Evapotranspiration, water demand and water footprint of urban green spaces

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Why do we need green spaces?

- World’s urban population grew from 30% of the total in 1950 to 56% in 2019 and is expected to reach 68% by 2050.
- Urban green spaces are key elements in maintaining and improving human health & wellbeing and provide a range of other environmental, social, and economic benefits and services.

“No time to lose - Green the cities now”
How much is enough?

Historically, the priority of most municipalities has been to develop grey infrastructures (e.g. roads, bridges, etc.). In recent years, more efforts to integrate grey and green infrastructures.

As urban areas continue to grow, green spaces are getting increasingly valued.

- Minimum: 9 m² per capita
- Ideal: 50 m² per capita.
“greening city” & “water management”

• Water scarcity is not only a challenge in agriculture but also in the urban. Most urban green spaces experience frequent droughts.

• Maintaining green spaces all-year-round requires smart management of green and blue water resources besides other drought response strategies (e.g. dry out green spaces).
Water demand of urban green spaces

Research on water accounting of agriculture well established. However, less research has been done on urban greenery.

In urban green spaces, the heterogeneous nature of vegetation, landscapes, soil and water characteristics, and the variability of management and watering practices contribute to complexity in the evapotranspiration (ET) estimation.

Literature on the water use of urban green spaces focusses either on the irrigation water or on the ET from green spaces. Irrigation water focuses on blue water needs whereas ET include both green and blue water consumption.
Methods to estimate ET of urban green spaces

- RS energy balance techniques
- Satellite-based ET using vegetation indices

Remote sensing-based

- Soil Water Balance
- Lysimeter
- Sap flow
- Eddy covariance
- Bowen ratio

Ground-based

- WUCOLS
- IPOS
- Plant Factor
- LIMP

Observational-based

A review of ET measurement techniques for estimating the water requirements of urban landscape vegetation

Hamideh Nouri, Simon Beecham, Fatemeh Kazemi & Ali Morad Hassanli
Average rainfall Isfahan, Iran

Average rainfall Adelaide, Australia

Average rainfall Fuzhou, China
Adelaide Parklands

The Adelaide Parklands comprises 29 parks that surround Adelaide, the capital city of South Australia. A green belt of approximately 720 hectares encircles the city centre.

A recycled wastewater project, Glenelg to the Adelaide Parklands (GAP), sourcing from the secondary effluent from an existing wastewater treatment plant, transports recycled wastewater to irrigate the Parklands.
Observational-based approaches (factor-based)

\[ ET_L = K_L \times ET_0 \]

- Water Use Classifications of Landscape Species (WUCOLS)
  \[ ET_L = ET_0 K_L = ET_0 K_{mc} K_s K_d \]

- Irrigated Public Open Space (IPOS)
  \[ ET_L = ET_0 \times K_c \times K_{st} \]

- Plant Factor (PF)
  \[ ET_L = PF \times ET_0 \]

- Landscape Irrigation Management Program (LIMP)
  \[ ET_l = ET_0 K_{mc} K_v K_d K_{sm} \]

Remote sensing-based

- **EOS-1, Aqua** (MODIS sensor with 36 bands, spatial resolution of 250m for the red and NIR bands, 500m for the remaining land bands, and 1km for all other bands)

- **Landsat** (ETM+ and OLI sensors with 11 bands, spatial resolution of 30m)

- **WorldView 2** (8 bands, spatial resolution of 0.46m panchromatic and 1.85 m multispectral)
High resolution-WorldView2 & 3

Effect of Spatial Resolution of Satellite Images on ET (MODIS, Landsat, WV2)

\[
\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}} \quad \text{EVI} = G \times \frac{\text{NIR} - \text{Red}}{\text{NIR} + C1(\text{Red}) - C2(\text{Blue}) + L} \quad \text{EVI2} = 2.5 \times \frac{\text{NIR} - \text{Red}}{\text{NIR} + 2.4(\text{Red}) + 1}
\]

Scenario Performance

1

2

3

4

5

Black-box models

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Variation of NDVI compared to the year 2011
Soil Water Balance (SWB)

Based on SWB principles, all input water (irrigation, precipitation and upward groundwater movements) and output water (ET, drainage, soil moisture and runoff) were regularly measured during the study period.
Weather data

Bureau of Meteorology (BOM) & in-situ weather station
Sampling points

Proximal sensing – EM38
Soil moisture status (12 tubes down to 4 m depth)

Neutron Moisture Meter (NMM)

CPN503 DR Hydro-probe and 32-sec count rates

Soil moisture readings
Drainage – lysimeters (4 lysimeters)

1. Drainage collector
2. Lysimeter tray
3. Water pipe
4. Air pipe

Images:
1. Drainage collector setup
2. Lysimeter tray
3. Water pipe installation
4. Air pipe connection
5. Setup with level
6. Teamwork on the installation
7. Spraying solution
To estimate the in-situ ET of mixed vegetation, the differences between the total amounts of input water (irrigation and precipitation) and the amounts of output water (soil moisture changes, drainage and runoff) were measured.
Water footprint of green spaces

The water footprint concept has been applied to a variety of water uses, from agriculture and forestry to industry and households; this is the first application to urban green spaces.

Defined as the volume of rainwater and irrigation water being consumed by these green spaces, i.e. the volume of water evaporating (volume/area).

Green WF: rainwater

Blue WF: irrigation water + capillary rise

*WF - Green & blue water consumption of urban green spaces rather than on water abstracted to irrigate green spaces*
Water Footprint; Partitioning into green & blue

\[
\frac{\Delta S_g}{\Delta t} = P - \left( \frac{S_g}{S} \right)(D + ET) - \left( \frac{P}{I+P} \right)RO
\]

\[
\frac{\Delta S_{b,I}}{\Delta t} = I - \left( \frac{S_{b,I}}{S} \right)(D + ET) - \left( \frac{I}{I+P} \right)RO
\]

\[
\frac{\Delta S_{b,CR}}{\Delta t} = CR - \left( \frac{S_{b,CR}}{S} \right)(D + ET)
\]

\[
ET_g = \left( \frac{S_g}{S_g + S_{b,I} + S_{b,CR}} \right) ET
\]

\[
ET_{b,I} = \left( \frac{S_{b,I}}{S_g + S_{b,I} + S_{b,CR}} \right) ET
\]

\[
ET_{b,CR} = \left( \frac{S_{b,CR}}{S_g + S_{b,I} + S_{b,CR}} \right) ET
\]

Total WF: 11,140 m³/ha/year

59% from blue water    41% from green water
Blue WF of urban greenery

- WF of ideal size is 16% of total UBW.
- Don’t ignore WF of urban greenery in Urban WF studies.
- Green spaces heavily rely on blue water resources, even in wet period.
Thank you

Terimah Kasih

Se衷心

Vielen Dank

Dank je wel

Dank

Gracias

MERCI

感谢

Xièxiè

ありがとうございます

Arigatōgozaimashita

Thank you
HS6.1

Evapotranspiration estimation using remote sensing: modeling, mapping and evaluation.

Convener: Hamideh Nouri | Co-conveners: Megan Blatchford\(^ECS\), Pamela Nagler, Naga Manohar Velpuri

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**Title:** Providing Solutions to a Current Environmental Problem Facing our Changing World: Improving Methods and Models Used to Measure and Scale Evapotranspiration (ET) to the Landscape Scale in Urban Regions, Catchments and Wetlands

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