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I-Tree in Europe

a powerful tool for creating healthy urban forests with a focus on ecosystem services

Al meer dan 40 jaar toonaangevend specialist op het gebied van boomverzorging.

Colofon

Rapportage

Status	Concept

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Inhoudsopgave

1. Summary

A healthy urban forest, with its ecosystem services, makes an important contribution to livability. The program i-Tree was developed in the USA in 2006 to quantify and monetize ecosystem services of urban trees. This free-to-use tool has continued to develop into a widely used program worldwide in the years since. The number of users is also rapidly increasing in Europe.

Using the i-Tree program, a variety of projects have been carried out across Europe to demonstrate the importance of trees in urban areas. In addition, quantifying tree ecosystem services with i-Tree provides a new approach to developing and managing a functional urban forest. The impacts resulting from various projects are promising, such as in the London i-Tree project (UK) and the TreeTag project (NL).

Application of i-Tree in Europe
To get an overview of the use of i-Tree in Europe, several colleagues in different countries were approached to ask how i-Tree is currently applied in their country. The United Kingdom leads the way in Europe when it comes to the application of i-Tree in concrete projects. Several plot studies have been conducted to understand the ecosystem services of the entire urban forest. In addition, i-Tree is being applied in several tools and policies as a means of understanding the value of trees. Several projects have also already been carried out in Sweden, including a nationwide i-Tree project in cooperation with 26 Swedish organizations. In the Netherlands, the use of i-Tree is also growing, since the national project in 2015. i-Tree is applied there, in addition to providing insight into ecosystem services, as a means of raising awareness about the importance of trees. i-Tree is also applied in several research projects, including the Ecosystem City project. In Switzerland and Spain, i-Tree is also applied for various purposes, including an i-Tree Eco-based Urban Forest Management Toolbox (Switzerland) and as a rationale for creating a green ring around Madrid (Spain). In Poland and Italy, i-Tree is still mainly used in academia.

Conclusions and prospects
The use of i-Tree in Europe has been increasing significantly in recent years. In particular, it is using the i-Tree Canopy and i-Tree Eco tools, which currently quantify 5 of the 20 ecosystem services provided by trees.
Importantly, when conducting an i-Tree project, the scale of the project in relation to the accuracy of the input data must be taken into account. For a small number of trees, a deviation in the input data can have a relatively large effect on the outcomes. By setting up Dutch and European i-Tree networks, knowledge can be shared and a uniform working method can be created for the application of i-Tree.

It is very important to properly define the purpose of the i-Tree study prior to a project. Roughly speaking, i-Tree is currently applied to the following 3 areas:

1. Creation of insight into the ecosystem services of a tree stock;
2. Tools for tree policy and management focused on a functional urban forest;
3. Creating awareness about the value of trees.

i-Tree also proves to be an engine for better cooperation between various departments and organizations. Government and industry are working closely together to implement and further develop i-Tree, such as in the i-Tree 2.0 NL project in the Netherlands.

In the United States, i-Tree is also being further developed. For example, i-Tree USA is investigating whether multiple ecosystem services can be quantified and an API has been developed so that i-Tree can communicate with existing tree management systems.

2. Introduction

In recent decades, many studies have shown the importance of trees in the urban environment. Trees provide over 20 ecosystem services in the urban area with which they make an important contribution to liveable and healthy cities. These include capturing rainwater during heavy showers and cooling the petrified environment, human health and capturing pollutants from the air. In addition, trees are essential for biodiversity in the urban environment. [CICES V5.1] The entire urban forest provides its function in this: all trees and shrubs in and around the urban environment, regardless of whether it is in public or private land. [Miller et al., 2015]
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. As a result, greenery had a weak position compared to other design elements in urban space. Moreover, unlike roads, sewers, car parks and buildings, green space is not considered an investment by a government or property owner: it has no tangible, monetary value. Over the past 20 years, several mathematical models have been developed to quantify ecosystem services, including i-Tree.

Designed specifically for tree ecosystem services, i-Tree can provide important information for awareness, planning and management of a functional urban forest. Figure 1 illustrates how values and services of a tree calculated by i-Tree can be displayed in an understandable way.

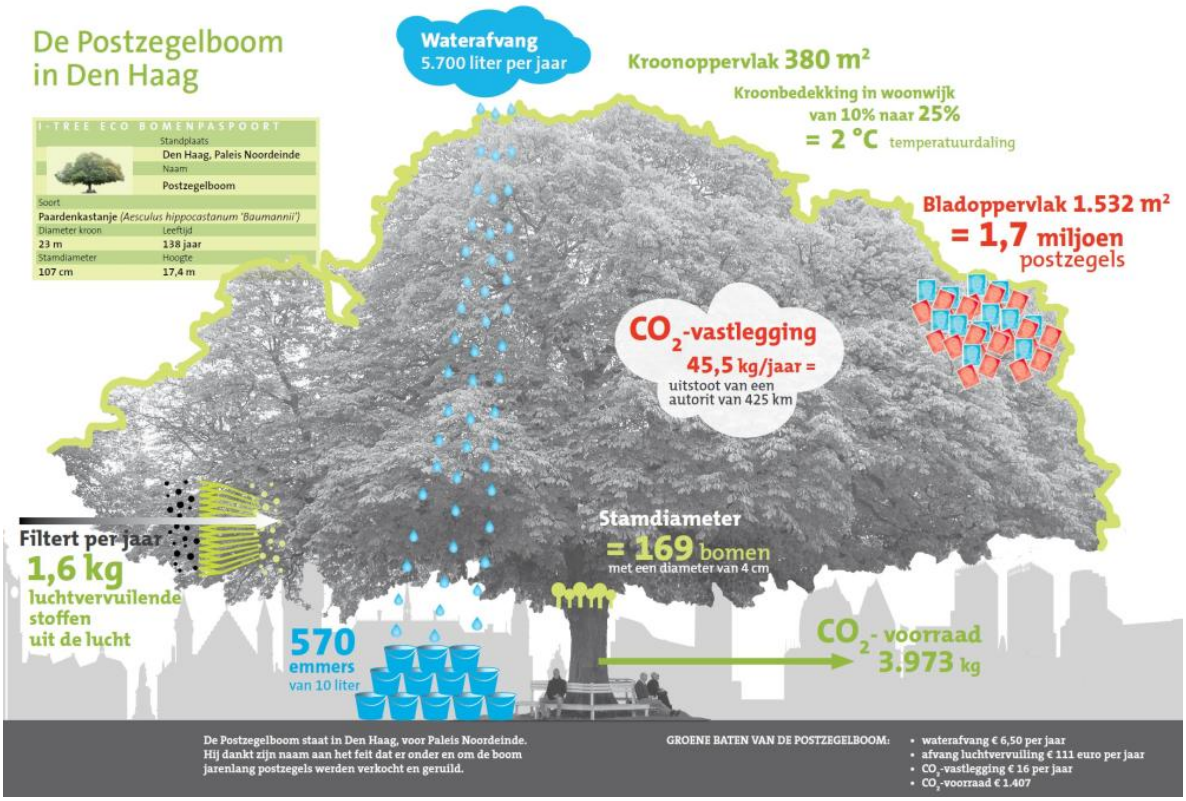


Figure 1: comprehensible visualisation of the ecosystem services of the monumental postage stamp tree in The Hague (NL), calculated using i-Tree Eco. (source: De Baten van Bomen, 2017)

This article gives an overview of the capabilities of i-Tree (in particular the tools i-Tree Canopy and i-Tree Eco) and the applications for which i-Tree is currently used in Europe. The article also gives an overview of new developments and future innovations within the i-Tree programme.

