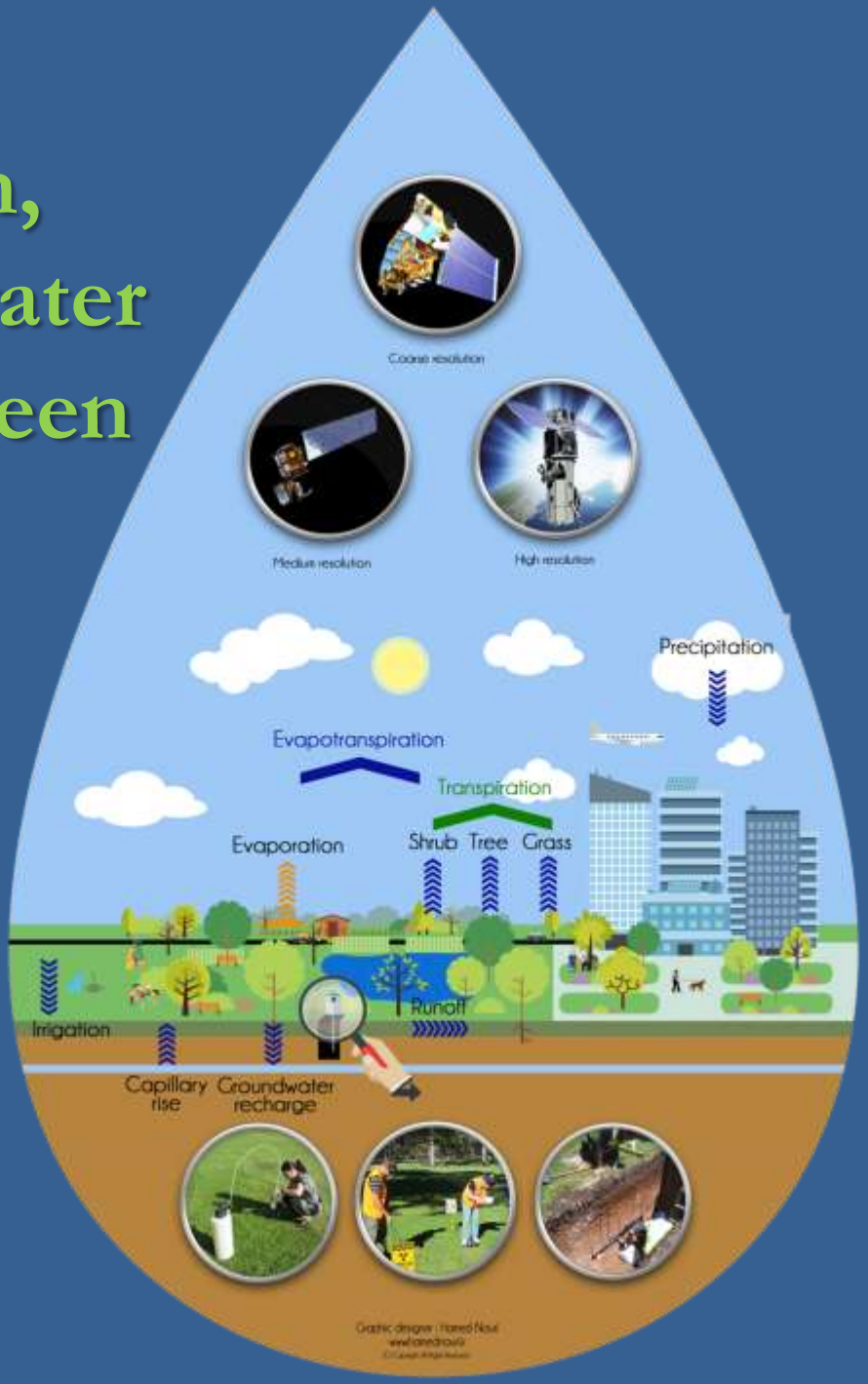
Evapotranspiration, water demand and water footprint of urban green spaces

