i-Tree 2.0-*NL*

Next-generation metrics and methodologies for urban forestry and climate resilience in Dutch cities

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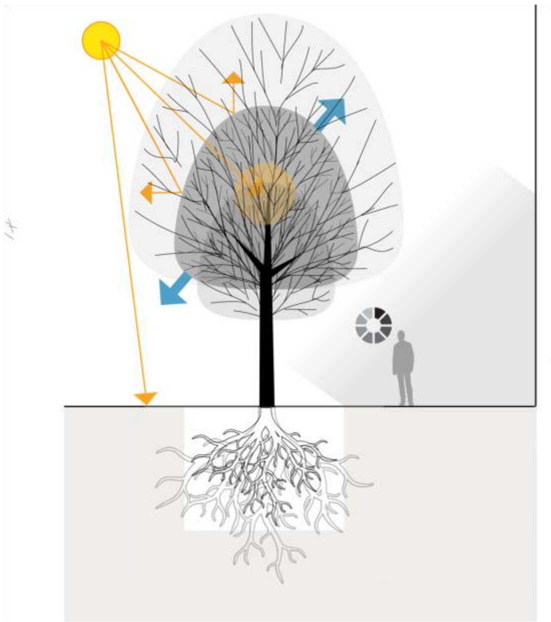
4. PROBLEM DEFINITION

Cities must adapt to deal with impacts of climate change such as higher temperatures and longer periods of heat stress, which come on top of existing problems caused by the Urban Heat Island phenomenon. Changes are needed in the physical realm, transitions need be made in policy and governance, and the resilience of urban communities to these conditions needs to be improved. Greenspace, and the urban forest in particular, is one of the most effective means of climate adaptation through the ability of trees to ameliorate extremes in urban thermal cycles. Beyond this, the urban forest (understood as the entire mosaic of trees in urban public open spaces) offers added benefits to urban water management, air quality, biodiversity, health & wellbeing, and overall urban liveability. The ubiquity of trees and greenspace in cities also positions them as effective agents for building climate resilience in urban communities. Despite these potentials however, and the long tradition of establishing and maintaining urban trees in Dutch cities, the role of the urban forest in addressing these new challenges remains limited. Barriers occur in three areas: the lack of data and relative infancy of scientific tools to model tree performances in relation to urban thermal cycles, the lack of (scientifically developed) methodologies for stakeholders to incorporate urban tree benefits into public infrastructure, and the absence of correlated strategies to effectively empower green infrastructure in resilience-building of urban communities.

Performance metrics & tools

Urban planners, spatial designers and greenspace professionals require precise data and instruments to monitor and model the benefits of urban trees in relation to thermal cycles and urban microclimates. This applies to both the base-line performances of different species, and to performances across the lifespan of the tree. With these performances quantified, the urban forest can be better managed to develop and maintain these benefits, and to form a more integral part of plans for 'cool' neighbourhoods and new urban developments. A central concept in the understanding of these performances is a tree's architecture, a knowledge domain in the research fellowship Urban Forestry at the Faculty of Architecture.

Physiognomic traits of a tree such as crown morphology, wood anatomy and foliage characteristics determine how and to what extent a tree cools its environment down, and how this aids thermal comfort. This data can be augmented with metrics on transpiration rates of different tree species, which adds to a tree's cooling capacity through evaporative cooling. If these performances are then calculated over the growth stages of the tree, we can for the first time gain a complete and accurate picture of the thermal benefits of the urban forest.



The translation of these insights into datasets and an implementation platform is a necessary related step. In recent years i-Tree, a peer-reviewed software suite from the USDA Forest Service that provides urban forestry analysis and benefits assessment has been released as international public domain software. Applications within this suite such as i-Tree Eco combines data on single trees or stands in a study area with local data such as meteorological conditions to quantify urban forest structure, ecosystem services, and other values to communities. Results from tests with the tool by sample municipalities and key stakeholders in the Netherlands have been positive, but its effectiveness in modelling the performances of trees for heat stress and across the life cycle of the tree was concluded to need further development. (Van Kuik, 2018) Drawbacks lie in the lack of metrics on trees specific to bio-geographical (Atlantic) and climatological (Cfb) zones where Dutch cities are located, and on the absence of baseline data on cooling performances in relation to tree growth curves. The platform does however offer a scientifically sound basis for elaboration and development internationally.