3. The software package i-Tree

The first version of i-Tree was released in the US in 2006 by the USDA Forest Service in collaboration with several partners. These included The Davey Tree Expert Company, The Arbor Day Foundation, Society of unicipal Arborists, International Society of Arboriculture and Casey Trees [https://www.itreetools.org/]. These parties entered into a collaboration with the aim of further developing i-Tree and providing technical support to users of the software. i-Tree is based on the Urban Forest Effects (UFORE) programme, which has already been used by the USDA Forest Service to understand various benefits of trees in a given area. [The Urban Forest Effects (UFORE) model: quantifying urban forest structure and functions, 2000]. A special feature is that i-Tree is a peer-reviewed tool, free for anyone to use. Users contribute their knowledge and input to the further development of the software.

Since 2016, thanks to the social enterprise Treeconomics and Forestry England, i-Tree has been applicable in the UK. Both organisations championing the importance of nature in and around our cities saw great value in being able to quantify the ecosystem services of trees. From 2019, i-Tree will be applicable in a large number of countries within Europe. To this end, European tree species have been added to the programme and weather data and pollution data have been linked from European monitoring stations. This data is based on data from The European Environment Agency (EEA). The most recent data linked to i-Tree is data from 2015 and, for some weather and pollution monitoring stations, from 2020. Calculations of ecosystem services by i-Tree are therefore based on pollution and weather data from that year. By linking the European data, it is possible to select a local monitoring station in the projects, thus calculating ecosystem services based on local conditions.

The number of i-Tree users in 2021 was about 622,000, of which more than 93,000 were outside the United States. Globally, the number of users is growing rapidly: by 2021, beyond the growth in the United States, more than 21,500 users were added. Notable is the long lead time in the United States itself: for the first six years, the number of users was still minimal, after which exponential growth began. [Behounek, 2022]

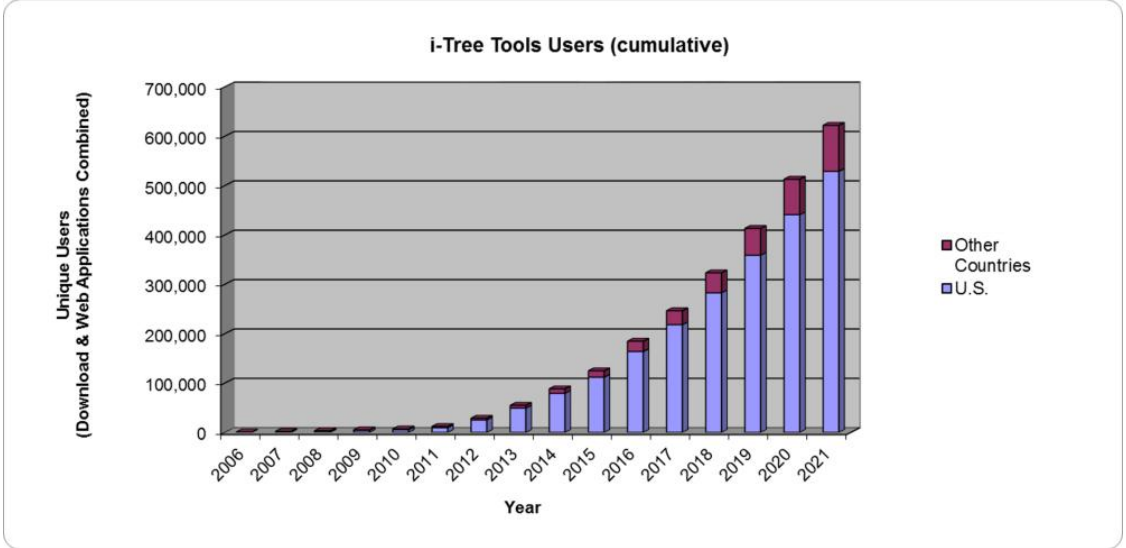


Chart 1: i-tree users, (source: Davey Resource Group)

3.1 i-Tree: 11 different programmes

The i-Tree package contains 11 different programmes, such as Landscape, County, Design, Hydro etc. (Figure 2) All these programmes have their own focus, e.g. on specific ecosystem services (such as Hydro, which provides insight into the effect of land use on water management) or in terms of scale (such as i-Tree landscape). i-Tree Canopy and i-Tree Eco are the most widely used and suitable for the European situation, as they include weather and air pollution data.

i-Tree Canopy works in an online environment and is applicable for larger areas (neighbourhoods, districts and cities). i-Tree Eco is a desktop application (free download) and applicable from the individual tree to an entire tree stock in a given area.

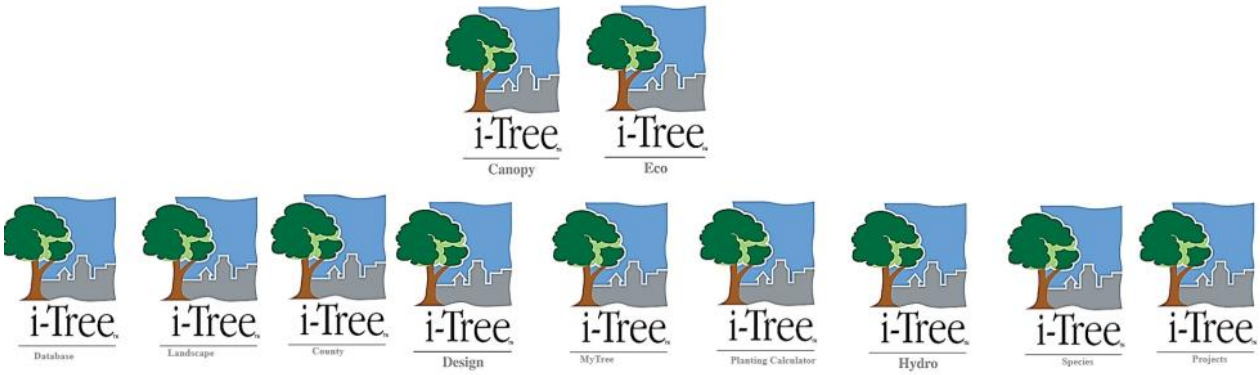


Figure 2: Overview of the eleven i-Tree programmes (i-Tree Suite). The i-Tree Canopy and i-Tree Eco programmes are particularly suitable for use in Europe due to their local weather and air pollution data. (source: iTree)

3.2 i-Tree Canopy

With i-Tree Canopy, it is possible to gain insight into the percentage of crown cover in a given area (city, district, etc.). This is the main function of i-Tree Canopy. It is a simple and quick-to-use online tool that allows analysis based on limited input data. Since up-to-date aerial photos from Google Maps are used for this purpose, this calculation is also possible in Europe.

By indicating from at least 500 randomly selected points on a Google aerial photo whether it is a tree canopy or not, the average tree canopy cover of an area can be determined. Nowadays, it is also possible to perform this calculation based on historical aerial photos. This allows a trend analysis of the development of the crown cover percentage in a given area over several years.

In the United States, i-Tree Canopy provides instant global estimates of the ecosystem services provided by the trees in the project area. Thanks to Treeconomics' work, this is now also possible for the UK and Sweden. As a result, when conducting an i-Tree Canopy study, an estimate of the ecosystem services provided by trees can be made directly on the basis of English and Swedish data. To make this possible across Europe, weather and pollution data needs to be linked to i-Tree Canopy. In addition, the interface of i-Tree Canopy needs to be adapted so that ecosystem services can be calculated based on location (country, region etc).

