"Cultivating a Greener Tomorrow": Solutions for quantifying urban tree ecosystem services

UNIVERSITÀ DEGLI STUDI DI MILANO
R3GIS managing spaces

Francesco Ferrini – University of Florence, Alessio Fini – University of Milan, Paolo Viskanic – R3Gis, Bolzano

Dundee, June 19th-21st 2024

UNIVERSITÀ DEGLI STUDI FIRENZE
DAGRI DIPARTIMENTO DI SCIENZE E TECNOLOGIE AGRARIE, ALIMENTARI, AMBIENTALI E FORESTALI


Image credits https://en.wikipedia.org/wiki/West_End,_Dundee#/media/File:Magdalen_Green.jpg

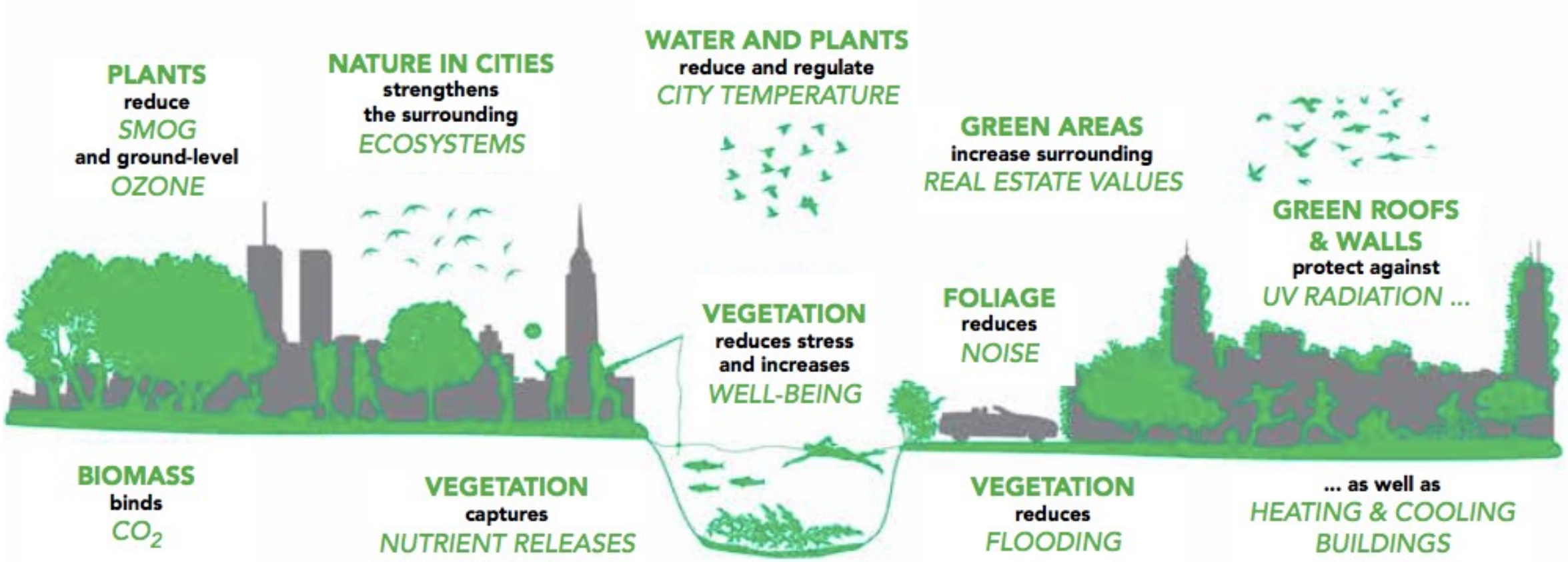
What are Urban Ecosystem services?

Urban ecosystem services are specifically defined as services that are being provided by urban ecosystems and their components. Ecosystems and their services are critical for

- sustenance of life in urban settlements (Odum, 1989);
- maintenance of health (Tzoulas et al., 2007; Lovell and Taylor, 2013);
- amicable socioeconomical relationships (EEA, European Environmental Agency, 2011);
- social and food security (Costanza et al., 2006; Dixon and Richards., 2016; Clark and Nicholas, 2013);
- and **overall human well-being** (TEEB, The Economics of Ecosystems and Biodiversity, 2011)

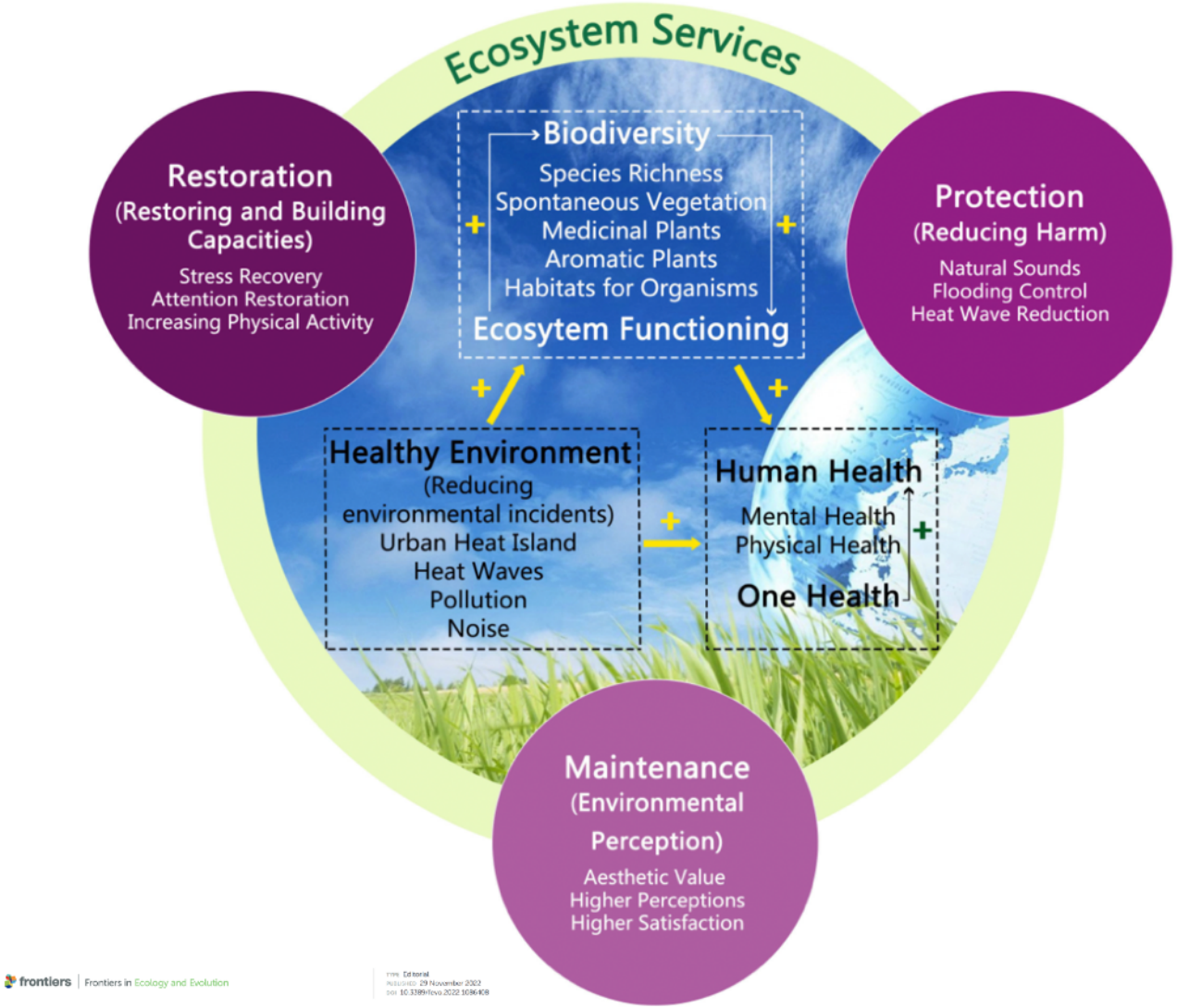
WHY measure the value of urban ecosystem services?

Image credits https://www.cocity.se/om-oss/urban-ecosystem-services/



Without an actual measure of ecosystem services, the services may be undervalued, and it may be difficult to assess needed funding for sustainable management of these resources

Values of Ecosystem services in the urban environment: the link with urban biodiversity



frontiers | Frontiers in Ecology and Evolution

Editorial: Biodiversity, ecosystem functions and services: Interrelationship with environmental and human health

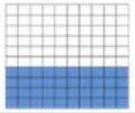
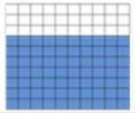
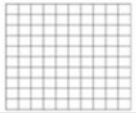
Biodiversity and Ecosystem Functions:

- Biodiversity is crucial for maintaining productivity, stability, and nutrient fluxes in ecosystems.
- Integrating biodiversity with ecosystem functions helps predict changes in ecosystem services amid multiple stressors like climate change.

Ecosystem Services and Human Health:

- Biodiversity and ecosystem services functions collectively maintain environmental health and provide essential benefits like clean water, healthy food, and disease suppression.
- The interconnectedness of biodiversity, ecosystem services, and human health is well-documented, emphasizing the need for further research.

Values of Ecosystem services in the urban environment:
Willingness to pay for

	Tree programme A	Tree programme B	No tree programme
Yearly reduction in pollution-related deaths	7 fewer pollution-related deaths	4 fewer pollution-related deaths	No reduction (115 pollution-related deaths)
Reduction in residential flood risk	500 fewer properties at risk of flooding	100 fewer properties at risk of flooding	No reduction (10,000 properties at risk of flooding)
Likelihood that reductions in pollution-related deaths and residential flood risk will occur	40% chance of reductions in deaths and flood risk occurring 	70% chance of reductions in deaths and flood risk occurring 	0% (no tree programme means no reductions) 
Change to appearance of Southampton's streets	Large trees planted 	Small trees planted 	No change 
Payment by your household to support new street tree planting in the city	£96 per year (£8 per month)	£24 per year (£2 per month)	£0
Your choice	☐	☐	☐

ELSEVIER

Resource and Energy Economics
Volume 71, February 2023, 101344

Willingness-to-pay for urban ecosystem services provision under objective and subjective uncertainty

Helen J. Davies [a], Hangjian Wu [b], Marije Schaafsma [a c]

Southampton, UK

Highlights

- **Respondents are willing to pay** for urban trees that reduce flood risk and air pollution.
- Willingness-to-pay for ecosystem services **declines with objective uncertainty.**

Programs/models to value Ecosystem services in the urban environment

Image credits Russo and Cirella, 2021

1. InVEST® (Integrated Valuation of Ecosystem Services and Tradeoffs):

InVEST®, developed by the **Natural Capital Project**, is a versatile software tool designed to assess and map ecosystem services at multiple spatial scales. From carbon sequestration and water purification to coastal protection and biodiversity conservation, **InVEST® provides a suite of models to quantify and visualize the benefits derived from natural landscapes**. Its user-friendly interface and customizable modules make it a valuable asset for policymakers, land managers, and researchers seeking to integrate ecosystem services into decision-making processes.

Image credits https://ap-plat.nies.go.jp/inas/goodpractices/tool/3.html

GI-Val is The Mersey Forest's green infrastructure valuation toolkit

2. Green Infrastructure Valuation Toolkit (GIVT):

Focused specifically on the valuation of green infrastructure, GIVT is a web-based toolkit developed by the World Resources Institute (WRI). GIVT offers a set of standardized methodologies and data sources for assessing the economic, social, and environmental benefits of green infrastructure investments. Through a combination of spatial analysis, economic valuation techniques, and stakeholder engagement, GIVT facilitates informed decision-making and strategic investment in urban green spaces.