Adoption methodologies

Developing accurate and climate zone-specific datasets within the i-Tree model tool will equip planners, designers and greenspace professionals to more effectively realise urban greenspace for climate adaptation. The adoption and success of tools such as i-Tree Eco however, cannot be assumed on performance benefits alone. New technologies do bring new forms of value, yet their novelty also presents a paradoxical challenge for adoption. For this reason new frameworks are required for planners, designers and greenspace professionals to benefit from the value created by a tool such as i-Tree. In technology development, it is crucial to generate use cases or scenarios where the technology creates value for stakeholders by solving problems. To do so, we must deeply understand the potential of the technology. However, superficial use cases that map assumed user needs are not enough and can lead to the ill-fated 'technology push'. The pushed technology will end up obsolete, as the problems faced by users and stakeholders are not addressed by the comprised solution. To avoid this we must comprehend the needs and desires of the users and various stakeholders to guide how technology is applied in a synchronous way to life. The latter requires an academically developed design approach that is human-centred, iterative and integrated in order to go back and forth between technological potential and human necessity. As such, synchronising - through the use of for instance co-design techniques - the technical potential of urban trees to stakeholder needs and interests via a next generation i-Tree platform is a central challenge here.

Transition strategies

The development of an uptake methodology around the i-Tree tool will prepare city ecosystems for its early adoption, leading to improvements in climate adaption of cities. Despite physical improvements to the urban tissue, urban communities can still remain vulnerable to the effects of climate change. Developing strategies to enable climate resilience among urban communities with and through the urban forest offers the potential for durable outcomes in areas such as sensing, sharing and solving. The need for improvements in urban liveability and particularly in areas of air quality, ecology, health and wellbeing form part of this problematique. The i-Tree tool presents itself as a promising (technical) basis to alter service and social paradigms. The potential of greenspace to form part of strategies enabling this transition lies for example in citizen input to GIS databases on urban heat, the identification of greenspace ‘cool-spots and cool routes’, the sharing of data, and greenspace implementation, adoption and maintenance. (Price et al., 2020)

5. GOALS & OUTCOMES

A. Develop methodologies and metrics on urban tree cooling performances and urban tree growth curves to:

- effectively measure and monitor the contribution of urban trees to ameliorate extremes in thermal cycles in cities caused by climate change (via embedding and application in i-Tree software);
- inform physical transformations of greenspace and the urban fabric using trees (via embedding and application in i-Tree software);
- contribute to the development of i-Tree as benchmark scientific toolset to quantify and qualify urban trees and forests in respect to their environmental, ecological and community benefits.

B. Realise effective adoption of the tool by:

- developing a methodology together with urban planners, designers, greenspace professionals to guide how the tool is applied in a synchronous way;
- effectuating optimum adoption, change and impact among public space development and management stakeholders around the iTree platform, through the ease and effectiveness of the methodology;

C. Effectuate transitions in climate resilience and urban liveability by:

- developing a methodology together with urban planners, designers, greenspace professionals to guide how the tool is applied in a synchronous way;

Specific Outcomes

I. Scientific classification system for tree architecture, relevant to urban thermal microclimate amelioration;
II. An innovative methodology to categorize the most relevant characteristics of urban trees for thermal microclimate amelioration;
III. Scientific data on tree cooling performances, which quantify the contribution of different tree species to shade cooling, transpiration cooling and human thermal comfort in Cfb climate zone cities, and these performances under varying subsurface conditions;
IV. Metrics on species-specific growth curves that allow for the assessment of existing urban forest assets and the modelling of performances over the life-span of urban trees;
V. Integration of these metrics into i-Tree source-code(s), for release as public domain software;
VI. Context mappings of values, experiences and needs of stakeholders in relation to urban (thermal) climate resilience;
VII. Speculative elaborations for resilient urban forests, city landscapes and communities;
VIII. implementation prototypes from these visions using back-casting;
IX. A roadmap for implementation and technology development of iTree 2.0;
X. Scientific publications on tree architecture, urban microclimate amelioration, urban tree growth curves, adoption strategies, modelling tools, and citizen resilience.
XI. ‘Demonstration arboretum’ Marineterrein Amsterdam Living Lab (MALL).
XII. Web-based platform on the research project, with regular updates of results and links to related projects and initiatives.