3.3 i-Tree Eco

I-Tree Eco is the flagship of the package. This tool provides insight into three important aspects of a city or area's tree stock: structure, function and (financial) value. This data constitutes useful information that can be used for various applications, including management and awareness focused on a functional urban forest.

An i-Tree Eco calculation can be made on the basis of a complete inventory or a plot study. The latter gives, based on a number of randomly selected plots, a good overview of structure, function and value of the entire local tree stock: public and private.

Plot study

A plot study is a very suitable method to apply i-Tree Eco in a larger area (entire city, forest areas). By randomly distributing plots with a diameter of 22.6 metres across the project area and surveying them completely, a representative picture of the ecosystem services in the entire project area can be formed. (Figure 3) For reliable extrapolation, a minimum of 200 plots are recommended to be inventoried. [Nowak et al., 2008]

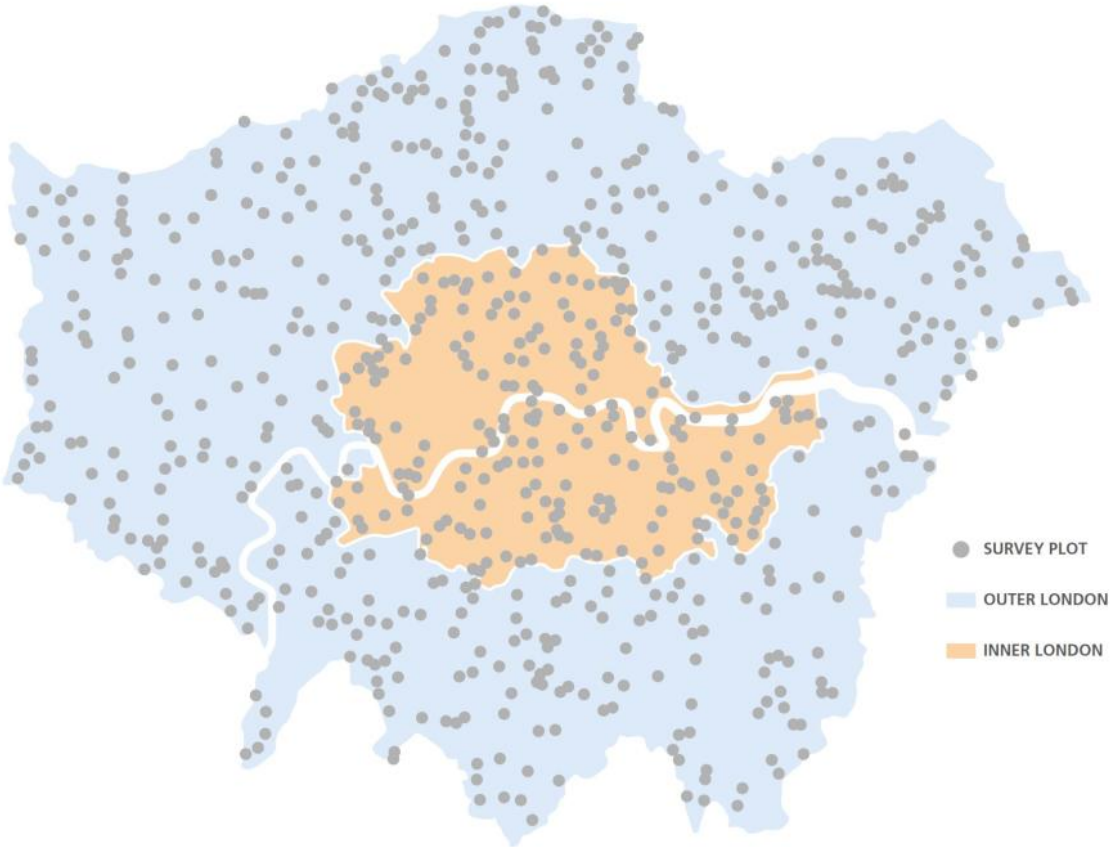


Figure 3: view plot study, source London i-Tree Project (source: London i-Tree Project, Treeconomics)

Full inventory

A full inventory includes all trees in the project area. This was applied, for example, in the Million Tree Project in New York City, where all 592,130 municipal trees were inventoried and entered into i-Tree Eco. This was the first public, large-scale i-Tree Eco project [Grove et al., 2006]. Also in Veenendaal (the Netherlands), a complete inventory of all 30,000 municipal trees was used to create an i-Tree Eco analysis.

Required data

To make an i-Tree Eco calculation, at least information on species and trunk diameter is needed at the individual tree level. i-Tree then models a tree based on that information and makes a leaf area calculation, which is an essential basis for calculating ecosystem services.

To make a more accurate calculation, it is recommended to enter more data, such as: land use, tree height, crown height, crown size, health, missing crown and light incidence on the crown. In our experience, the accuracy and completeness of this data greatly affects the final calculated ecosystem services provided.

The data is read into the application via an import (e.g. Excel) or by entering the trees directly. After checking the completeness and correctness of the data, it is submitted to the server in the USA, where the i-Tree calculations are made. Within a few hours, the user is notified to download the results to the application.

Structure of the tree stock

i-Tree then provides information on the structure of the tree stock, such as: numbers of trees, species distribution, stem diameter classes, susceptibility to diseases and pests and tree crown volumes. If known, it also provides insight into ownership and ratio of public and private trees.

Function

Based on the structure, the number of ecosystem services provided by the introduced tree stock is then calculated. Currently in Europe, it is possible to quantify five of the approximately 20 ecosystem services [CICES V5.1] provided by trees in the urban environment with i-Tree:

- Carbon storage (kg)
- Carbon sequestration (kg/year)
- Capture of air pollution (NO2, O3, PM2.5, CO and SO2) (g/year)
- Stormwater capture (avoided runoff) (m3/year)
- Oxygen production (kg/year)

Economic value

From the quantitative quantities, i-Tree then calculates the economic value. i-Tree has standard parameters for this (e.g. € / kg Carbon). These are based on data from the United States. Therefore, as with local meteorological information, it is recommended to use local environmental damage prices. In the Netherlands, for example, environmental damage costs prepared for the Dutch government are used. These have been specified for i-Tree by CE Delft [Vries and Bruyn, 2020]. These are the social costs caused by one kilogram of pollutant. As a result, the calculated value best matches the local/national situation.

For the Netherlands, the Environmental Prices from Table 1 were determined for application in i-Tree. Also in England, Poland and Sweden, locally applicable values are applied in i-Tree calculations. This therefore does not use the 'default' value parameters in i-Tree.

Table 1: environmental damage costs Netherlands 2020 (source: CE Delft)

Environmental prices 2020 (source: CE Delft)	
CO2	€ 0,120 / kg
C in CO2 (€ / tC)	€ 439 / ton
SO2	€ 26,80 / kg
PM 2,5 (emission height 2-20 metres):	
- City <50.000 inhabitants	€ 85,50 / kg
- City 50.000 - 150.000 inhabitants	€ 85,50 / kg
- City 150.000 - 300.000 inhabitants	€ 111,30 / kg
- City 300.000 - 500.000 inhabitants	€ 168,40 / kg
- City >500.000 inhabitants	€ 285,15 / kg

The financial value, the result, consists of one static value, which is the total amount in the trees the time of measurement. The remaining values are dynamic, annual values current tree stock with current sizing, also calculating the annual carbon uptake.

