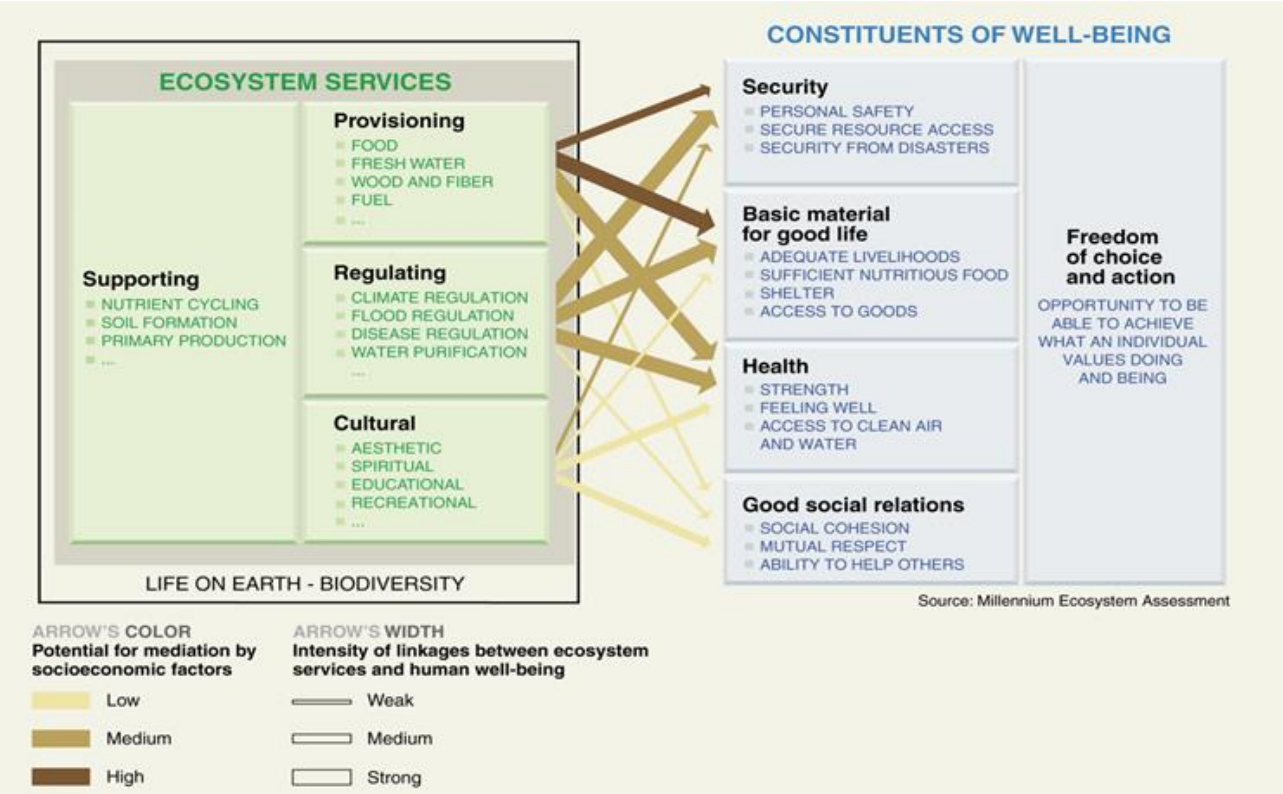

Fig. 1 Ecosystem services, their classification and relationships with human well-being. Source: Millennium Ecosystem Assessment, 2005.

MEA represents a fundamental milestone: not only it defines the four ES categories, but it raises academic and stake-holders attention on the state of degradation of natural environments, since more than 60% of the ES were classified as at risk.

The four categories include provisioning services (e.g., material goods such as food, drinking water, timber, fibres, medicinal plants); regulating services (e.g., environmental processes that have effects on the natural capital as well as anthropogenic activities), and cultural services (e.g., mainly non-material, such as spiritual enrichment, cognitive development, recreational activities, aesthetic values and experiences, knowledge systems, social relationships). To these three main categories, supporting services were added, to indicate fundamental processes – e.g., the production of atmospheric oxygen, the formation and protection of the soil, the water cycle, the formation and maintenance of habitats – necessary to maintain the first three categories.