Image credits https://ecosystemsknowledge.net/resources/tool-assessor/green-infrastructure-valuation-toolkit-gi-val/

3. OpenStreetMap (OSM) and Geographic Information Systems (GIS):

OpenStreetMap (OSM), a collaborative mapping platform, coupled with Geographic Information Systems (GIS), provides essential tools for **spatial analysis and visualization of urban green spaces.**

By coupling crowdsourced data and satellite imagery, OSM offers detailed information on the location, extent, and attributes of green infrastructure elements, such as parks, gardens, and street trees. GIS complements OSM by enabling users to perform spatial analyses, such as proximity analysis, habitat suitability modeling, and accessibility assessments, to better understand the distribution and connectivity of urban green spaces.

Image from Ludwig, C.; Hecht, R.; Lautenbach, S.; Schorcht, M.; Zipf, A. Mapping Public Urban Green Spaces Based on OpenStreetMap and Sentinel-2 Imagery Using Belief Functions. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 251. https://doi.org/10.3390/ijgi10040251

•4. Mobile Applications and Citizen Science Platforms:

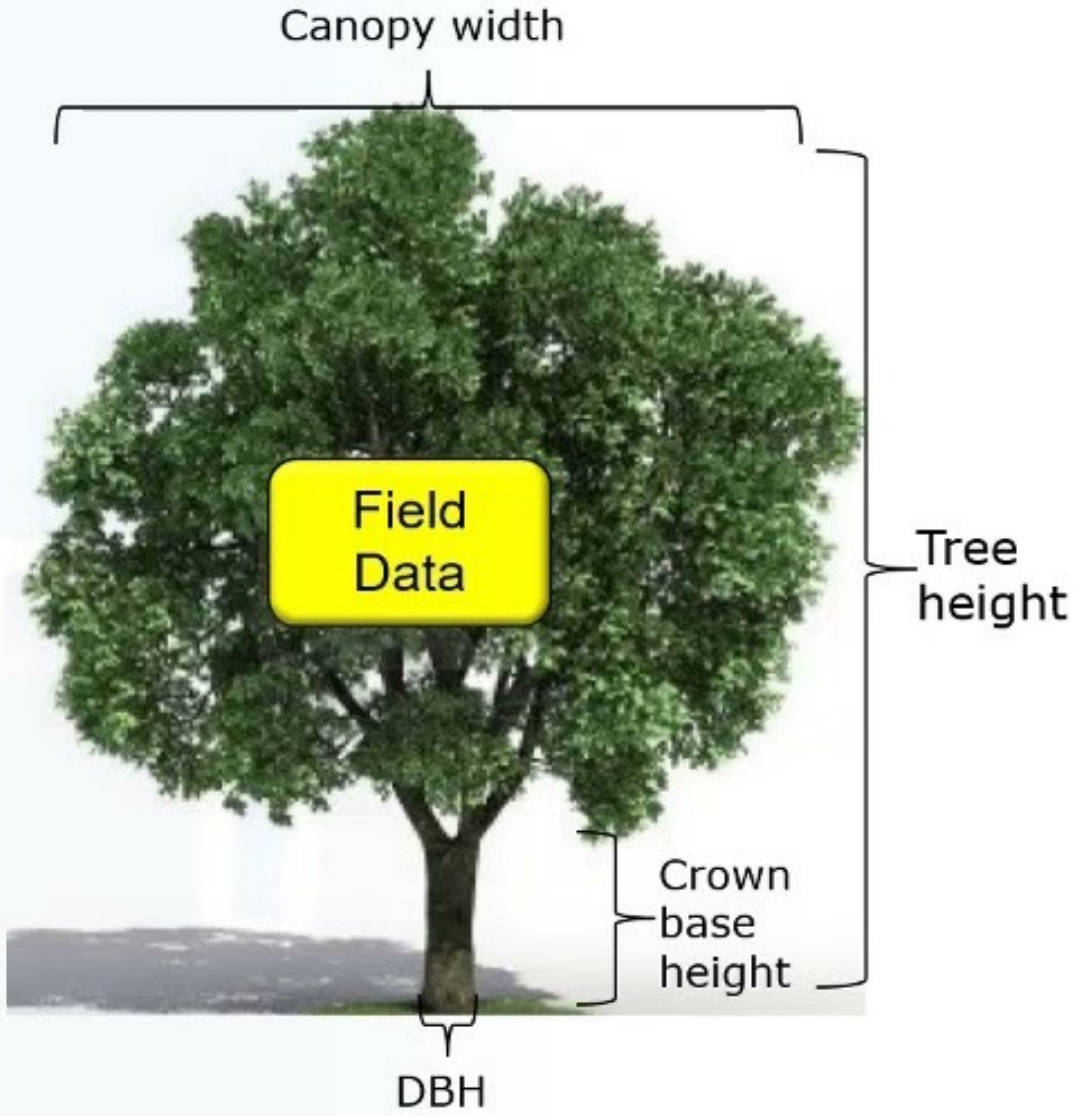
•Advancements in mobile technology have paved the way for citizen science initiatives and mobile applications dedicated to monitoring and assessing urban ecosystems.

•Apps such as iNaturalist, TreeSnap, and PlantNet empower citizens to contribute data on biodiversity, tree health, and habitat quality, enriching our understanding of urban ecology.

•These crowd-sourced data streams complement traditional monitoring efforts and provide valuable insights into the health and functioning of urban green spaces.

Image credits https://digitaldaze.io/the-rise-of-citizen-science/

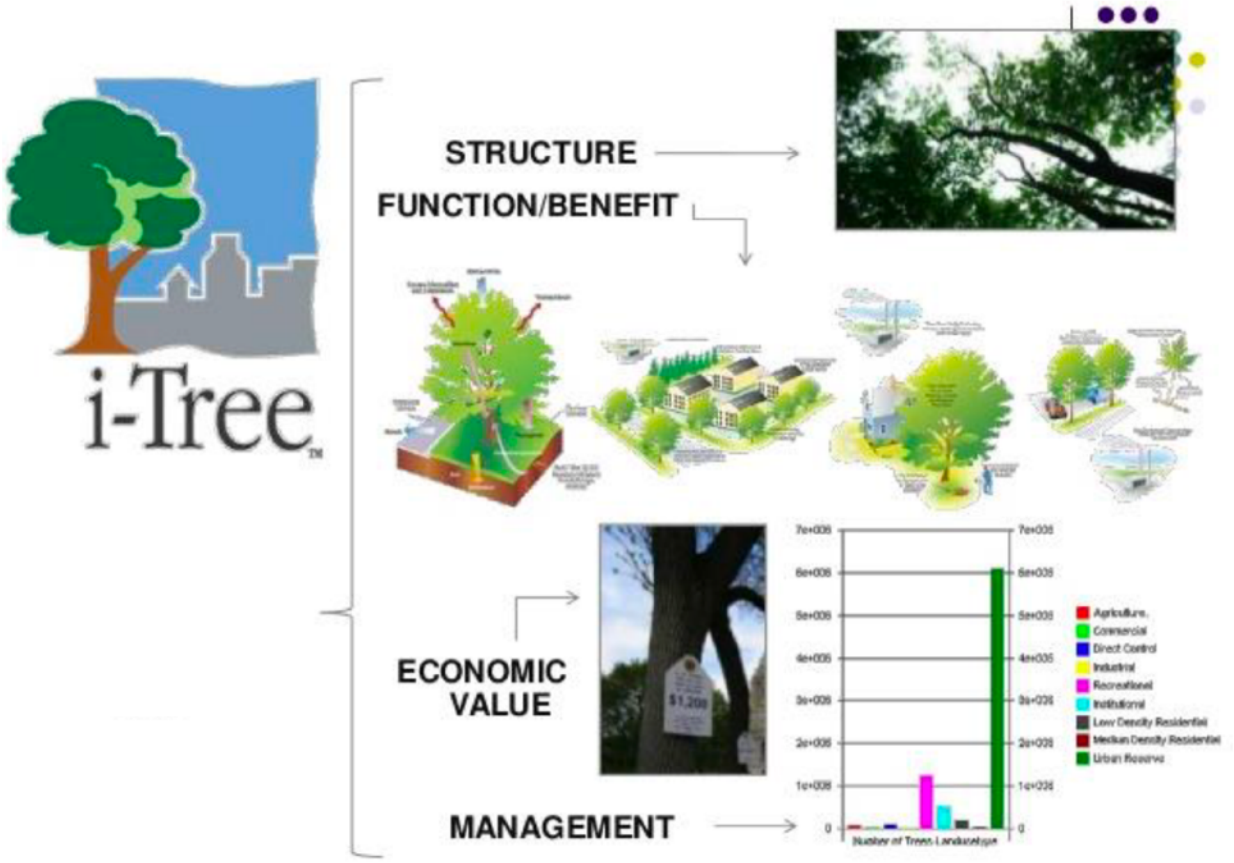
i-Tree model concept: Inventory data ➡ benefit assessments?



5. I-Tree Suite:

At the forefront of urban forestry assessment tools stands I-Tree, a comprehensive software suite developed by the USDA Forest Service. I-Tree offers a range of tools tailored to evaluate various aspects of urban forests, including tree canopy cover, carbon storage, air quality improvement, and stormwater mitigation. By leveraging data inputs such as tree inventories, land cover maps, and pollution levels, **I-Tree enables users to quantify the ecosystem services provided by trees in urban environments accurately.**

Data needed



1. **Tree Data**:
   - **Species**: The scientific and common names of the tree species.
   - **DBH (Diameter at Breast Height)**: The diameter of the tree trunk measured at 4.5 feet above the ground.
   - **Tree Height**: Total height of the tree.
   - **Crown Characteristics**: Measurements of crown width and height to assess the tree's canopy.
   - **Condition**: Health status of the tree, including signs of damage or disease.
   - **Location**: Geographic coordinates (latitude and longitude) of each tree.
2. **Environmental Data**:
   - **Weather Data**: Local climate information including average temperature, precipitation, and humidity.
   - **Air Quality Data**: Levels of air pollutants like ozone, nitrogen dioxide, sulfur dioxide, and particulate matter.
   - **Soil Data**: Information about soil type and conditions that affect tree growth and health.
3. **Land Use Data**:
   - **Land Cover**: Types of surfaces in the study area such as impervious surfaces (roads, buildings), water bodies, and vegetative cover.
   - **Land Use**: Classification of land use types, such as residential, commercial, industrial, and parkland.
4. **Socioeconomic Data**:
   - **Population Density**: Number of people living in the study area.
   - **Economic Data**: Property values, energy costs, and other economic indicators that can help estimate the financial benefits provided by trees.

Conceptual diagram for i-Tree suite of tools (USDA Forest Service, 2019)

Pros of the I-Tree Eco Model

1.Comprehensive Data Collection: The I-Tree Eco model provides a robust framework for collecting detailed data on urban trees.

2.Quantification of Ecosystem Services: One of the primary strengths of I-Tree Eco is its ability to quantify a wide range of ecosystem services.

3.Policy and Planning Support: The outputs from I-Tree Eco can inform urban planning and policy decisions.

4.Public Engagement and Education: The model's ability to translate complex environmental data into understandable and relatable metrics makes it an excellent tool for public engagement and education.

5.Customizability and Scalability: I-Tree Eco can be customized to fit different geographic regions and scales, from individual trees to entire cities. This flexibility makes it suitable for a wide range of projects, from small community tree inventories to large-scale urban forest assessments.

Cons of the I-Tree Eco Model

1.Data Intensive: The comprehensive data collection required by I-Tree Eco can be resource-intensive.

2.Expertise Requirement: Properly using I-Tree Eco requires a certain level of expertise in urban forestry and data analysis. Users must be knowledgeable about tree species identification, field data collection techniques, and data interpretation.

3.Static Assumptions: Some critics argue that I-Tree Eco relies on static assumptions that may not account for dynamic environmental changes.