4. Current status of i-Tree in Europe

To get an idea of i-Tree developments within Europe, colleagues actively working with i-Tree were contacted. These are the countries United Kingdom, Sweden, the Netherlands, Switzerland, Spain, Italy and Poland. In addition, information on facts and figures and concrete i-Tree projects was extracted from literature research.

Colleagues in Europe were asked about the status of i-Tree currently in the respective country, in what kind of studies i-Tree is applied, what are the new developments and innovations in the field of i-Tree and what effects the i-Tree studies carried out have had. There may be other initiatives and projects ongoing in the same or other countries not named in the overview below.

In Europe, the number of i-Tree users is rising sharply across countries. Leading the way is the UK, but the number of users is also growing rapidly in Sweden, the Netherlands, Belgium, Italy, Spain and Poland.

At the initiative of Treeconomics and Pius Floris Boomverzorging, an i-Tree Europe Network is being set up, inspired in part by user networks in countries such as the Netherlands and Sweden. Pius Floris Boomverzorging is a company in the Netherlands and Belgium active in tree care and tree consultancy.

This network with i-Tree specialists from different European countries aims at knowledge exchange and joint further development of i-Tree in Europe. In addition, since 2014, a European i-Tree congress is organised every two years to share knowledge and experiences. The last congress was in 2022 in Amsterdam (Figure 4). Next congress is likely to be held in 2024 in Dundee, Scotland.

Figure 4: speakers i-Tree conference Amsterdam 2022 (source: Pius Floris Tree Care)

4.1 United Kingdom

In the UK, i-Tree is currently being used very widely. For example, by calculating the ecosystem services provided during a tree inventory, drawing up Urban Forest Masterplans, planting strategies or carrying out an i-Tree Eco Plot study in collaboration with volunteers. These projects collected important data on the urban forest and made a significant contribution to raising awareness about the value of trees for the urban environment.

Torbay

The first i-Tree studies were carried out in 2010 in Torbay by Treeconomics. There, crown area was calculated and the benefits of the tree stock were depicted through an i-Tree Eco study. A second study was carried out here in 2021, providing insight into the development of the tree stock. It concluded that the number of trees has decreased sharply from 692,000 to 458,800, while the overall canopy cover has actually grown from 11.2% to 18.2%. Also, with the exception of annual carbon sequestration, all ecosystem services increased. The main results of both studies are presented in Table 2.
In the 2021 study, other calculation methods besides i-Tree were applied, including CAVAT (Capital Asset Value for Amenity Trees) and ORVal (Outdoor Recreation Valuation). [Vaughan-Johncey et. Al., 2021]

Structure and composition Headline Figures		
	2010	2022
Number of trees (estimate)	692.000	459.000
Tree density (trees/ha)	109	71
Tree crown surface	11,8%	18,2%
Shrub cover	6,4%	10,8%
Most common tree species	Cuprocyparis leylandii Fraxinus excelsior Acer pseudoplatanus	Fraxinus excelsior 14,1% Acer pseudoplatanus 10,8% Corylus avellana 7,6%
Most common genera		Fraxinus (18,1%) Acer (12,0%) Quercus (11,4%)
Replacement cost (CLTA)	£280 million	£306 million
Experience value (CAVAT)		£4.1 billion
Recreational value (ORVal)		£44.5 million

Table 2: main research results i-Tree Eco studies Torbay (2021) (source: Treeconomics)

Valuing London's Urban Forest

Since the first survey in Torbay in 2010, several i-Tree projects have been carried out in the UK. One of the best-known is the London i-Tree Project from 2015, in which 200 plots in the city centre and 524 plots in the outskirts of the city were inventoried in collaboration with volunteers. A summary of the results from this survey is presented in Figure 5 [Rogers et al. 2015].

Important gains have already been achieved during the project: the huge involvement of hundreds of residents to make this project a success. In addition, the results provide a basis to continue building the London City Forest in a structured way. Of particular note is that this project was sponsored by

Unilever, which wants to contribute to a more sustainable future through their BrightFuture movement.

Environment Minister Rory Stewart said, "Our trees and forests have long been central to British identity. But we are beginning to understand with even greater precision how important they are to our air quality, our health and our happiness. This is a fantastic initiative. And it fits very well with our commitment to plant a further 11 million trees in this parliament and support green spaces across the country." [source: London Tree Officers Association]

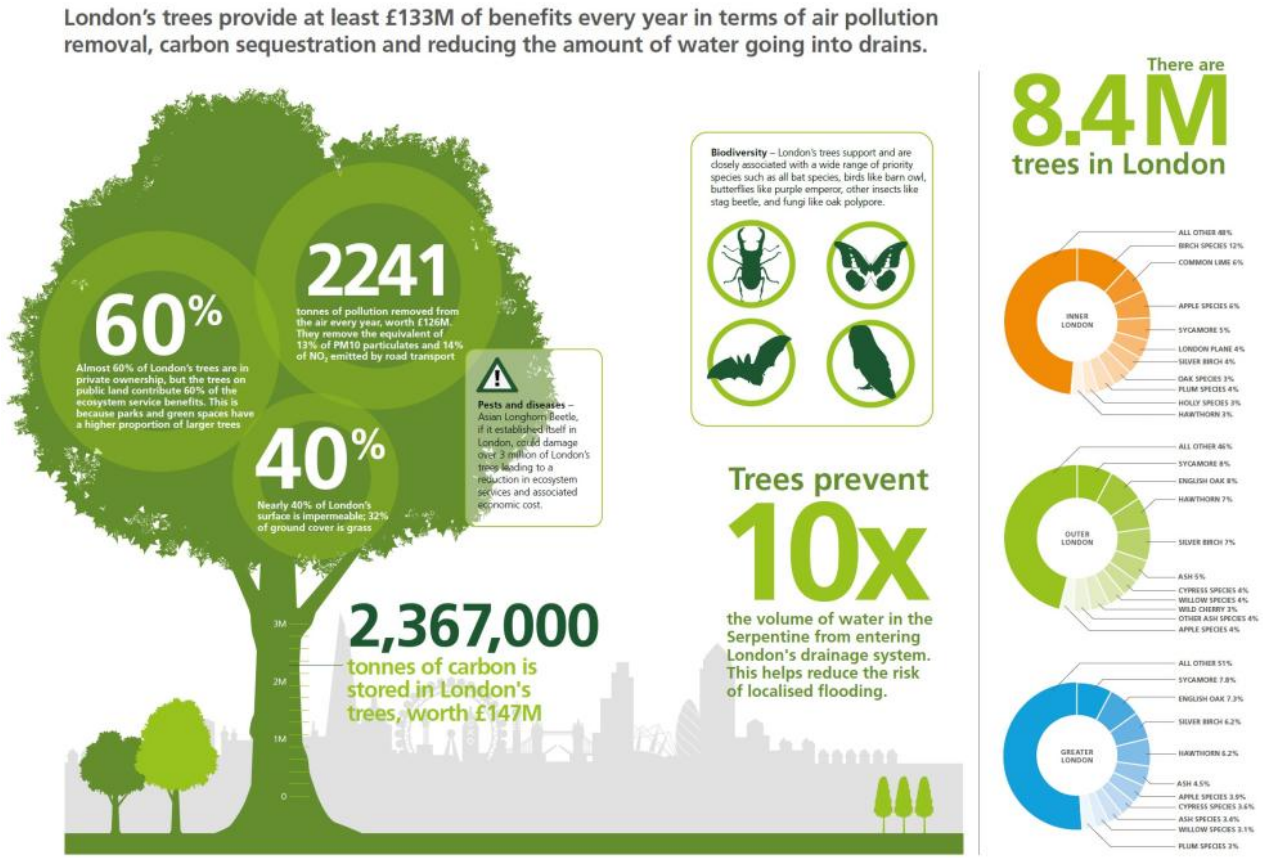


Figure 5: summary results London i-Tree Project (source: Valuing Londons Urban Forest, 2015)

i-Tree tool for highways

In the UK, i-Tree itself is also being further developed. In collaboration with Highways England and i-Tree USA, Treeconomics has developed the i-Tree Highways England tool. This tool is based on the i-Tree Design tool, which is already applicable for the United States.