In the latest years, the ES concept gained even more importance thanks to Agenda 2030 and the achievement of its goals, that underline the importance of providing ES for human well-being: e.g., Agenda's 11 goal highlights the need for sustainability in our cities, setting precise targets that should be reached within 2030:

- *11.6 Reduction of the per capita negative environmental impact, paying particular attention to air quality and urban waste management.*
- *11.7 Provision of universal access to safe, inclusive and accessible green public spaces, especially for women, children, the elderly and persons with disabilities.*
- *11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas, strengthening national and regional development planning.*
- *11.b Considerable improvement of cities adopting and implementing integrated policies and plans to foster inclusion, resource efficiency, climate change mitigation and adaptation, disaster resistance, that promote and implement holistic disaster risk management at all levels, following the Sendai for Disaster Risk Reduction 2015-2030.*

Therefore, it is essential to preserve, improve and implement green areas in urban and peri-urban areas, enhancing and evaluating ES provision, to achieve Agenda 2030's ambitious goals, and guarantee sustainable and pleasant environments for citizens inhabitants.

4. Ecosystem Services analysis and quantification

From this academic starting point, Viridis Loci's partners aim at translating into practical and appliable guidance to everyday working situations, with a focus on what urban vegetation can offer in terms of Ecosystem Services. In recent decades, many studies have shown the importance of urban vegetation and urban trees in providing ecosystem services. These include capturing rainwater and cooling the built environment, capturing pollutants from the air. As stated, until recently, it was not possible to measure and give a financial value to these ecosystem services. There was too little concrete knowledge about the benefits of green space for our cities.

Currently, different methodologies are available to conduct an analysis of urban trees. Most of the times, the evaluation goal is to establish the economic values of trees and/or the tree risk assessment. In example, a widespread system in Italy is based on the evaluation of fixed factors - the definition of which is partly left to the subjectivity of the evaluator - multiplied by a price coefficient, called "unit price", which is a tenth of the price of a tree with ten cm² of basal area (e.g., having 3.57 cm in diameter or 11 cm in circumference), taken from a nursery Price List. This methodology considers different tree parameters (aesthetic value, phytosanitary status, size and position) multiplied by the economic value to reach an overall economic value of the tree. However, most of the times, the end-value is very low when compared to the actual tree sizes and dimensions: e.g., it is clear that a tree with a circumference of 11 cm can not be considered equal to a mature specimen with a circumference of more than 200 cm. Therefore, the information coming from this kind of evaluation are often misleading and not accurate.

Regarding tree risk assessment, usually, evaluators follow specific protocols – e.g., ISA protocol – to evaluate tree static conditions and then decide the necessary interventions according to a logical process based on four fundamental phases: anamnesis, diagnosis, prognosis and prescriptions. The goal is thus different and does not include ecosystem services quantification, but it mainly refers to risk management. In the more common protocols, the first fundamental step is to individually evaluate each tree, filling out a VTA (Visual Tree Assessment) form, which reports the tree characteristics and any visible defects, with general information about the environment in which it is rooted. If necessary, the evaluator can deepen the analysis with appropriate tools and techniques (e.g., dendrodensimeter, sonic tomography, pulling tests with SIM method) in order to further investigate the stability of a tree, with the final attribution of a grade (A, B, C, C/D, D), which represents the propension at the failure, establishing re-checks in the following years, or tree care maintenance or removal (grade C/D and D) to be performed immediately.

So, how is it possible to assess and quantify the ecosystem services offered by urban trees?