XIII. Workshops on location in collaboration with MALL, around key steps and outcomes in the various work packages.
XIV. informal interaction between other MALL projects, with expected iterative development of i-Tree 2.0-NL and business development spin-offs.
XV. on-site demonstrations and 'trialing days' with key government, industry, research and societal partners invited to test research results in personal case studies.

6. IMPACT

Research institutes

This project equips participating research institutes with novel methodologies and classification systems on and around tree physiognomy and physiology in relation to urban microclimate amelioration. It also provides participating research institutes with specific datasets on cooling performances of various urban tree species and their growth curves in the Cfb climate zone. These datasets are also intended to contribute to the international scientific community initiative i-Tree, an initiative developed by urban forestry and greenspace researchers and practitioners on five continents.

Urban administrations

The development of data on the cooling performances of different tree species, over the life cycle of the tree, will equip greenspaces managers, planners and development teams with metrics to accurately quantify the performance of the existing and proposed urban forest in ameliorating extremes in urban heat cycles. The application of this data via its embedding in user-friendly tools based around the i-Tree platform is expected to significantly improve the resilience of Dutch cities to future climate change impacts and urban liveability generally by improving inputs for greenspace management. It is also expected to critically improve planning and design processes by not only providing a modelling tool with data to predict the performance of proposed urban forestry measures, but also to incorporate broad stakeholder participation at various stages of design and implementation. Moreover, the results of this project – both the scientific data and the application tool(s) – enables more objective reasoning and faster decision-making in discussions on existing as well as future greenspace.

Urban tree/greenspace consultancies

Participating arboriculture firms, as key advisors in various aspects urban greenspace management, planning and design, will be equipped with scientifically sound data and toolsets to help cities make accurate predictions of ecosystem services over the entire life cycle of trees, and better arguments for conservation and creation of green space in relation to climate objectives when considering urban development. These assets can also be expected to offer a significant competitive advantage in the domestic and international arena, and open up opportunities for new business in terms of client base and industry collaborations. The connection which the project sets up between industry partners and participating large, medium and small cities can be seen as a significant spinoff of value to participating firms in its own right. New avenues for business in related urban planning, design and greenspace management areas can also be expected to emerge from competencies and insights developed in the project.

Tree nurseries

The project provides tree nurseries with insights in the micro-climatic best performing tree characteristics, and enables them to timely adapt their assortment to emerging changes in the purchase polices of green asset managers in cities. Our network of participating large, medium and small cities partners, promises a growing client base during and after the project.

Design & Engineering firms

The new i-Tree module enables design and engineering firms to accurately assess the real impact and value of their own design proposals in an world where clients (urban administrations, private developers) increasingly demand objective information for societal discussions on the best ideas and choices to be made. New insights on the performance of the urban forest, is also expected to input into new visions on the future of cities and urban green infrastructure, with expected spinoffs for their own competitive edge and resonance in policies for urban development. These assets can also be expected to offer a significant competitive advantage in the domestic and international arena, and open up opportunities for new business in terms of client base and industry collaborations. The connection which the project sets up between industry partners and participating large, medium and small cities can be seen as a significant spinoff of value to participating firms in its own right. New avenues for business in related urban planning, design and greenspace management areas can also be expected to emerge from competencies and insights developed in the project.

7. WORK PLAN SUMMARY

The proposal centres around three work packages:

Work Package 1: Tree Architecture Typology & Baseline Cooling Metrics

Work package 1 focuses on the development of a baseline set of metrics elaborating the optimal/maximum cooling performance of tree species relevant to urban micro-climates in the Netherlands climate zone. This involves the development an advanced tree architecture typology (TAT) accommodating the range of urban tree species relevant to this zone, and integration of existing and new data on various (3) cooling performance indicators. Validation of the TAT is carried out through field observations and measurements of both adult and juvenile trees, including foliage transpiration rates, for integration into the TAT framework. This step also documents a range of urban surface conditions and urban typo-morphologies where appropriate. An interactive online database of micro-climatic thermal regulation performances for each tree architecture type is then created. The relationship between these performances and variables in soil-water balances (impacting transpiration rates) is then measured and integrated. Metrics for each tree species is then transferred to i-Tree (Eco or equivalent) as source-code, for use as open access software for applications in Cfb climate-zone cities.

Involved disciplines/expertise: environmental science; dendrology; landscape architecture; plant sciences; hydrology; (micro)meteorology; data sciences.