The Higways England tool makes it possible to provide insight into the loss of ecosystem services and how much will be compensated by the planned replanting in reconstructions or road modifications where trees have to be cut down. For a 100-year period, the predicted quantitative and financial benefits are visualised. With this tool, Highways England's civil engineers can determine how best to carry out a reconstruction with optimal preservation of ecosystem services and/or optimal compensation for the loss of ecosystem services through felling and replanting. Remarkably, this tool was developed at the initiative of the UK and is now available via the official i-Tree website.

4.2 Sweden

Swedish i-Tree project

In 2017, the Swedish i-Tree Project was set up by the Swedish University of Agricultural Sciences in cooperation with 26 Swedish organisations, including nine municipalities, three housing associations, cemeteries, consultancies and independent tree specialists.

It is a nationwide project in which municipalities and housing associations contributed their inventory files to make i-Tree Eco calculations. What was interesting about this was the geographical distribution of the different cities and corporations across the country, which allowed a representative picture of urban tree stocks in different climate and vegetation zones.

The aim of the project was to visualise the ecosystem services provided and the value of urban trees in Sweden, which can serve as a basis for policy choices regarding trees. The information from this project can be used by politicians and decision-makers, but also between departments within the municipal organisation or between the municipality and housing corporations or developers.

The project resulted in an inventory of 16,223 trees, representative of a total urban tree stock across all participating cities of 12,530,555 trees across the entire project. From this, it was calculated that the total annual uptake of air pollution (NO_2, SO_2, VOC and $PM_{2.5}$) is 1,190,568 kilograms. The total carbon stored is 727,821 tonnes, equivalent to the annual CO_2 emissions of 5,640,391 passenger cars. The trees in this project capture rainwater equivalent to 2,263 Olympic-sized swimming pools annually. This is shown in Figure 6 in an infographic. [Östberg & Deak Sjöman, 2020]

Figure 6: infographic captured rainwater by participating city. (source: i-Tree Sverige, 2020)

Ryhov County Hospital

Another study was done at the Ryhov County Hospital, which has been located on an old royal estate since 1988. This i-Tree Eco study was done to understand the importance of trees as part of the healing, green environment. The park has increasingly become an important part in the recovery process of patients with circular walks and resting places in the greenery. Information boards have been placed in the park to inform patients and visitors about the park, the trees in it and their value. This raises awareness about the importance of trees.

Within the i-Tree project, 2,035 trees were inventoried, consisting of 244 different species and varieties. Besides providing insight into the distribution of species, this also provides insight into the susceptibility of the tree stock to diseases and pests. For example, 14% of the tree stock consists of Lime trees (Tilia spp.), which are responsible for an annual capture of 1,042 kg of pollutants and 9.8 tonnes of CO2 storage per year. So if this species disappears, there will be a big gap in the ecosystem services provided.

i-Tree Eco is a powerful tool increasingly used in Sweden to calculate the ecosystem services of trees. As a result, recognition of the value of trees and funding for urban trees is steadily increasing.

4.3 Netherlands

Dutch i-Tree project

The i-Tree Netherlands project was launched in 2015. In an initial pilot, 500 trees were inventoried and calculated in i-Tree Eco at five municipalities (Amsterdam, Rotterdam, The Hague, Dordrecht and Heerhugowaard).

In 2017, a second pilot was launched in which 14 municipalities, 4 tree consultancies, industry associations, colleges and universities worked together. In the 14 municipalities, one or two tree stocks were calculated using i-Tree Eco. In addition, in-depth research was conducted into (climate) themes to which i-Tree Eco could contribute: water regulation, cooling, air quality, health and (bio)diversity. This involved investigating what the i-Tree Tools could already calculate and what this means, what is known from scientific research about the contribution of trees to these themes, what this means for the Netherlands and whether these effects can be quantified and possibly made applicable in i-Tree Eco. The conclusion: i-Tree Eco is well applicable under Dutch conditions for the themes of air quality, water capture and CO2 sequestration. Further development of the tool is promising. [Kuijper & Batenburg, 2019]

Platform i-Tree Netherlands

It has turned out that creating awareness about the application and possibilities of i-Tree requires a lot of mission work. In addition, it is essential for subject specialists to work uniformly with i-Tree and the resulting data.

For this reason, following the pilots, a partnership was formed between four leading tree consultancy firms: Platform i-Tree Netherlands. This platform consists of Pius Floris Boomverzorging, IdVerde Bomendienst, Cobra Groeninzicht and Terra Nostra. [www.platform-itree-nederland.nl]

The aim of this platform is to promote working with i-Tree in the Netherlands, with the following objectives:

- Secure and promote the proper application of i-Tree in the Netherlands;
- Exchange knowledge and experience between the consulting firms involved on ecosystem services and i-Tree in particular;
- Sharing knowledge about i-Tree and ecosystem services with the market.

i-Tree 2.0-NL project

The i-Tree 2.0 NL project will run from 2021 to 2024 and is a major research project in which eight municipalities, seven tree consultancy firms, five tree nurseries, three design firms, two industry associations, five knowledge institutes and i-Tree USA / Davey are working together.

Within this project, accurate measurement data are being developed on the optimal cooling performance of hundreds of tree species in Dutch cities. In the process, estimates of lifecycle performance are made. These data will be integrated into i-Tree, with the aim of using i-Tree to provide insight into the cooling performance of trees in the urban environment. In addition, this project will determine accurate growth ratios of trees in Dutch cities in order to further tailor the forecast. [Velde & Price, 2021]

TreeTag-project

In 2019, Pius Floris Tree Care organised an international TreeTag project. Inspired by Jenny Garden (Australia) about using TreeTags to create awareness about the value of trees, the idea was born to hang an information poster on a tree at 150 locations in the Netherlands, Belgium, England and Sweden on a single day. This poster provides insight into the benefits of that particular tree. This information is easily accessible and understandable, such as the number of car kilometres saved in CO2 or number of days of oxygen for one person that this tree produces. An example of a TreeTag is included as Figure 7. Immediately upon hanging, press releases with information about that specific tree were also sent to local media and photos were posted on social media. All TreeTags were also placed on an online map with photos as well as the calculated data [www.treetags.eu].

Figure 7: A TreeTag on a Dutch tree (Quercus rubra). (source: Pius Floris Boomverzorging)

This project was opened together with an alderman from the municipality of Alphen aan den Rijn and has gained huge publicity. Many TreeTag projects have since been carried out in the Netherlands with the aim of informing local people and politicians about the value of trees. The TreeTag campaign has also received a lot of attention internationally. Meanwhile, TreeTag has been translated into Swedish, English, Polish and Italian and TreeTag campaigns have also been held in those countries.