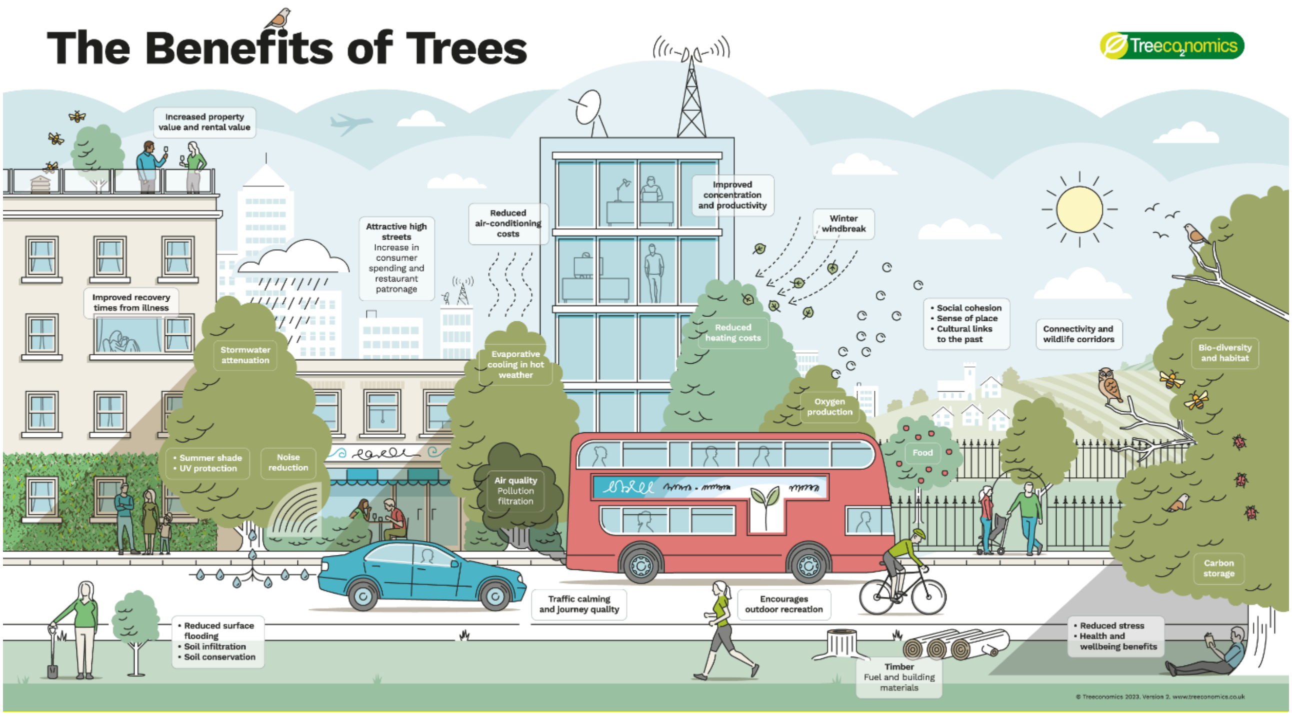

Fig. 2 The various benefits offered by trees in urban areas. Credit: Treeconomics

Among different tools that have been developed in the last years, the most accurate and spread is I-Tree, developed by the United States Department of Agriculture (USDA). This software can calculate different benefits provided by trees and shrubs in urban environments. A partnership between the USDA Forest Service and various collaborators (including The Davey Tree Expert Company, The Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, and Casey Trees) released I-Tree in 2006. I-Tree, rooted in the Urban Forest Effects (UFORE) program utilized by the USDA Forest Service to assess the diverse benefits of trees in specific locales, stands out as a peer-reviewed tool, accessible to all without charge. Users actively contribute to its ongoing evolution. I-Tree extended its reach across numerous European countries, incorporating local tree species and harnessing weather and pollution data sourced from European monitoring stations, facilitated by The European Environment Agency (EEA). Recent data, spanning from 2015 to 2020 for select weather and pollution monitoring stations, underpins the ecosystem service computations within I-Tree. This integration of European data empowers users to tailor analyses to their specific locales by selecting corresponding monitoring stations: by 2021, the global community of I-Tree users surpassed 622 000, with over 93 000 users operating outside the US.

I-Tree is made of 11 different software, such as Landscape, County, Design, Hydro etc.

Figure 3: Overview of the I-Tree Suite, with the different freely available software. Source: I-Tree.