4.Maintenance and Updates: The model requires regular updates and maintenance to remain accurate and relevant.

5.Social and Economic Factors: While I-Tree Eco excels at quantifying environmental benefits, it is less robust in addressing social and economic factors.


RESEARCH
NEWS

FlorTree tries to answers the question of the best/worst tree species to plant in a polluted city

AIRFRESH

AnaEE Analysis and Experimentation on Ecosystems Italy

LIFE19 ENV/FR/00086

Tree selection is a crucial step for proper urban planning:

- High gaseous pollutant removal
- Low bVOC release
- High PM abatement

FlorTree model

Urban Forestry & Urban Greening 85 (2023) 127967

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Original article

FlorTree: A unifying modelling framework for estimating the species-specific pollution removal by individual trees and shrubs

Jacopo Manzini [a,b], Yasutomo Hoshika [a,c,*], Elisa Carrari [b], Pierre Sicard [d], Makoto Watanabe [e], Tanaka Ryoji [e], Ovidiu Badea [f,g], Francesco Paolo Nicese [b], Francesco Ferrini [b,h], Elena Paoletti [a,c]

For 220 species (trees and shrubs) commonly used in Tuscany values of :

- Maximum stomatal conductance (g_{max})
- Emission rates of volatile organic compounds (bVOC)
- Morphometric parameters (LAI, LMA, leaf/shoot morphology, height and size of the canopy at maturity, leaf habit) have been searched in the scientific literature and plant nursery catalogs.

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Slide courtesy Elena Paoletti

The best ones – O_3 and NO_2

AIRFRESH

AnaEE Italy

LIFE19 ENV/FR/00086

Acer

Tilia

Genus	Species	Net O_3 (g/tree/day)
Fraxinus	***excelsior***	**13.96**
Fagus	*sylvatica*	12.01
Tilia	*cordata*	9.87
Tilia	*platyphyllos*	8.01
Acer	*pseudoplatanus*	7.11
Aesculus	*hippocastanum*	6.85
Gleditsia	*triacanthos*	6.80
Tilia	*x europaea*	6.60
Acer	*platanoides*	5.22
Liriodendron	*tulipifera*	4.86

Genus	Species	NO_2 (g/tree/day)
Fraxinus	***excelsior***	**17.23**
Fagus	*sylvatica*	15.84
Liriodendron	*tulipifera*	14.89
Tilia	*cordata*	12.62
Pseudotsuga	*menziesii*	12.60
Quercus	*petraea*	12.33
Quercus	*rubra*	11.35
Quercus	*douglasii*	10.88
Eucalyptus	*globulus*	10.79
Tilia	*platyphyllos*	10.43

Fraxinus

Fagus

Slide courtesy Elena Paoletti

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The worst ones – O_3

Genus	Species	O_3 removal	OFP	Net O_3 (g/tree/day)
Liquidambar	*styraciflua*	8.08	63.58	-55.50
Quercus	*petraea*	18.41	85.89	-67.49
Quercus	*suber*	11.11	79.14	-68.03
Quercus	*ilex*	19.02	103.53	-84.51
Populus	*nigra*	10.27	125.73	-115.46
Eucalyptus	*glaucescens*	3.89	128.51	-124.62
Quercus	*robur*	13.79	138.58	-124.79
Quercus	*frainetto*	5.13	184.37	-179.24
Quercus	*coccinea*	9.31	243.10	-233.79
Eucalyptus	*globulus*	17.43	428.93	-411.49

Quercus spp.

Populus spp.

Eucalyptus spp.

AIRFRESH
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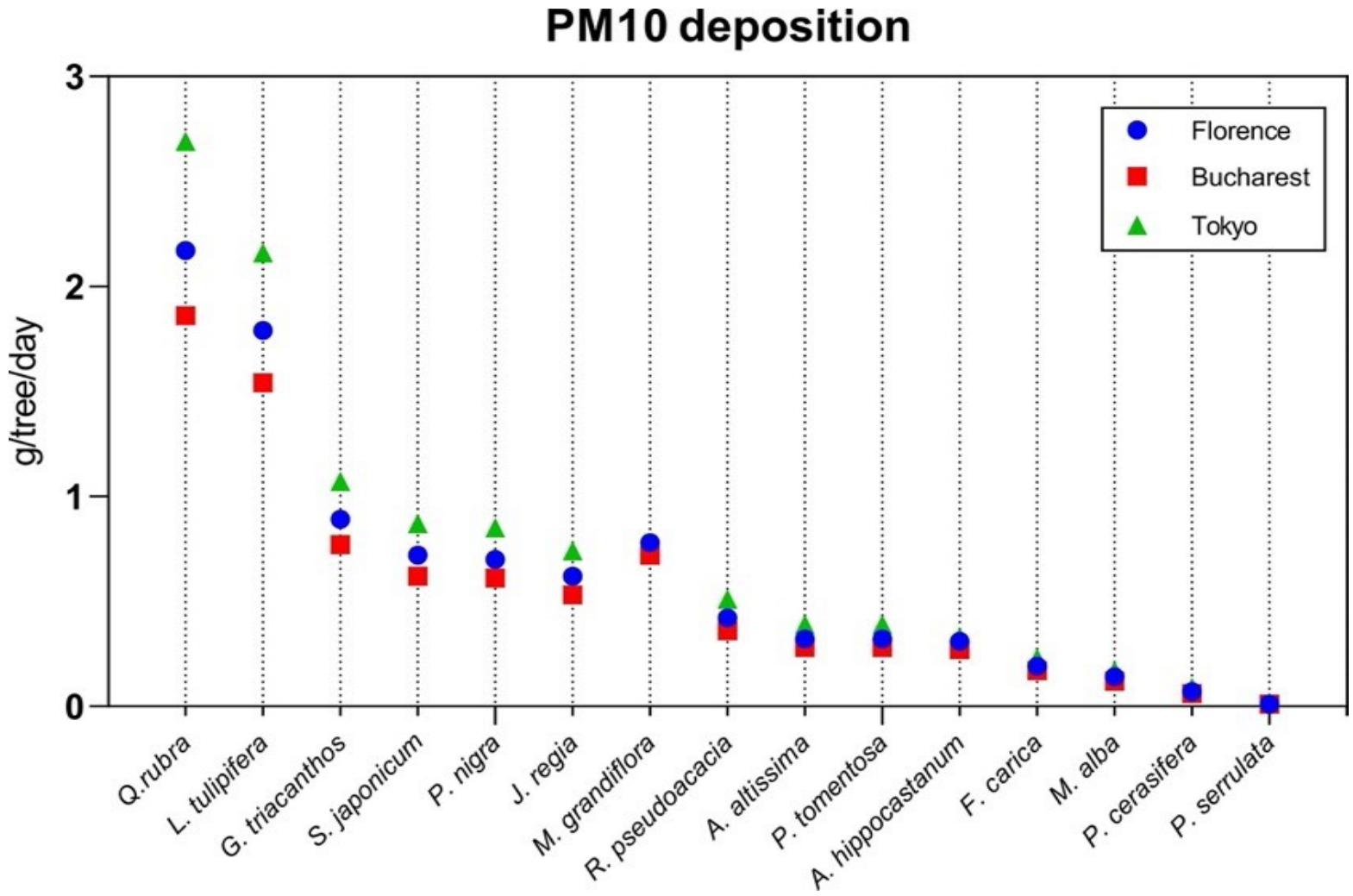
NATIONAL BIODIVERSITY FUTURE CENTER

Urban Forestry & Urban Greening
Volume 85, July 2023, 127967

Original article

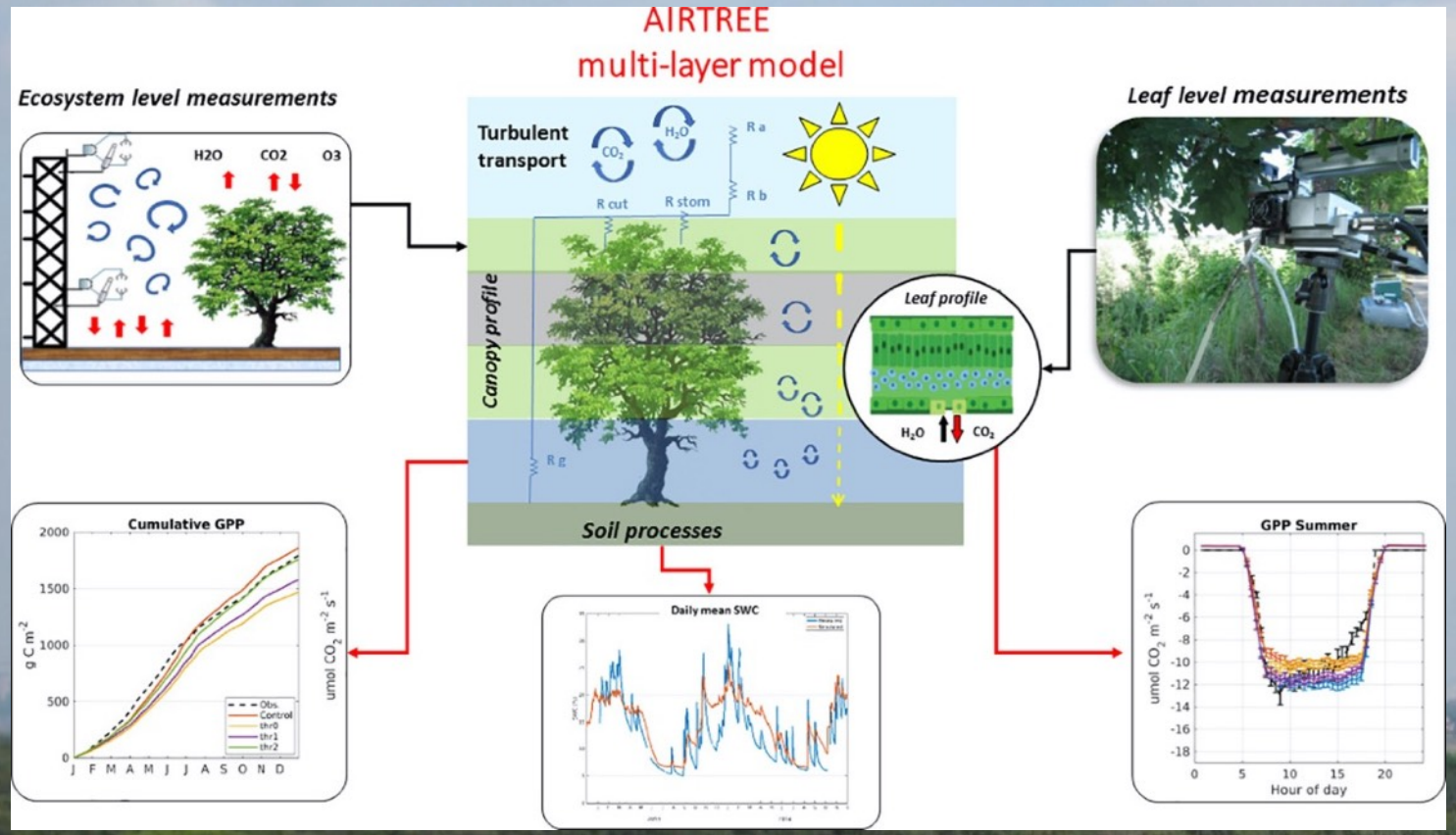
FlorTree: A unifying modelling framework for estimating the species-specific pollution removal by individual trees and shrubs

Jacopo Manzini [a b], Yasutomo Hoshika [a c], Elisa Carrari [b], Pierre Sicard [d], Makoto Watanabe [e], Ryoji Tanaka [e], Ovidiu Badea [f g], Francesco Paolo Nicese [b], Francesco Ferrini [b h], Elena Paoletti [a c]