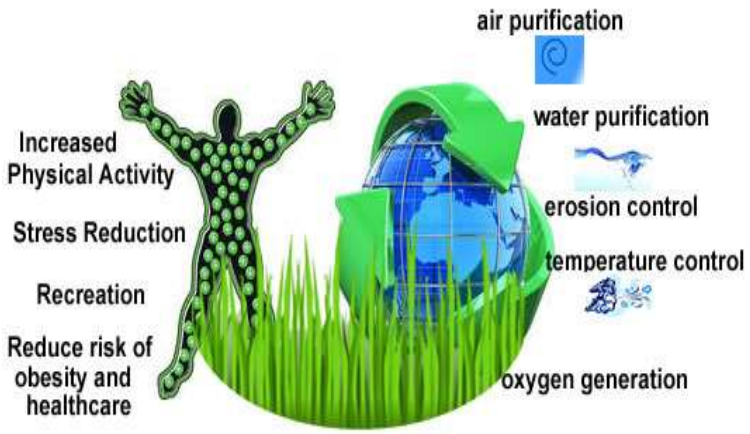


Dr Hamideh Nouri
Senior Research Fellow
University of Gottingen

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.

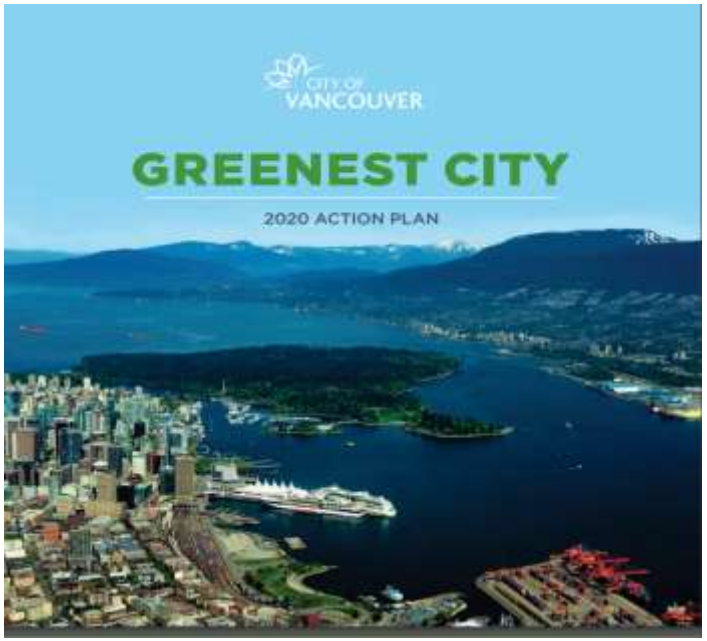
"No time to lose - Green the cities now"



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.



Canada, Greenest City Action Plan (Vancouver 2020)

- **Minimum: 9 m^2 per capita**
- **Ideal: 50 m^2 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).

London – Summer 2019

Water demand of urban green spaces

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

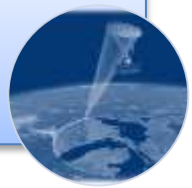
In urban green spaces, the **heterogeneous nature** of vegetation, landscapes, soil and water characteristics, and the variability of management and watering practices contribute to complexity in the evapotranspiration (ET) estimation.

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

Urban Water Journal

ISSN: 1573-062X (Print) 1744-9006 (Online) Journal homepage: http://www.tandfonline.com/loi/nurw20