Each of these hones in on distinct aspects, whether it's specific ecosystem services like Hydro, which delves into land use effects on water management, or varied scales like I-Tree landscape. I-Tree Canopy and Eco stand out as the most utilized and fitting for European contexts, as they integrate weather and air pollution data. I-Tree Canopy operates online and suits larger areas such as neighborhoods, districts, and cities. On the other hand, I-Tree Eco, available as a free desktop download, spans from individual trees to entire tree stocks within a designated area. I-Tree Eco is by far the most utilized software, offering insights into three crucial facets of a city or area's tree inventory: structure, function, and economic value. Calculations with I-Tree Eco can stem from a comprehensive inventory or a plot study. The latter method, employing a selection of randomly distributed plots measuring 22.6 meters in diameter across the project area, yields a holistic overview of the local tree stock's structure, function, and value—both public and private. A plot study proves particularly adept for implementing I-Tree Eco across expansive regions like entire cities or forested areas. By surveying a minimum of 200 plots, an accurate portrayal of ecosystem services across the project area emerges. Conversely, a full inventory encompasses all trees within the designated area, exemplified by the Million Tree Project in New York City, which inventoried all 592,130 municipal trees, marking a pioneering large-scale implementation of I-Tree Eco. To conduct an I-Tree Eco calculation, essential data like species and trunk diameter at the individual tree level is required. I-Tree then utilizes this information to model each tree, facilitating leaf area calculations. For enhanced precision, additional data inputs such as land use, tree height, crown dimensions, health status, and light exposure are recommended. The accuracy and comprehensiveness of this data significantly influence the resulting ecosystem service calculations. Data can be imported into the application via various means like Excel or inputted directly. After ensuring data completeness and accuracy, it is submitted to the US-based server for i-Tree calculations. Within a short timeframe, typically a few hours, users receive notification to retrieve the results from the application.

The parameters used by I-Tree as input are different and numerous. The software, thanks to these inputs, can calculate the following outputs:

- Structure and composition of the urban forest,
- Carbon storage and Carbon sequestration,
- Oxygen production,
- Atmospheric pollutants removal (PM 2,5; O_3; NO_2; CO),
- Effects on water cycle (avoided run-off).

For each of these outputs, the software – in addition to the quantification – can calculate an economic value, corresponding to the quantities removed multiplied by monetary coefficients. Each output is quantified thanks to the use of different mathematical models calibrated and validated for each simulation, with high reliability, certified by multiple peer-reviewed scientific papers, as well as by other case studies concerning urban forests analysis in different parts of the world.

Structure and composition of the urban forest

The overall set of urban trees forms the so-called urban forest. Understanding the actual urban forest composition is crucial to properly assess and quantify the provided ecosystem services. In this perspective, the database has great importance: the more detailed are the data, the greater is the accuracy of the analysis. I-Tree can analyse the urban forest, providing, for example, a complete framework of the present species, the most common diameter classes and their origin. In addition to these purely informative outputs, I-Tree can calculate leaf area and vegetation cover, used as metadata to quantify the environmental benefits.

Carbon storage and Carbon sequestration

Trees' role in climate change mitigation is well known, thanks to the capacity of sequestering and storing atmospheric carbon. In particular, trees reduce carbon levels, sequestering it from the atmosphere and storing it in the new growth that develops year after year. To estimate the amount of carbon sequestered, the model bases its analysis on each tree's diameters – provided as input, in the year considered 0 – and then calculates the estimated average annual growth, using specific genus and species parameters and the health conditions provided. Therefore, I-Tree estimates tree diameter and relative sequestration in the year 0 + 1.

Instead, carbon storage can be defined as the amount of carbon in the tree biomass – aerial and underground. To calculate C storage, the model estimates each tree's total biomass, starting from the measured data and bibliographic references. Since trees with expanded crown and subjected to maintenance – as the ones under analysis – tend to have less biomass than trees in natural environments, where most of the models are calibrated, I-Tree solve this issue by multiplying the results with a standard coefficient of 0,8. This adjustment is not performed on trees considered as grown in natural conditions. Finally, the model multiplies the dry biomass by 0,5, thus obtaining the carbon stored in each tree.