As a follow-up to the TreeTag Project, an awareness campaign has been launched in the municipality of Almere: Our Trees. The aim is to encourage residents in 2023 to measure trees themselves, enter them via an online application after which the benefits of that particular tree are calculated. This is then displayed on an online map and a TreeTag is attached to the tree. The aim is to hang a TreeTag on 1,000 trees in Almere next growing season, giving residents an insight into the value of trees for the urban environment. For more information, see: https://www.ivn.nl/onze-bomen.

Ecosystem City

i-Tree is also used as a tool in various scientific studies in the Netherlands, such as in the Ecosystem City project. A consortium of knowledge institutes, consultancy firms (including Pius Floris Tree Care), civil society organisations and governments is working together in a project to gain insight into how to create balance in the water needs of functional greenery and the availability of water in the climate-proof and nature-inclusive city.

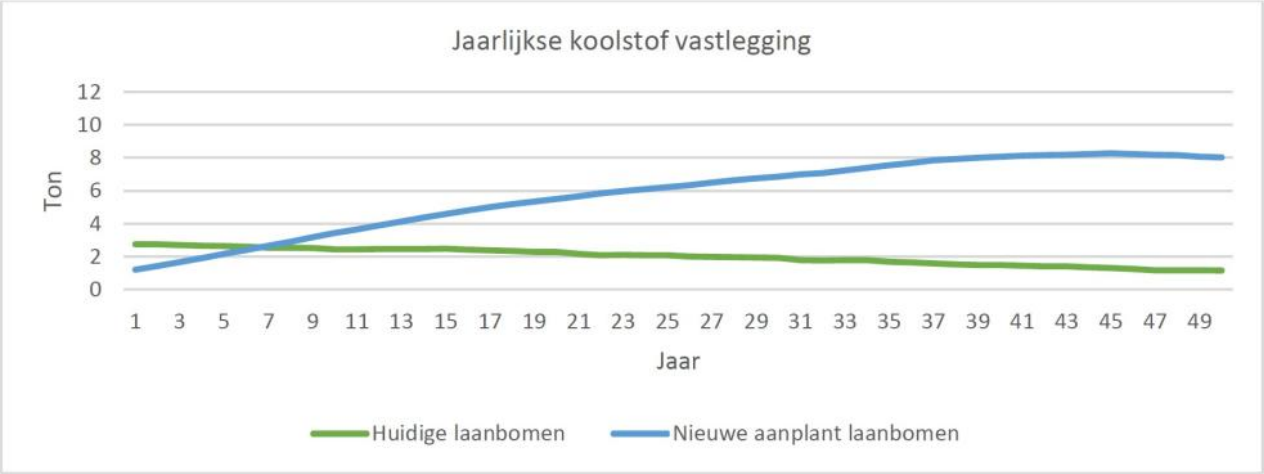
i-Tree provides insight into how trees develop in different types of growing sites (poor to very good), what the costs are over 100 years and how many ecosystem services the trees provide over 100 years. This allows a long-term cost-benefit analysis to be made for the realisation of good growing places with sufficient water versus cheap but poor growing places.

By deploying i-Tree, it has been shown that the ecosystem services of trees in a good growth site, with a healthy growth period of at least 80 years, provide exponentially more ecosystem services than trees in a poor growth site with a growth period of up to 15 years. For more information, see: https://www.ecosysteemstad.nl/.

Felling and replanting: compensation based on ecosystem services

In several studies, i-Tree has been applied to determine if and when the number of ecosystem services provided by the trees present is compensated for when felling and replanting. These studies reveal how many ecosystem services are lost by felling trees in a particular project. They then calculate what and how many trees need to be replanted to compensate for the loss immediately or within a certain period (10 years, for example).

The graph in Figure 6 shows the evolution of sequestered carbon over the years, for the existing and newly planted trees. While the total amount of stored carbon is limited in the first few years, it steadily increases over 40 years to an amount of about 8 tonnes. At the 0 situation, the existing trees still sequester about 3 tonnes of carbon per year, but this is surpassed by the new trees after only seven years. [Hoef et al. 2020]



Graph 2: carbon sequestration of existing and new trees (source: Pius Floris Boomverzorging)

Through these surveys, the importance of preserving mature trees is made clear to clients such as developers and governments.

Municipality of Veenendaal: i-Tree Eco and Canopy

In the municipality of Veenendaal, an i-Tree Eco study was conducted on 30,000 municipal trees. Of these, the structural and annual ecosystem services were calculated. This was determined quantitatively and financially. Typically, the 30,000 trees with only 3 annual ecosystem services (air pollution capture, rainwater capture and carbon sequestration) provide €335,000 in benefits (see table 3), while the budget for maintaining these trees is only €250,000.

Table 3: main research results i-Tree Eco study Veenendaal (2020) (source: Pius Floris Boomverzorging)

Results i-Tree Eco study municipal trees Veenendaal		
Number of (municipal) trees	30.016	
Number of tree species	Quercus robur, Fraxinus excelsior and Alnus glutinosa	
Number of tree species	263	
Green benefits		
Structural value		
- Carbon stock (C)	10.120 tonnes	€ 4.020.207,-
Annual benefits		
- Carbon sequestration (C / year)	340,8 tonnes	€ 135.335,-
- Water capture (m3 / year)	17.020 m3	€ 32.400,-
- Air pollution capture (tonnes/year)	6,45 tonnes	€ 169.000,-
Total annual benefits: € 336.732,-		

The actual annual benefits are many times higher still if all the more than 20 ecosystem services provided by trees are included. This figure has proved to be an important one for tree managers in discussions with politicians about budgets for tree management. The return is many times higher than the cost of maintenance.

In addition, an i-Tree Canopy survey was conducted. The percentage of crown cover for each neighbourhood was determined. The potential easy-to-plant space was also determined, giving insight into the potential maximum crown cover percentage.
This was then compared at neighbourhood level to societal challenges such as heat island effect, air pollution, wellbeing and obesity. Although this is not a scientific approach, it gives the tree manager/politician insight into focus areas: where is the demand for trees greatest and do they potentially have the most impact on urban climate and health? See Figure 7 showing focus areas by theme. [Hoef et al. 2020]

Figure 8: Focus areas social challenges in relation to percentage crown cover. (source: Pius Floris Boomverzorging)

4.4 Switzerland

Creating an i-Tree Eco-based Urban Forest Management Toolbox
In Switzerland, a 3-year i-Tree project, subsidised by the national government in the framework of green-blue solutions, is ongoing. By this is meant interventions in the urban environment with greenery and/or water that contribute to a climate-proof and sustainable living environment. This project aims to translate i-Tree Eco outcomes into the climate-adaptive contribution of the tree stock, on the basis of which management plans can be made for Swiss urban forests. The project is being implemented in

seven Swiss cities and 1 canton.

As part of this project, an online database of studies on urban forests and their value has been set up. The i-Tree Eco Guides have also been translated into German and French. Practical training was developed for surveying data and translated into information sheets with measurement protocols and illustrations, see Figure 9. The outcomes from the i-Tree Eco survey were discussed in local workshops, focusing specifically on translating i-Tree Eco data into clear communication tools. In addition, two Urban Forest Management Toolbox workshops were developed to share the results of the i-Tree research and how this can be translated into climate mitigation and adaptation strategies for the Swiss cities of the future.

