MEASURED AND MODELLED LEAF AREA OF URBAN WOODLANDS, PARKS AND TREES IN A HIGH LATITUDE CITY

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Valuation of ecosystem services provided by urban greenery

• Rapid urbanization transform the natural environment

• Urban ecosystem services
  – Climate regulation
  – Biodiversity
  – Air, water and soil management
  – Noise reduction
  – Recreation and well-being
Leaf area

• The amount of foliage is a basic ecological characteristic
• Drives within and below canopy microclimate, determines and controls canopy water interception, radiation extinction, water and carbon gas exchange, etc.
• Measured as leaf area index (LAI), a dimensionless quantity defined as the total one-sided leaf area (m²) per unit ground surface area (m²).
• Measurement methods include destructive, allometric techniques and optical methods based on measurements of light transmission through the canopies.
Aim

• describe seven different types of urban green areas in terms of leaf area index (LAI) of trees
• compare two different methods to measure LAI of urban trees
• estimate urban LAI based on aerial discrete-return LiDAR
Study area - Gothenburg, Sweden

- 7 case study areas
  - Residential area with green yards
  - New park by river
  - Old central park
  - Suburban forest
  - Allotment gardens
  - Central woodland
  - Traffic area
Ground measurements

• Commercial plant canopy analyzer LAI-2200 (LI-COR Biosciences, Lincoln, USA)
  – Measures solar radiation below and above the canopy
  – FV2200 software
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  - Nikon D5100 with Sigma 4.5 mm fish-eye lense
  - Hemisfer software (Schleppi, WSL)
  - Blue channel, underexposed images
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• Effective LAI ($L_e$) - include all canopy elements intercepting radiation (do not distinguish photosynthetically active leaves from other plant elements e.g. stems and branches).

• Overcast skies
Aerial light detection and ranging - LiDAR

• Discrete-return LiDAR of the Gothenburg municipality
• Max scan angle $\pm 20^\circ$ and mean pulse density 13.65 m$^{-2}$
• FUSION software
• Vegetation (>1 m) part of the point cloud filtered according to Lindberg and Grimmond (2011)

$$L_e = -\beta \ln \left( \frac{R_{\text{ground}}}{R_{\text{total}}} \right)$$

• where $R_{\text{ground}}$ is ground returns, $R_{\text{total}}$ is ground + canopy returns and $\beta$ is a constant (2.097, Richardson et al. 2009).
Comparison of measurement methods

$y = 0.83x + 0.92$

$R^2 = 0.75$

Uniformly overcast sky
Comparison of measurement methods

\[ y = 1.37x + 1.26 \]

\[ R^2 = 0.45 \]

- Central woodland
- Suburban woodland
- Roadside grove

Sunny and blue sky
Single street trees (leaf area density based on LAI-2200)
Modelled and measured $L_e$

$y = 0.94x + 0.60$
$R^2 = 0.74$

- Central park
- Central woodland

$Le$ (LiDAR) vs. $Le$ (hemispherical photo)
$L_e$ in urban greenery (based on LiDAR)
Vegetation (>1m) cover (based on LiDAR)
Summary

• It is challenging to measure leaf area in the urban environment, but hemispherical photography was found to be advantageous to LAI-2200.

• $L_e$ can be successfully modelled based on LiDAR data in the urban environment.

• The large variation in leaf area between species and types of greenery in the urban environment emphasizes the importance of detailed estimates of $L_e$ for urban applications.
Future research

- Estimation of LAI instead of $L_e$
  - NIR hemispherical photography allows distinguishing photosynthetically active leaves from other plant elements and buildings based on NDVI (difference between the reflectance of visible and infrared light)

- Improved estimation of $T_{mrt}$ from hemispherical photographs at vegetated urban sites

![Raw picture](image)

![Blue channel (VIS)](image)

![Red channel (NIR)](image)

![NDVI](image)