Oxygen production

Oxygen production is one of the main and best-known benefits guaranteed by urban forest. The oxygen produced each year is directly related to the carbon sequestration activity. The total oxygen produced is therefore estimated thanks to C sequestered and its atomic weight:

O_2 produced (kg/year) = net C sequestered (kg/year) / 32/12

It is interesting to underline that the production of oxygen by vegetation has a relatively minor impact from a global point of view: indeed, our atmosphere contains high and stable oxygen levels, mainly thanks to the aquatic component of the planet.

Air pollution removal

Bad air quality is a common issue in many urban areas and can cause various problems to human health and natural ecosystem processes. Vegetation, especially in urban environments where anthropogenic pressure is maximum, can lead to air quality improvements, for example, by reducing its temperature, directly removing pollutants and lowering energy consumption in nearby buildings, which consequently reduces emissions of air pollutants due to energy consumption. I-Tree considers vegetation impact on the removal of the most common urban pollutants: ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide and particulate matter (PM) of 2,5 microns.

These estimations on air pollution removal derive from different models, which consider the hourly foliar resistances, calculated with a hybrid foliar model. Furthermore, since the removal of carbon monoxide and PM is not directly related to transpiration, the removal rates for these pollutants have been calculated from average values obtained from the literature, adjusted according to phenology and leaf area. Regarding the removal of fine atmospheric particulate, the model considers a resuspension rate equal to 50 % of the deposited particles, which then return into the atmosphere – due to adverse weather, which in particular cases can also lead to an increase in the concentration of PM 2,5 in the atmosphere.

Future ecosystem services simulation

To quantify the ecosystem services provision in the future, it is possible to leverage on the I-Tree Forecast tool. This tool simulates urban trees' growth and development in a future period. Based on the previously conducted I-Tree Eco assessment, the model can simulate the community's annual evolution, taking into account possible disturbing factors (parasites, adverse weather events) that may alter tree development. Also, the tool allows the setting of some parameters regarding trees vitality, including death rate and new plant/year rate, which affect urban forestry consistency and composition. The tool is thus able to simulate the provision of the following services: Carbon storage; Carbon sequestration; Air pollution removal (NO_2, O_3 and SO_2 removed).

Results

Backed by this solid methodology and requiring a complete set of data, I-Tree is then able to present its results in various ways, depending on user needs and interests. A written report is provided in form of a pdf file, reporting the main outcomes and graphics for all the above ecosystem services. In addition, it is possible to deepen the analysis, e.g., to evaluate the contribution of singular specimen and/or species. This is specifically thought to facilitate the comprehension and the usage from a larger stakeholder audience, and therefore make urban vegetation benefits more mainstream.

The data then can be used for tailored media and awareness campaigns. A positive example of this can be seen in the TreeTag campaign, started in the Netherlands and now running in different European countries (further information on www.treetags.eu). Pius Floris Tree Care developed an information poster (the TreeTag) and applied it on 150 urban trees. Each poster provides insight into the benefits of that particular tree, based on I-Tree Eco calculations, aiming at involving local inhabitants in tree protection. The I-Tree data were made even more accessible thank to a conversion into more understandable metrics, such as the number of car kilometres saved in CO2 or number of days of oxygen for one person that this tree produces.

Fig. 4 An example of TreeTag being installed on *Quercus rubra* in the Netherlands Credit: Pius Floris Boomverzorging.

5. Conclusions and next steps

The present document is aimed at showcasing one of the current available solutions to assess and quantify the ecosystem services provided by urban vegetation, with particular reference to urban trees.

Viridis Loci's partnership believes that by implementing this and similar approaches an increased awareness of the benefits of urban greenery can be reached, with positive consequences on territorial planning and management and during the decision-making process. The methodology here presented does not want to offer a complete answer, or to provide a "one-size-fits-all" solutions. Indeed, several points might be added to the analysis, starting from cultural ecosystem services to animal habitats creation and to the other vegetation and soil layers.

Thanks to several ongoing projects and to past and current researches, there is more widespread awareness within the academics and practitioners worlds about these needs and the efforts to have a valued urban vegetation for liveable and healthy cities.

It is therefore important to keep local stakeholders informed and updated on this topic, upskilling their professional profile with the use of new methodologies that can help their everyday work.

6. Appendix

For further information and to deep dive into the topic, the following materials are suggested as source:

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