Important message that follows from the i-Tree Eco studies is that the current method of tree management (short-term management, no long-term vision for a healthy and functioning tree stock) will not lead to the trees we need in the cities of the future. Focus should be on large, healthy and mature trees that provide by far the most ecosystem services.

To give a handle on how best to translate the findings from the i-Tree surveys into projects, an article "Creative strategies for using i-Tree data outputs in Switzerland" was written by Naomi Zürcher. [Zürcher, 2022]

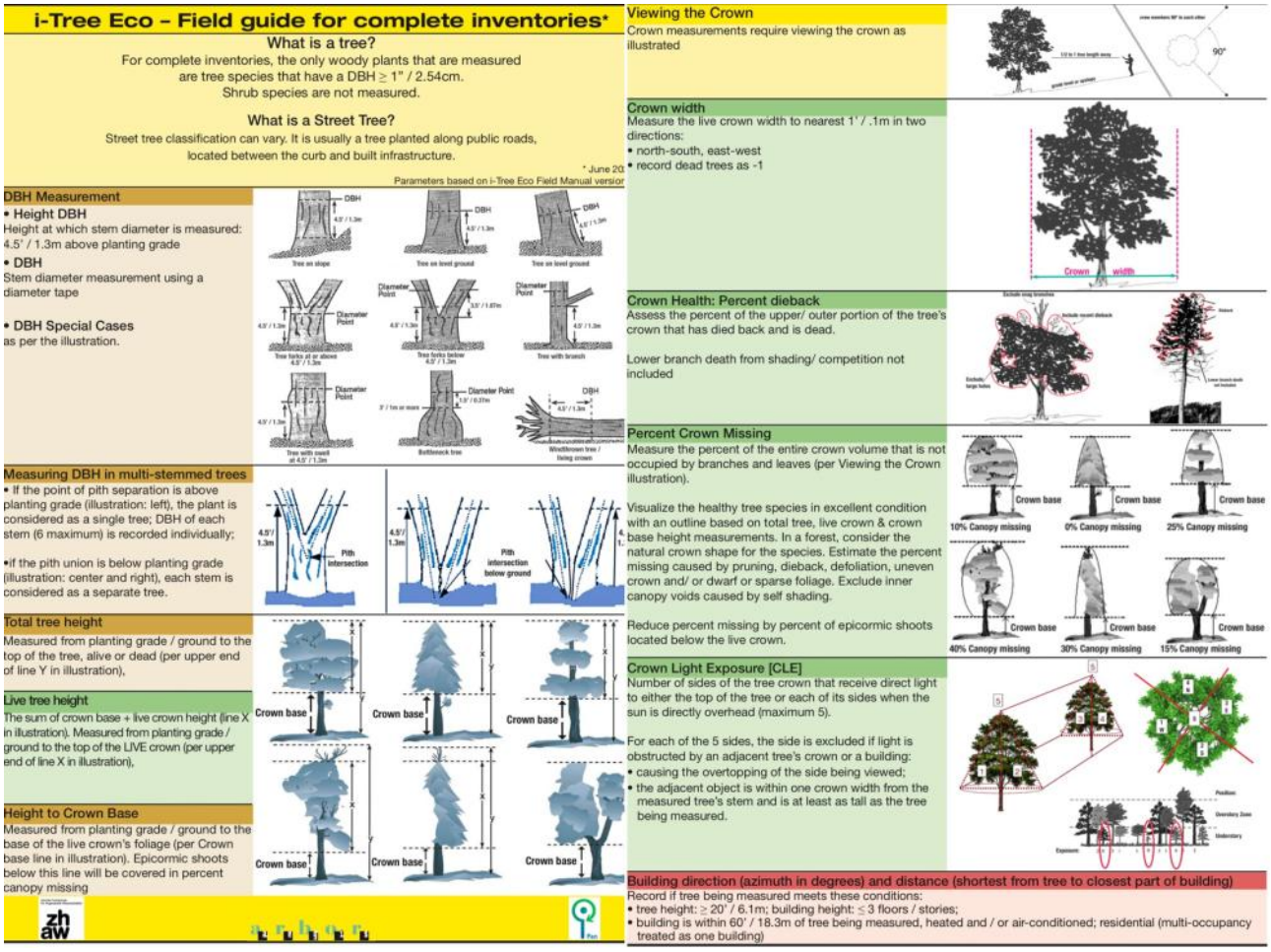


Figure 9: i-Tree Eco Fieldguide (Source: Zürcher, 2022)

New projects in Switzerland

In addition, several new projects are being set up. For example, as in Basel or Zürich, municipal tree inventories can directly include the data needed for an i-Tree Eco study. Linked to this, training courses are being developed to record this data properly and projects are being set up where citizens themselves can provide information. i-Tree is also used to assess the effects of spatial developments on ecosystem services provided.

4.5 Spain

With the development of i-Tree worldwide, Spanish cities are also following suit to use i-Tree as a tool to quantify and value the ecosystem services of urban forests. Spanish cities are using this data in their own strategic plans and policy choices regarding trees.

To date, there is no national initiative to apply i-Tree widely in Spain. The current projects have been initiated by individual municipalities. i-Tree Canopy is the most accessible tool and most frequently applied. Several small and medium-sized towns have published their results. In addition, some universities have used this tool to value the green infrastructure present on campus, including Universidad de Jaen and Universidad Politecnica de Madrid.

Limited i-Tree Eco studies have also been carried out, such as in Madrid, Barcelona, Vitoria-Gasteiz and Santa Cruz de Tenerife. The first i-Tree Eco studies were based on a plot study. Later, full municipal inventories of public trees were also calculated using i-Tree Eco. The number of i-Tree users is growing, starting with i-Tree Canopy studies and then i-Tree Eco studies.

Madrid was the first city in Spain to make an i-Tree Eco calculation based on a complete inventory. Municipal inventories from 2016 and National Heritage inventories were used for this purpose. An analysis was carried out with a total of 3,740,000 trees. From this data, results can be predicted for all trees in Madrid, which is estimated at 5,700,000 trees. A second i-Tree study was carried out in 2021 based on the same inventories, in collaboration with the 21 city districts. The impact of both studies has so far been limited. Besides media attention on the importance of trees, both studies have yet to achieve many results, such as in other legislation or increases in green budgets.

Barcelona has already carried out several i-Tree studies. The first was in 2009, using the UFORE model. From 2014, i-Tree Eco studies have been carried out. Both are based on a plot study with 579 randomly distributed plots throughout the city. The results of these studies have been used for Barcelona's tree strategy.

A new i-Tree Eco study was carried out in 2019 with an inventory of 200,000 trees as part of a study on the geographical distribution of urban trees and their impact on the environment. These studies have also received media coverage in Barcelona, but the impact is otherwise limited.

Although the impact of i-Tree studies carried out to date has been limited in Spanish cities, this is slowly starting to change. The latest i-Tree Eco study in Madrid was not based on the existing urban forest, but on the ecosystem services of the future green ring around Madrid that the municipality plans to plant in the coming years. I-Tree was used to calculate the economic return on ecosystem services compared to the investment for planting. The results of this study are even used by politicians as a selling point for realising the green ring around the city. Valencia is also currently (2023) undergoing an i-Tree Eco study, the results of which will be used in a new Green Infrastructure Strategy for the city. [Arboricultural Association, 2022]

4.6 Developments in other European countries

The use of i-Tree within Europe is growing rapidly. However, most countries are still in the exploration phase and i-Tree is mainly used in academia.