- An innovative single-tree model (FlorTree) was developed for species selection.
- FlorTree was applied in Florence and allowed to categorise 221 species.
- A list of 24 most performing trees (20 broadleaves and 4 conifers) was obtained.
- FlorTree was applied to 15 species common to Florence, Bucharest and

The AIRTREE model for quantifying the ability to removal of air pollutants from urban forests



CNR - ISAFOM

AirTree

MULTIFOR
Multi-scale observations to predict Forest response to pollution and climate change

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

Consiglio Nazionale delle Ricerche

Tecnoverde

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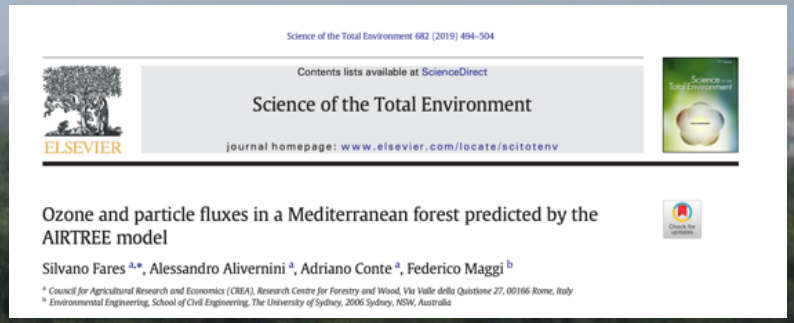
LAZIO INNOVA


Science of the Total Environment 682 (2019) 494–504
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv
ELSEVIER

Ozone and particle fluxes in a Mediterranean forest predicted by the AIRTREE model

Silvano Fares [a,*], Alessandro Alivernini [a], Adriano Conte [a], Federico Maggi [b]
[a] Council for Agricultural Research and Economics (CREA), Research Centre for Forestry and Wood, Via Valle della Quistione 27, 00166 Rome, Italy
[b] Environmental Engineering, School of Civil Engineering, The University of Sydney, 2006 Sydney, NSW, Australia

Highlights

- A multi-layer canopy model was set up to predict energy and carbon exchanges.
- Results were in agreement with fluxes measured with Eddy Covariance.
- Partitioning of ozone fluxes served to parameterize ozone-risk assessment metrics.
- AIRTREE supported evaluation of losses in carbon sequestration due to ozone.

Slide courtesy Fares, 2024

Target:

1. Study the capacity of carbon and pollutant sequestration by Mediterranean vegetation with particular reference to urban trees

2. Develop a model capable of quantifying these exchanges

3. Develop a portal useful to stakeholders

Tecnoverde

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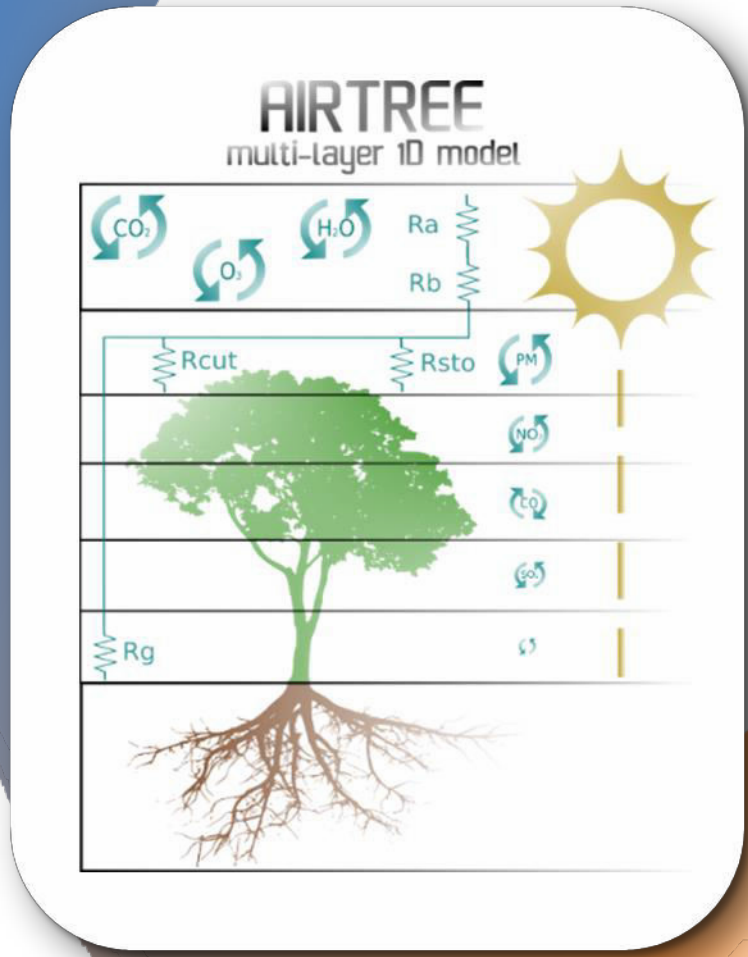
MULTIFOR

Multi-scale observations to predict Forest response to pollution and climate change

AirTree



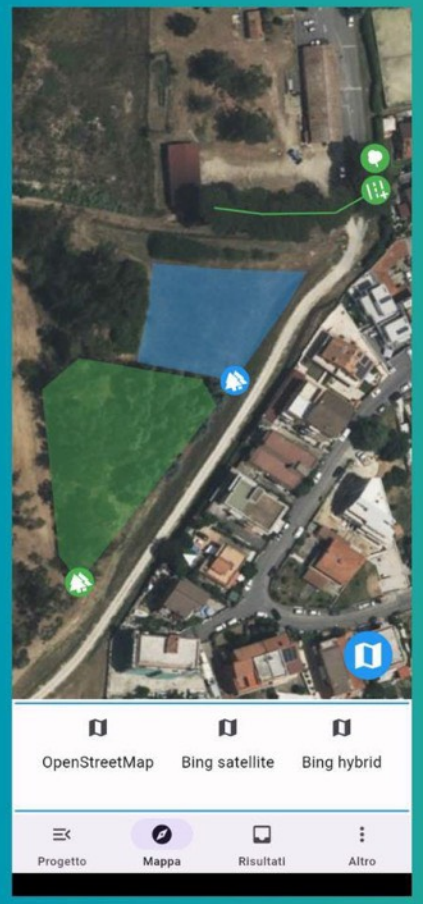
Case study 1: Capacity of urban parks to provide ecosystem services

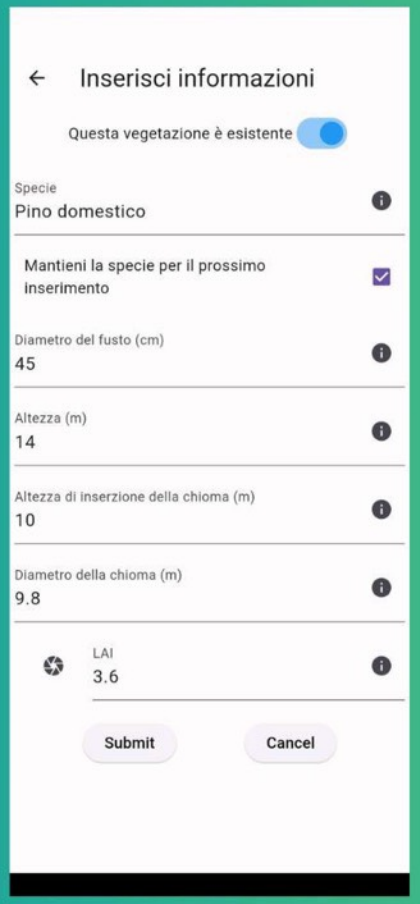
Consiglio Nazionale delle Ricerche · crea · VegGap Vegetation for Urban Green Air Quality Plans · MULTOFOR Multi-scale observations to predict Forest response to pollution and climate change · EUFORICC · REGIONE LAZIO · LAZIO INNOVA · Tecnoverde

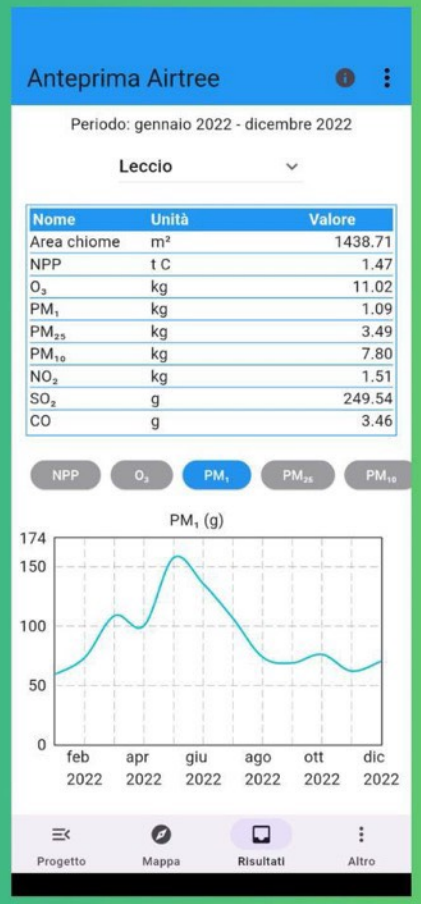
AIRTREE

Come gli alberi migliorano la qualità dell'aria

Raccogli le informazioni sul verde della tua città e progetta nuove aree verdi: Airtree ti mostra quanti inquinanti atmosferici sono rimossi dagli alberi







crea
Consiglio per la ricerca in agricoltur e l'analisi dell'economia agrari

Consiglio Nazionale delle Ricerche

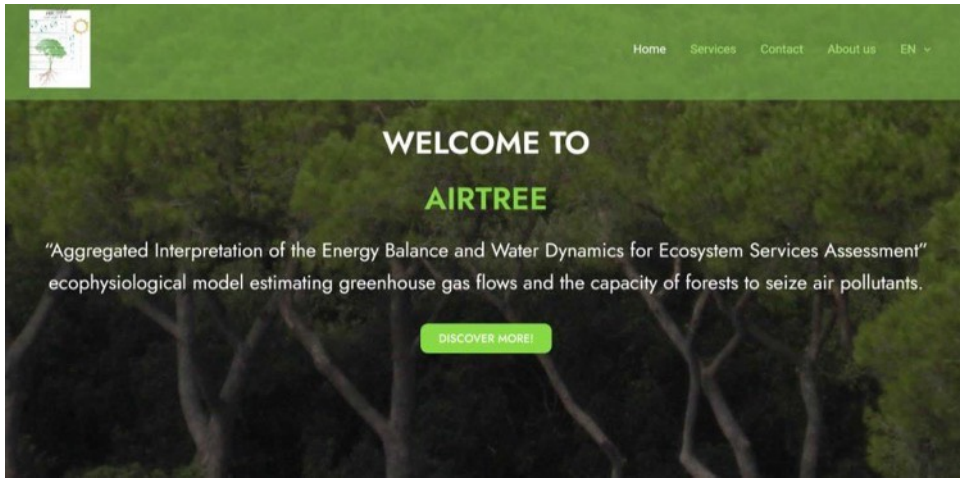
Prova in anteprima l'applicazione sul tuo smartphone Android

https://groups.google.com/g/airtree-app-testing/

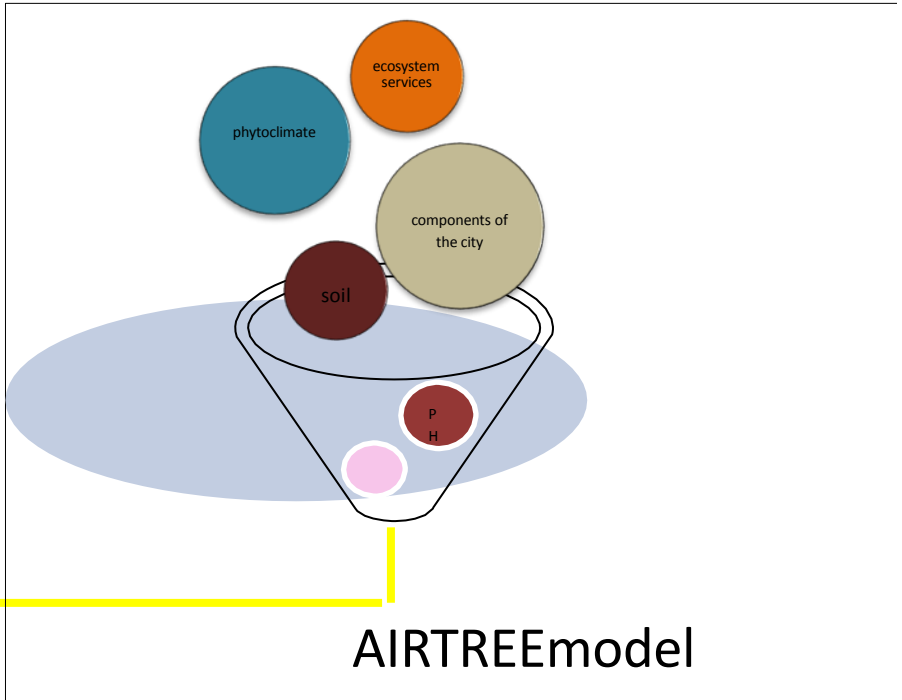
1) Inquadra il codice QR e iscriviti al gruppo di Airtree