Work Package 2: Tree Allometry & Cooing Performance Curves

The second line of research focuses on growth curves of urban trees in the Cfb climate zone. Knowledge of tree growth curves makes it possible to estimate ecosystem services such as the cooling performance of urban trees up to their adult stage (results of WP1). It also makes it possible to calculate the performance of city tree species under future climate scenarios. Tree allometry describes the relationship between tree biometric variables, such as trunk diameter (at chest height, DBH), tree height and crown width. Accurate measurement of urban tree biometric parameters is essential for calculating crown volume and leaf area that are directly related to the ecosystem services that trees provide. There is little systematic knowledge about the growth curves of urban trees in the Netherlands, and how the relationships between those variables change between trees from different urban areas or species. This WP aims to develop generic growth curves to cover the range of city tree species in the Netherlands, to allow reverse calculations from optimal cooling performances metrics determined for mature trees in WP1. These growth curves are developed using variables in allometric relationships of different tree species, subdivided into tree types developed in WP1, from different sources, datasets, and measurements. Furthermore, this WP focuses on developing an innovative methodology to automatically estimate the most relevant characteristics of urban trees. We use existing knowledge that is supplemented with new research and validated under Dutch growth / climate conditions. We use new technology such as Remote Sensing and LiDAR (Light Detection & Ranging). Aerial photos and satellite images are analyzed with image and recognition programs that also use artificial intelligence.

Involved disciplines/expertise: dendrology; environmental modelling; data sciences.

Work Package 3: Resilience mapping, Vision-building & Prototyping

Work package 3 aims to synchronize the technical potential of i-Tree as a tool for integrating the cooling performance of urban trees to relevant stakeholder needs in urban Dutch environments. The first stage of WP3 identifies and map values, experiences and needs of citizens in relation to resilience, including project cities and partners, via context mapping. This method includes interviews, observations and fieldwork. Phase B follows with co-design sessions themed around three major areas/settings for climate resilience: citizen resilience, greenspace management and spatial transformations. Outcomes of these co-design workshops are then synthesized into speculative visions for resilient urban forests, city landscapes and communities, in a way that explicitly addresses the potential impact of iTree 2.0. These visions will spark also debate, promote this project internationally and drive interest in i-Tree 2.0. Snapshots from these visions are then selected to prototype using back-casting to bring a futuristic idea towards a prototype for implementation. In the 3rd phase of WP3, these prototypes are tested in pilot city Amsterdam. The focus of prototyping is on effective applications of i-Tree for the three specific areas/settings: spatial transformations, greenspace management and citizen resilience. We have identified the Marine-terrein as a test location for the prototyping in these three areas/settings and we will also identify other test locations in various urban contexts which reflect urban conditions elsewhere in the Netherlands. We will work closely with municipalities to develop these prototypes on representative test locations in partner cities and conduct an evaluation of the impact of those prototypes. Learning captured from city prototypes will be reported as part of WP3 Phase C. WP3 will conclude with the development of a roadmap to adopt i-Tree 2.0 technology offering a technical pathway for cities to follow, supported with practical recommendations.

Involved disciplines/expertise: industrial design, landscape architecture; urban design; architecture; product design; digital design; system & process design.

8. OUTREACH, DISSEMINATION AND EXPLOITATION

A central component of the i-Tree 2.0-NL project is outreach, dissemination and exploitation of results. A series of strategies are proposed, centering around the Marineterrein Amsterdam. This former Amsterdam naval base, whose future conversion to a mixed use residential area forms the setting for forecasting and prototyping of various i-Tree applications in work package three, will also take up a parallel role in ensuring rapid dissemination andinnovative transition and exploitation of research results. Prior to the urban redevelopment phase, the site functions as R&D zone for collaboration between science, industry, government agencies and citizens on various sustainability challenges in the urban realm, as Marineterrein Amsterdam Living Lab (MALL).