Poland

In Poland, there was an i-Tree Canopy study in Warsaw ten years ago, but it has not been followed up. Currently, however, i-Tree Canopy and i-Tree Eco are increasingly being used in tree inventories (e.g. of monumental trees) and Tree Impact Analyses in which ecosystem services are added as an extra value in addition to the replacement value. I-Tree is thereby also used to calculate how many trees need to be compensated to offset the ecosystem services provided by trees to be removed. Several TreeTag projects have also been set up in Poland to raise awareness about the value of trees.

Italy

In Italy, i-Tree is so far mainly known in the scientific community. There are still few consulting firms using i-Tree as a tool in their tree engineering advice. There have been some trials of calculating existing inventories with i-Tree (such as Varese's Urban Forest, with about 8,000 public trees). There are also reforestation projects (to compensate for polluted air emissions), where i-Tree is used to provide insight into the ecosystem services of trees. The reactions from a broad public to this data are very positive.

5. Conclusions and prospects

The use of the i-Tree programme in Europe has increased significantly in recent years, and especially from 2016 onwards. For now, this mainly involves the use of the tools i-Tree Canopy and i-Tree Eco, which are suitable for application in the European situation. I-Tree Eco currently calculates 5 of the more than 20 ecosystem services of trees. So it does not give a complete picture of all ecosystem services provided and their associated financial value. However, a strong point is that the ecosystem services calculated can be expressed in quantitative and financial value. In addition, they are very specific: based on tree species, shape, condition and local weather and air pollution data. However, this air pollution data is not current (2015). More up-to-date data can often be applied from weather data (2020).

In addition, when applying i-Tree, the scale of the project, the accuracy of the input data and the degree of rounding of the results must be taken into account. It is known from some data that a slightly different value (e.g. condition) has a relatively large effect on the results from i-Tree. For a limited number of trees, the importance of accurate measurement is greater than for an entire municipal tree stock, where the result is often about the big numbers and not at the individual tree level. The same applies to harnessing the financial or quantitative value of ecosystem services. Experience shows that deploying the financial value is really only useful for large numbers of trees. Setting up national and European i-Tree networks is a useful tool to create and use a uniform working method in this respect, such as in the i-Tree Platform Netherlands. These networks can also jointly set up projects to develop i-Tree specifically for their country, making the programme even more accurate and applicable.

The purpose of an i-Tree study must be determined beforehand. Based on this, it can be determined which tool (from within the i-Tree package or in combination with other tools) should be used to achieve the desired result. In addition, the level of detail in recording data and presenting the results is then also immediately determined.

5.1 Application of i-Tree in Europe

In summary, there are three areas where the i-Tree programme is currently applied within Europe: creating understanding, tree policy and management and awareness.

Creating insight

Conducting i-Tree Canopy and i-Tree Eco-studies provides a better understanding of the urban tree stock. An i-Tree Canopy study provides insight into the amount of crown cover in a certain area and the distribution between certain areas. This is determined regardless of ownership status of the tree, so private and public trees are both included.

i-Tree Eco provides insight into 5 out of more than 20 ecosystem services provided by trees. This can be done either by entering a complete inventory (e.g. a municipal tree stock), or from and plot study. The advantage of the plot study is that it provides insight into the entire urban forest. Not only public, but also private trees are included. As a rule, it is precisely the private trees that are not yet well understood by tree managers, even though they form a large part of the urban forest.

Tree policy and management

The insight gained from the i-Tree studies gives the tree manager tools to better define the tree policy, aimed at a functional urban forest. It also provides opportunities to generate more budgets for tree planting and tree management, as well as targeted policy for planting and maintaining trees on private land.

i-Tree is often used in the preparation of planting strategies, Urban Forest Masterplans and tree policy plans. For example, in Torbay, London and Veenendaal, i-Tree research has made a significant contribution to the municipality's tree policy.

Awareness

An important added value of i-Tree is the possibility to create more awareness about the value of trees. On the one hand among politicians and civil society organisations, but also among residents and area owners. Several awareness-raising campaigns have been carried out in Europe, such as a TreeTag action or an i-Tree Plot study in cooperation with volunteers and ambassadors.

Figure 10: instruction volunteers for recording tree data for the purpose of i-Tree (Source: Naomi Zürcher)

In these campaigns, quantitative benefits (i.e. kg of CO2 stored, etc.) are used in particular. By making these quantitative ecosystem services of trees transparent and presenting them in an understandable way, people become aware of the great added value trees represent. Precisely because a large proportion of (mature) trees are in private areas, it is essential that residents and area owners also understand the value of trees.

This awareness will also be used to generate more attention to planting trees in good growth sites and preserving (potentially) valuable trees. By providing insight into the potential ecosystem services of a healthy mature tree versus a tree in a poor growing site, more targeted planting and maintenance can be carried out on a functional urban forest.

5.2 Cooperation

i-Tree is an engine for various disciplines to work together more. Research institutes, (landscape) architects, tree consultancy firms, governments and implementing organisations are working intensively together in different countries to further develop i-Tree. But also within concrete projects where the ecosystem services of trees play an important role, new collaborations are being developed with the help of i-Tree, such as in the Onze Bomen project in Almere (the Netherlands) or in the projects where the compensation needed for lost ecosystem services is being clarified.

In addition, i-Tree provides a unique connection between professionals, governments and society. In a large number of i-Tree projects, i-Tree is used to make society aware of the importance of trees. This can be done by using volunteers to collect data or by using the results of an i-Tree calculation to inform society about the benefits of trees in an accessible way.

5.3 New developments i-Tree United States

Besides developments from various countries, including the i-Tree 2.0 project in the Netherlands and the i-Tree Highways England tool, there are also new developments from I-Tree US. On the one hand, the servers and usability are being further modernised and developed. In addition, there are several specific projects to add new ecosystem services or develop tools. I-Tree USA is currently exploring ways to include new ecosystem services in i-Tree Eco, such as:

- Health effects
- Tree Equity (equal tree distribution)
- Biodiversity
- Carbon credits

API

Until now, conducting an i-Tree Eco survey was done by sending in a completed i-Tree inventory, after which the results were calculated and sent back.

i-Tree has developed an Application Programming Interface (API) to link i-Tree Eco to existing tree management systems. This allows the benefits provided by trees to be automatically calculated and made transparent. This simplifies linking delivered ecosystem services to existing tree inventories and encourages the use of this data in day-to-day tree management.

6. In conclusion

Thanks to all the research of the past decades, there is more specific knowledge within the professional world and academics about the value of the urban forest for liveable and healthy cities. Programmes like i-Tree make it possible to translate this value into concrete numbers, allowing urban forests to be managed and developed with a new perspective. In addition, this approach creates unique collaborations and conversations about urban forests on a different level. I-Tree represents an important tool for professionals to communicate the importance of a healthy urban forest with other disciplines and stakeholders, such as politicians and residents.

i-Tree is not the complete answer, partly because only a limited number of ecosystem services can currently be quantified. The worldwide use and further development of the programme, which is being used in several countries, but also by the US itself, does demonstrate the importance of this type of programme for the professional world. Thereby, i-Tree will always have to be used together with other tools and guidelines to achieve the maximum effect.

For years, i-Tree surveys (in Europe, but also in the US) were something extra, mainly driven by academia and urban tree managers, separate from policy or strategic plans. Currently, the shift is towards quantifying ecosystem services and the economic valuation of trees as an important part of strategic plans for urban forests.

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