2) Installa Airtree dal collegamento visualizzato

www.air-tree.eu



DECISION SUPPORT SYSTEM

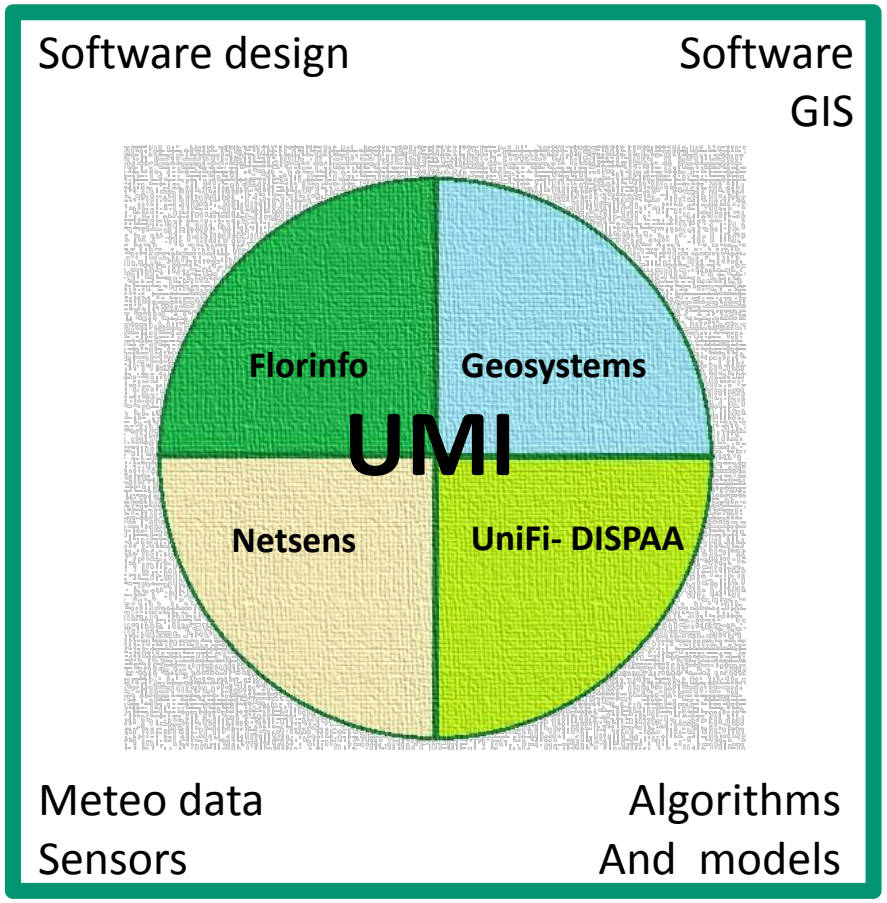


AIRTREEmodel

Our projects

Evaluating the effects of species selection and planning on microclimate:

PROJECT SMARTURBAN



(Unified Model Interface)

Apparent Temperature Index - ATI

Universal Thermal Climate Index - UTCI

- ATI-UTCI THERMAL COMFORT
- CO_2 ASSIMILATION AND STORAGE
- ENERGETIC BALANCE
- DRY DEPOSITION

Main purposes: Evaluation of URBAN and peri-urban projects based on simulation algorithms validated by scientific studies of the effects on some main aspects: Gaseous pollutants - PM_{10}, Environmental comfort, CO_2, Water disposal

SMARTURBAN TARGETS

CREATION OF A SOFTWARE SYSTEM FOR SUSTAINABLE PLANNING OF URBAN GREEN SPACES

OPTIMIZATION

- **LIVEABILITY**
- **ENVIRONMENTAL SUSTAINABLE**

Thanks to specific calculation algorithms and a database with variables that can be entered by the user or via a sensor network or GIS, the software allows you to determine the variations induced by the design choices of:

THERMAL COMFORT
LEVEL OF POLLUTANTS

SMARTURBAN
Sistema di monitoraggio e ricerca territoriale urbana

Build Simul (2019) 12: 169–175
https://doi.org/10.1007/s12273-018-0490-4

Modelling the effect of urban design on thermal comfort and air quality: The SMARTUrban Project

Luciano Massetti[1], Martina Petralli[2,3], Giada Brandani[2,3] (✉), Marco Napoli[2], Francesco Ferrini[2], Alessio Fini[2,4], David Pearlmutter[5], Simone Orlandini[2,3], Alberto Giuntoli[6]

1. Institute of Biometeorology, National Research Council, Florence, Italy
2. Centre of Bioclimatology, University of Florence, Italy
3. Department of Agrifood Production and Environmental Sciences, University of Florence, Italy
4. Department of Agricultural and Environmental Sciences – Production, Landscape, Agroenergy, University of Milan, Italy
5. Ben-Gurion University, Israel
6. Studio Bellesi Giuntoli, Florence, Italy

Research Article

SMARTURBAN

Innovative and unique in the European panorama

Versatile and adaptable to various situations

Scalable from small urban spaces up to large areas.

User-friendly, can also be used by non-specialised personnel

The end user could also direct his choices on an informed basis

BUT….

The Tuscany region decided not to finance the patent and marketing of the software

SMARTURBAN
Sistema di monitoraggio e ricerca territoriale urbana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HOME
PROJECT
NEWS
GALLERY
CONTACTS
LIFE URBANGREEN
INNOVATIVE TECHNOLOGICAL PLATFORM TO IMPROVE MANAGEMENT OF GREEN AREAS FOR BETTER CLIMATE ADAPTATION
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www.lifeurbangreen.eu


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ITALIA SVIZZERA - ITALIE SUISSE - ITALIEN SCHWEIZ
VERDEVALE
VERDEVALE
Innovative methodologies for the management and valorisation of urban green infrastructure
www.verdevale.eu

Three main project pillars

RESEARCH

- Leaf transpiration measurements
- Pollutant deposition analysis
- LiDAR survey
- Meteo data analysis
- IOT sensors integration
- Satellite data analysis

SOFTWARE TOOLS

- Ecosystem services calculation
- Meteo data integration
- Smart irrigation tool
- IOT sensors integration
- Improved job planning
- Public portal for citizens

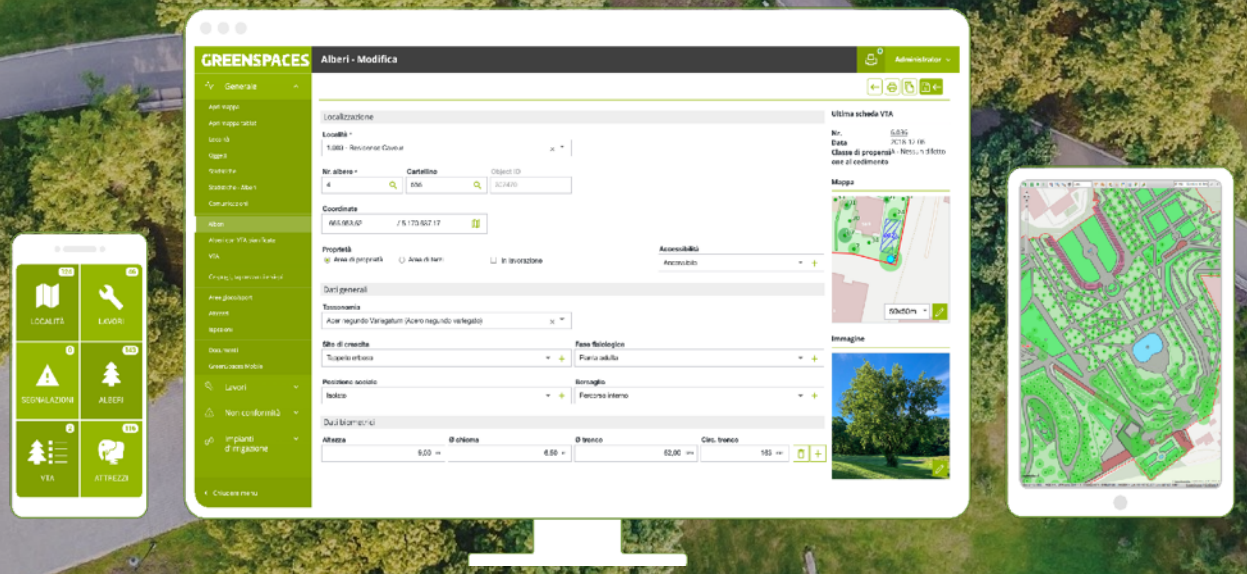
TEST ON PILOT SITES

Test new tools in Krakow and Rimini and assess the effect of best practices on trees:

- Target pruning
- Irrigation
- Soil decompaction
- Mulching

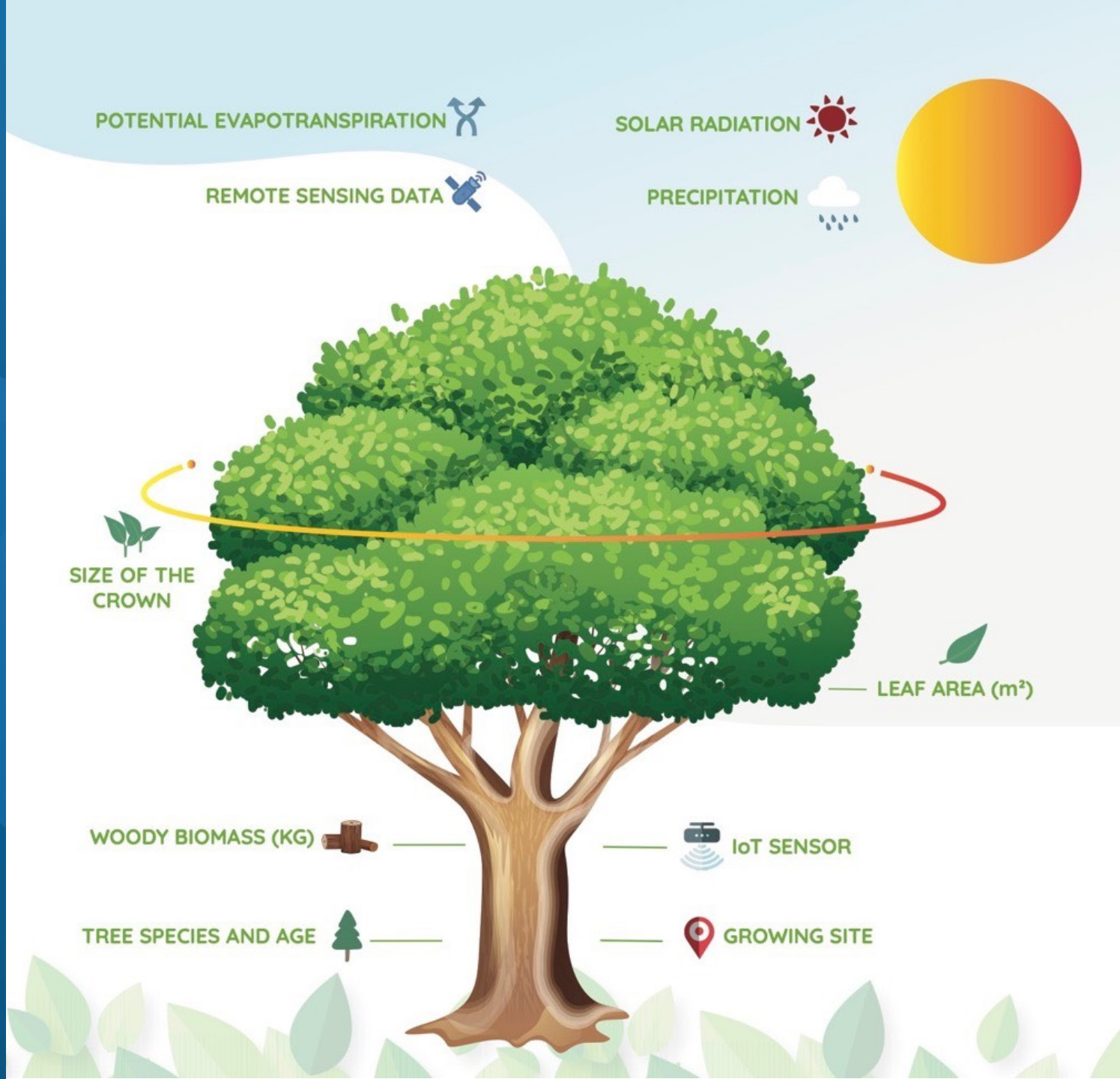
GREENSPACES

Existing Platform to manage urban green areas of the two cities: Inventory of green areas including trees, VTA management, job management, playgrounds and inspections, etc.



Weather dashboard

Measurement campaign on 500 urban trees representing 20 species in Rimini and Krakow



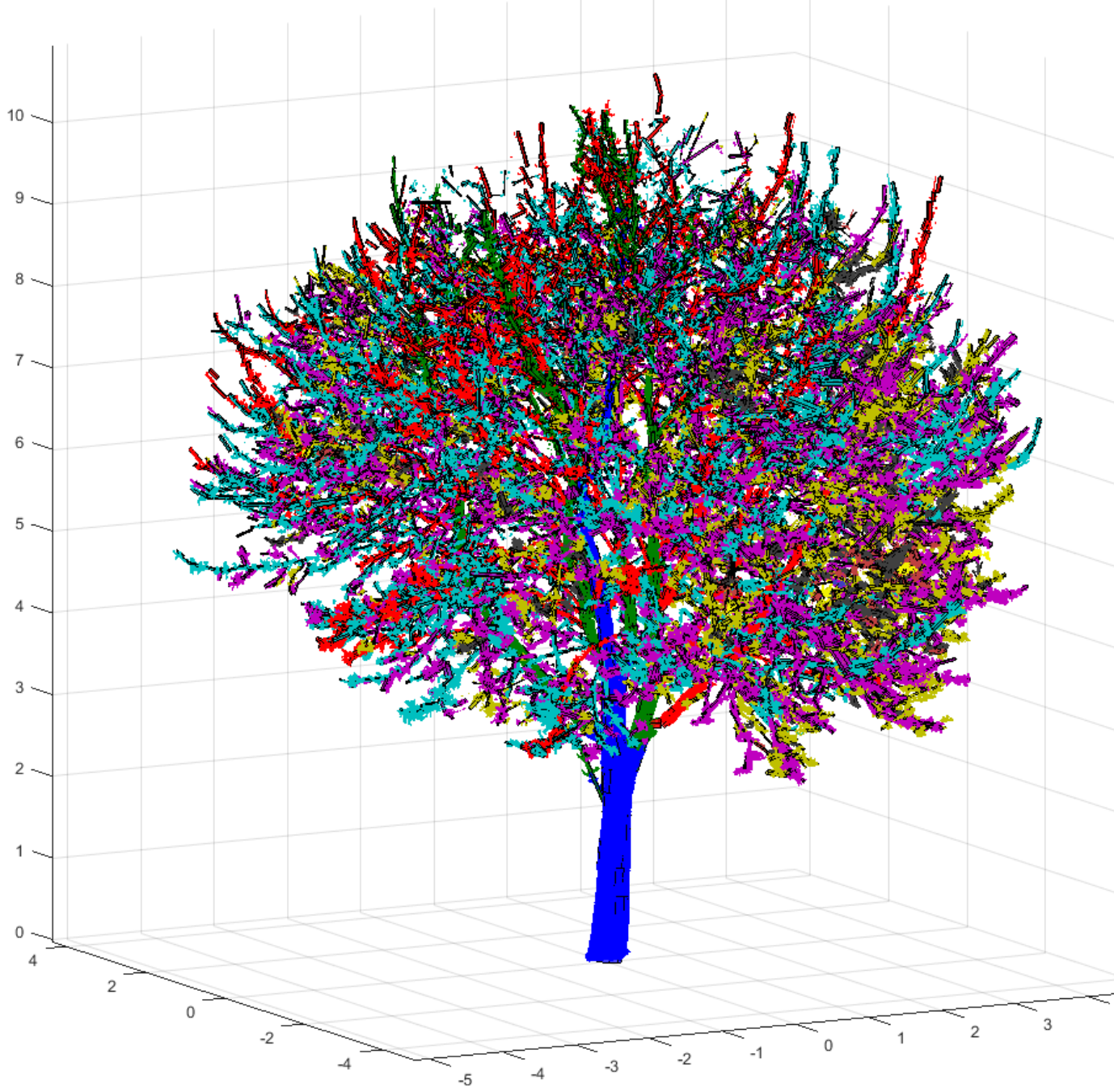
Measurement campaigns

500 trees were selected in Rimini and Kraków for measurement campaigns during three years on a total of 17 species, accounting for more than 50% of the tree population of the two cities. Leaf transpiration was measured to derive CO_2 adsorption and water transpiration.

LiDAR TLS surveys

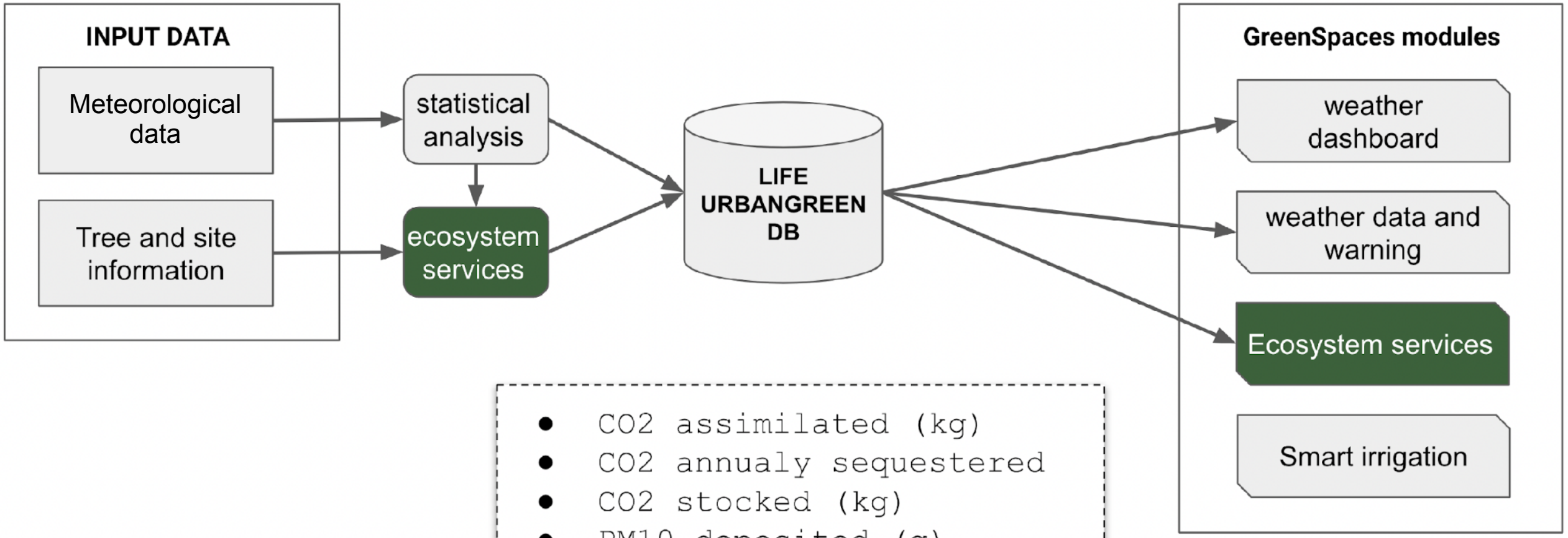
Accurate LiDAR measurement on selected trees was used to derive trunk volume, total leaf area and its distribution at different heights.

In addition, leaf samples were collected and analyzed in laboratory for deposition of pollutants (PM_{10}, $PM_{2.5}$).