A first strategy involves the deployment of the current assemblage of trees on the complex, conceptualized as a ‘demonstration arboretum’. Interactive panels amongst the trees provide information on the project,

with QR-code links giving access to detailed real-time updates of research results. 24-hour public accessibility to this site located in a central point in the capital city offers maximum exposure to audiences around and outside the consortium. The second strategy involves the setting up and updating of a web-based platform on the research project, with regular updates of results and links to related projects and initiatives. A third strategy involves the organization of workshops on location in collaboration with MALL, around key steps and outcomes in the various work packages, with active participation by researchers and consortium members. These sessions are open to (passive) participation by key invited industry and government partners and the MALL community. Ongoing informal interaction between other MALL projects on the campus is a fourth strategy, with expected results in iterative development of i-Tree 2.0-NL and business development spin-offs. A fifth strategy involves on-site demonstrations and 'trialing days' in which key government, industry, research and societal partners are invited to test the results of the research in case studies they bring themselves.
Parallel activities not linked to MALL include dissemination moments via designated national events such as Netherlands *boominfodagen*, and presentations at scientific conferences, summits and congresses in the knowledge exchange networks of research team members and consortium partners. Given the international profile of i-Tree and the considerable scientific and industry community working in and with the tool, it is expected the project will garner significant international attention and dissemination possibilities, spreading results to the largest possible audience outside the consortium.

9. CONNECTION TO THE TOPSECTOR CREATIVE INDUSTRIES

This project relates to multiple mission themes, roadmaps, and Key Enabling Methodologies that are presented in the ClickNL Knowledge and Innovation Agenda 2020-2023.

Mission themes

By measuring the impact that trees can have on several factors in the urban environment, the involvement of multiple stakeholders, and ensuring that these results can be used by municipalities in their future planning, this project connects to the theme Energy Transition and Sustainability. This includes making sure that citizens are actively involved as a valued party in the process and end result of the project.

In a way, this project also aims to connect to the mission theme Health and Care. This project aims to discover which impact the usage of trees in an urban environment has on several topics. Amongst them is the wellbeing of a cities' inhabitants. This projects forms the basis of possible future environmental interventions that can have a direct impact on the health of individuals, and also stimulate them to pursue a healthier lifestyle.

Roadmap Design for Change

Trying to facilitate a transition in an urban setting is a complex problem, with a multitude of actors. The Creative Industry is involved in this project to ensure that all stakeholders that are part of this setting are involved in an inclusive and constructive manner. Creative professionals will guide this process, using design skills, methods and tools to combine different perspectives, views, disciplines, and ideas into a holistic vision. This active involvement of all relevant stakeholders during the project will help creating a support base that can enlarge the possible success and implementation of the project results. Therefore this project and its intended results connect to the ambitions of the roadmap Design for Change.

Roadmap Value creation

This project and its results also connect to the CLickNL Roadmap Value Creation. This project has a strong focus on urban innovation on a meso level. Creative professionals participate in this process by connecting

stakeholders from different backgrounds and disciplines in a co-creative environment. Their skills and expertise are used in this project to join the multitude of perspectives that these stakeholders have, and create a shared vision for livability and resilience for future cities in the Netherlands.
At the same time, the creative industry involved will learn and develop the skills, tools and methods needed to successfully engage in, and guide such projects. The competences that they will develop will enable these professionals to show their value as a party who can add the needed expertise to finding a solution of complex societal challenges where multiple stakeholders are involved.

Connection to the ClickNL – KEM's

In this project, we aim to synchronise, through co-design techniques, the technical potential of urban trees to stakeholder needs and interests. The methods used are consistent with the Key Enabling Methodologies as mentioned in the Knowledge and Innovation Agenda. We will apply 'methods that help to go through the process systematically and involve stakeholders' in order to true adoption, change and impact related to iTree 2.0. the project will continuously and iteratively involve stakeholders in the development of iTree 2.0 so as to enable a more realized solution. As stated in the work package plan, we plan to employ context mapping and co-design workshops specifically.
This project also employs 'methods that support testing and validation'. In WP3, we plan to prepare the Dutch city ecosystem for the adoption of iTree 2.0 during and after the project and so will utilise roadmapping and prototyping to cast into the future and align stakeholders within this consortium.

WP3 is planned in three phases, with the following KEM alignments identified:

Phase 1: Identifying and mapping high-level values related to the livability and resilience of Dutch cities from internal and external project partners
(KEM: Experimental Environments)

Phase 2: Synthesizing a shared vision for the future livability and resilience of Dutch cities
(KEM: Vision and imagination, participation and co-creation and experimental environment)

Phase 3: Co-design i-Tree 2.0 technological use cases for test-city locations, operationalizing the vision, by understanding the needs of various stakeholders in this contexts. Build a framework for adoption of the iTree 2.0 in test locations.
(KEM: Experimental environments, Institutional change, system change, value creation and upscaling)

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