Calculation of benefits of trees

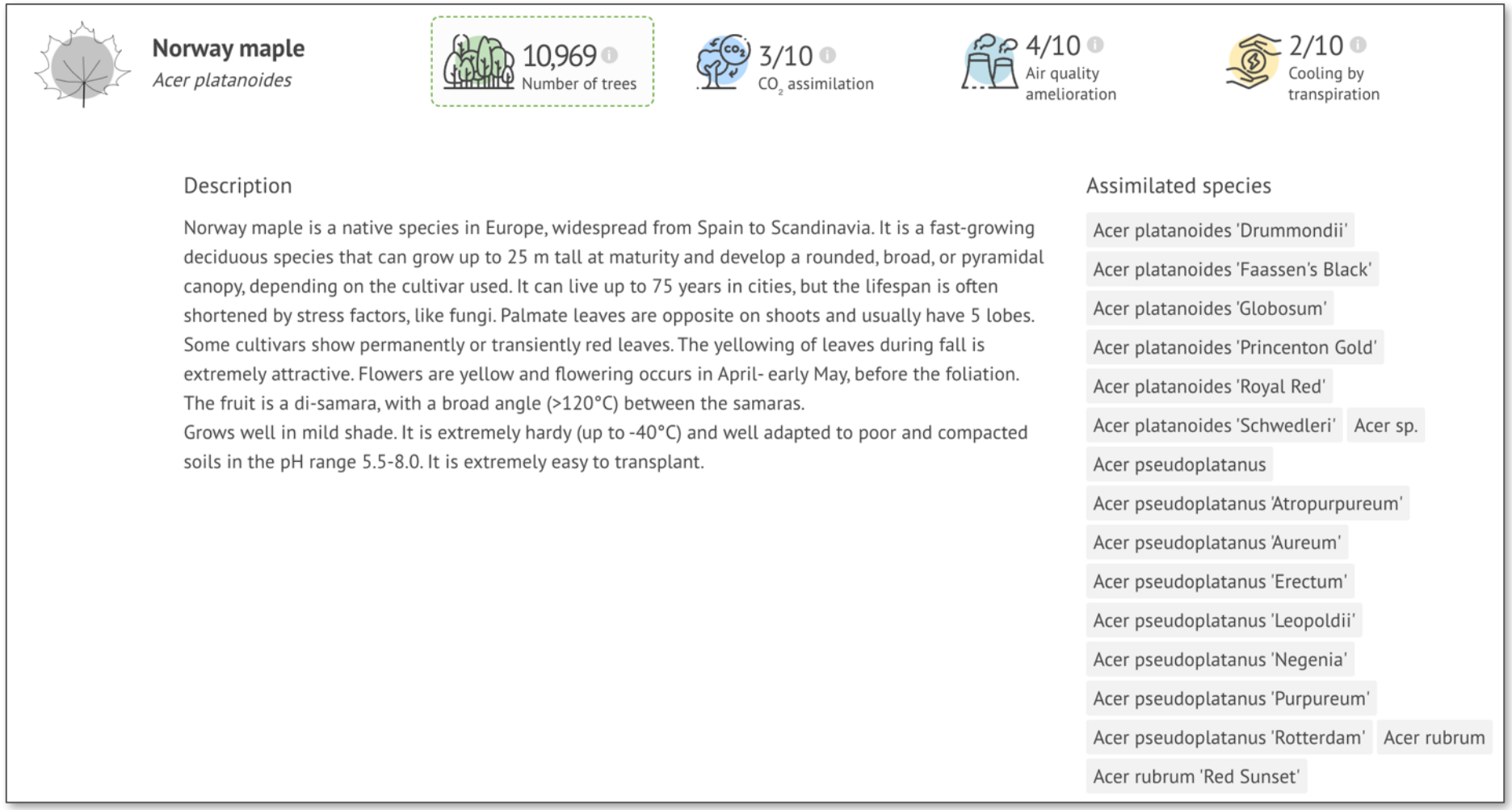
Ecosystem services calculation



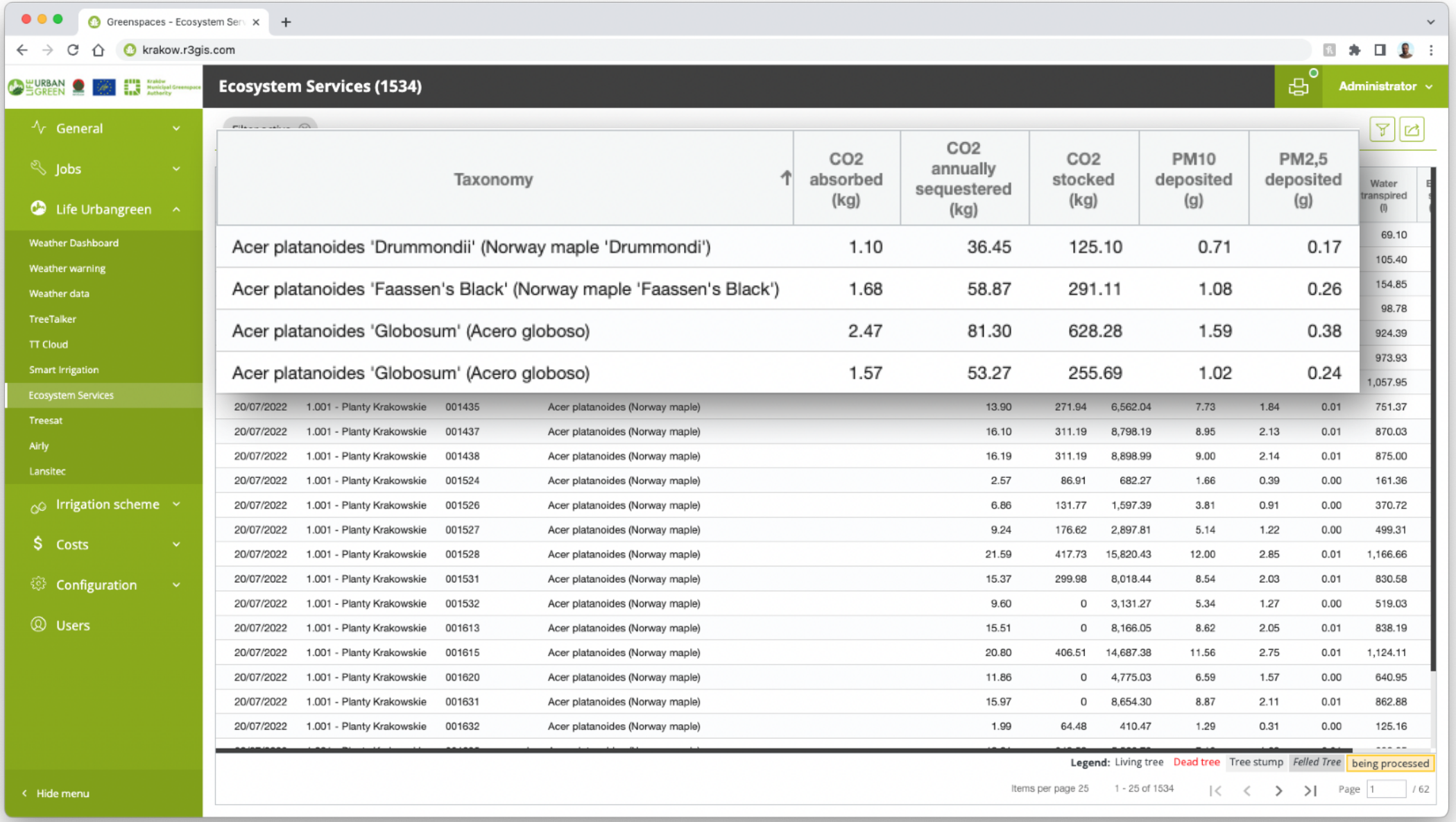
- CO2 assimilated (kg)
- CO2 annualy sequestered
- CO2 stocked (kg)
- PM10 deposited (g)
- PM2,5 deposited (g)
- Water transpired (l)
- Energy saved (kWh)

Tree benefits

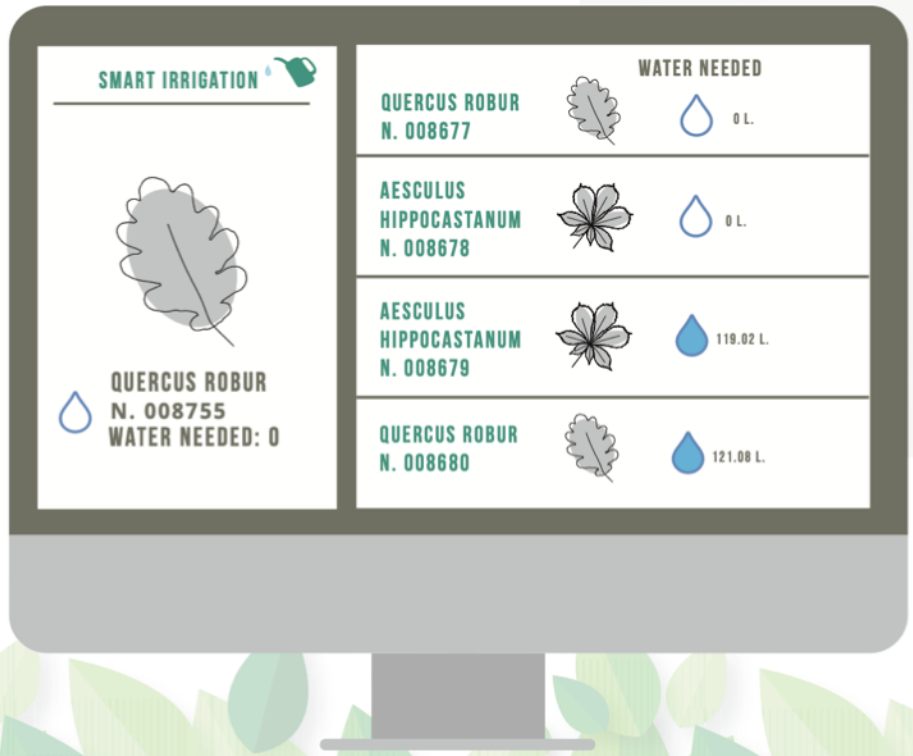
Benefits extended to other species with similar behaviour:



Daily tree benefits

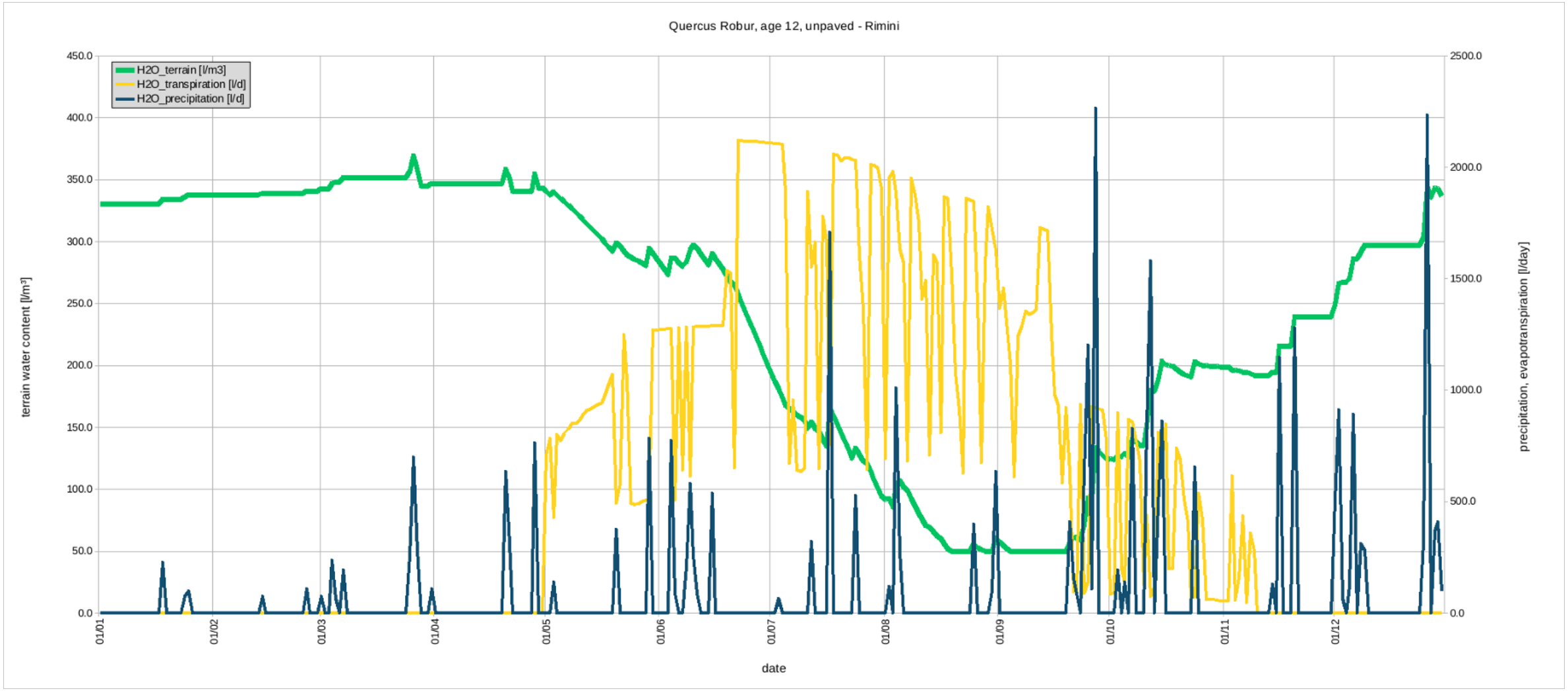


Smart irrigation tool



Smart irrigation

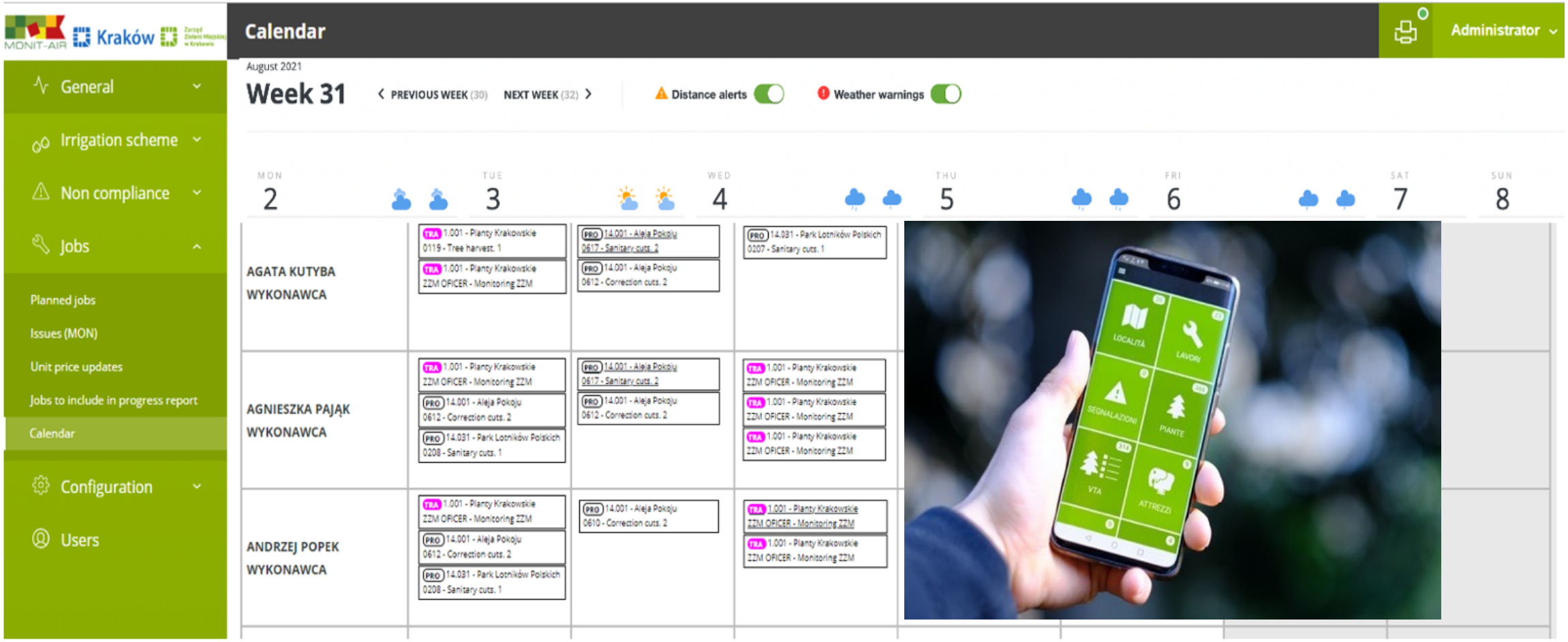
Water balance based on precipitation (irrigation) and transpiration



Efficient planning of care and maintenance activities

Smart job scheduling

To increase maintenance efficiency and **reduce the carbon footprint**, tools have been developed to schedule jobs considering weather forecast and distance between sites.



Engagement of citizens

Public portal

Life update of green area census, tree inventory and ecosystem services on a daily basis.

26.590
Studied trees

1.984 t
CO_2 sequestered per year

9.410 kg
PM absorbed per year

12.125 MWh
Energy saved per year

London Plane Tree

Nome area	Diametro del tronco	Altezza	Cartellino
Parco Te	166.0 cm	26-32 m	0

7 Jun 2024 / 09:09
Mantova
19,6 °C

Precipitazioni	Umidità relativa	Evapotraspirazione	Velocità del vento
- mm/m²	82 %	0,08 mm/h	6,9 km/h

Valore della CO_2 stoccata nella pianta
10,03 t | 874 €

Benefici anno 2023
1856 €
Energia risparmiata
PM_{10} rimosso
CO_2 assorbita

Best practices

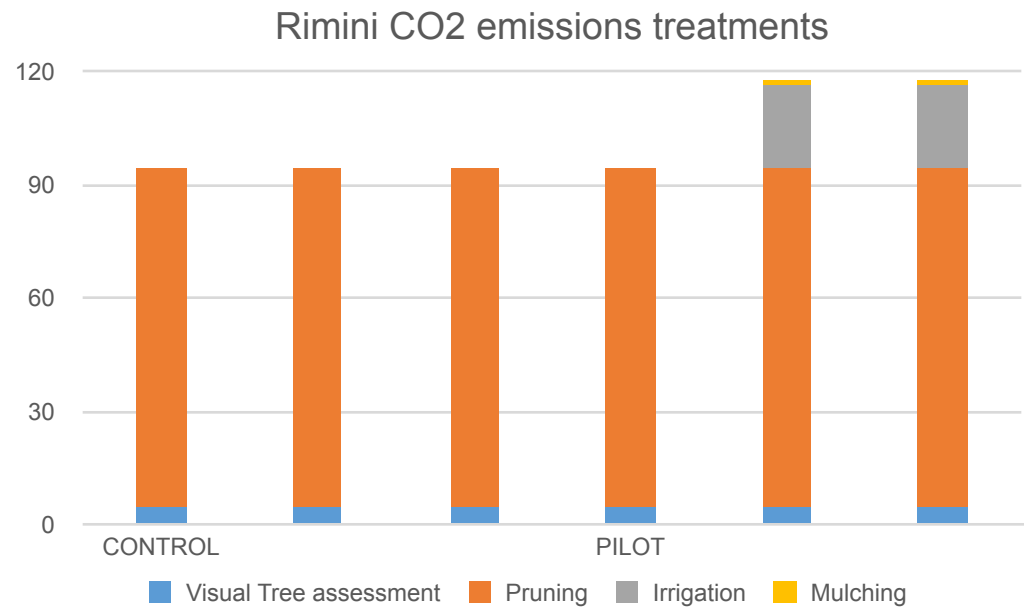
In pilot areas best practices were applied to ensure optimal conditions and ecosystem services maximization

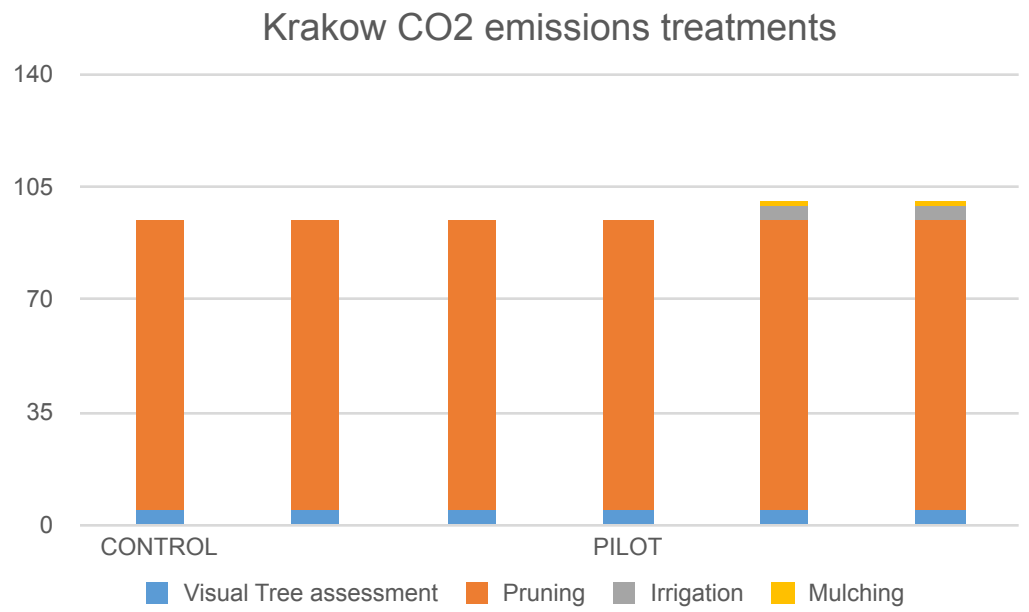
TARGET PRUNING (ETW)

MULCHING

TREE IRRIGATION

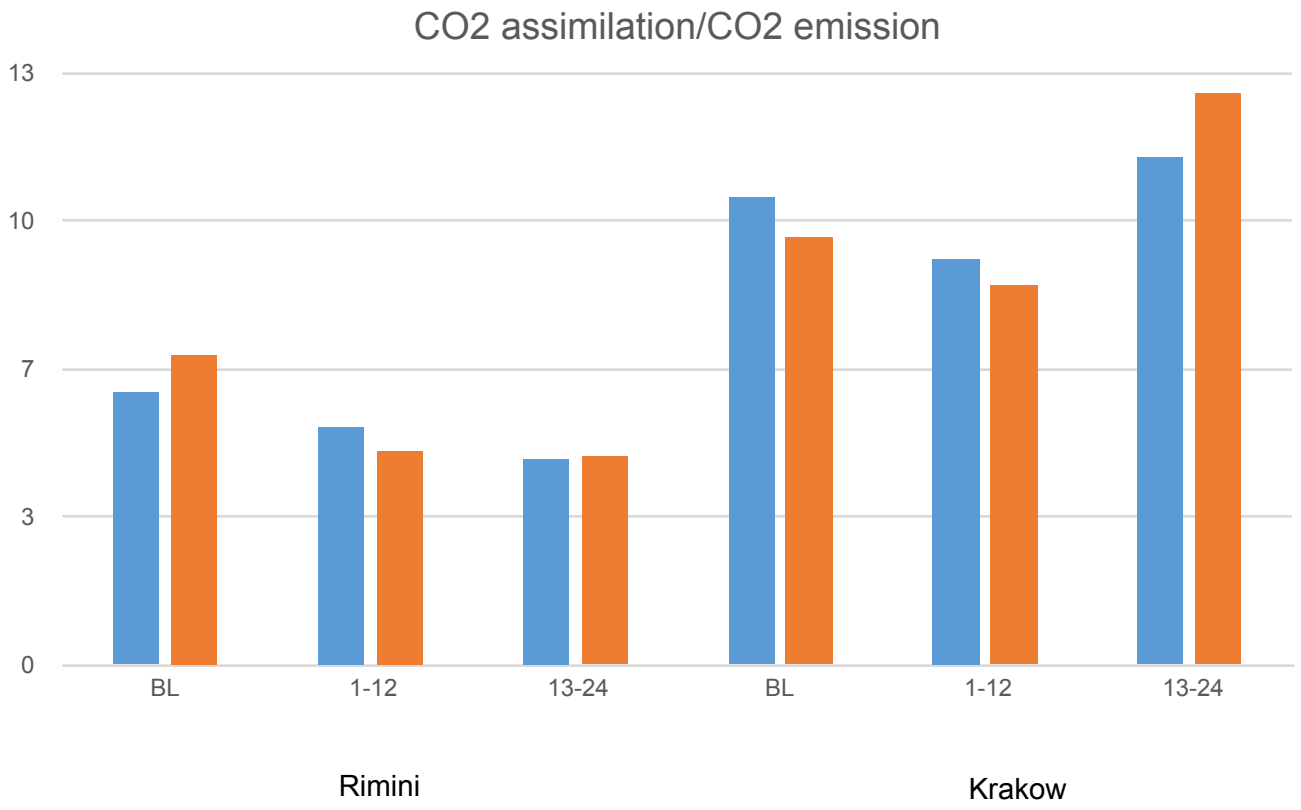
SOIL AERATION





Management applied during the impact period:

Control trees: pruning (5-year cycle) + VTA (2-year cycle)
Pilot trees: pruning (5-year cycle) + VTA (2-year cycle) + mulching (once) + irrigation (5 events/year in Rimini; 1 event/ year in Krakow)

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