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

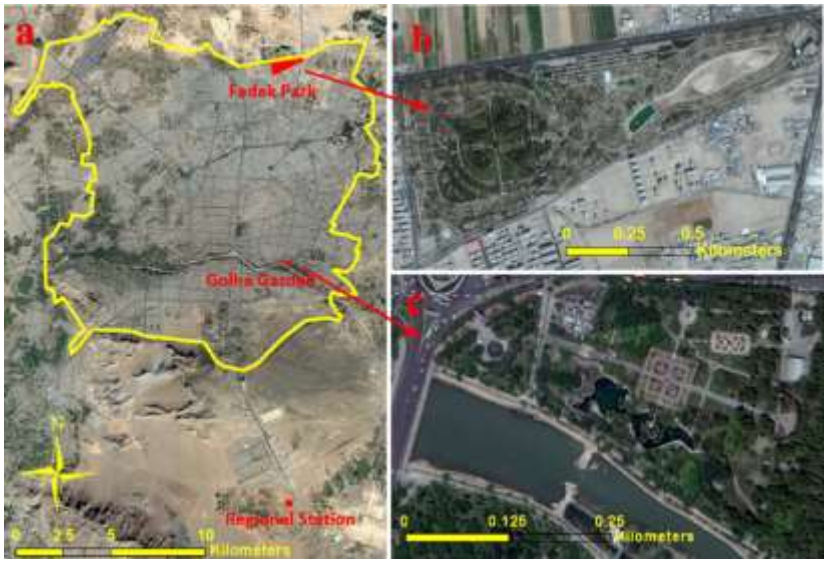
Hamideh Nouri , Simon Beecham , Fatemeh Kazemi & Ali Morad Hassanli

Urban Water Journal

ISSN: 1573-062X (Print) 1744-9006 (Online) Journal homepage: http://www.tandfonline.com/loi/nurw20

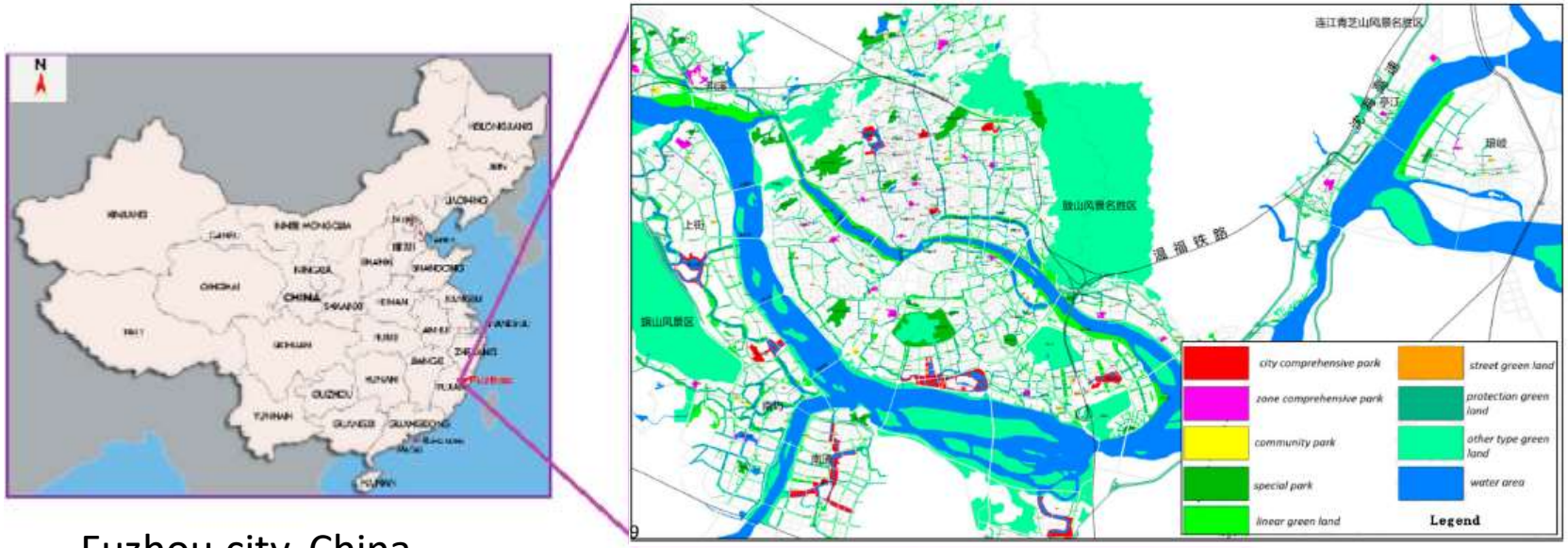
Remote sensing techniques for predicting evapotranspiration from mixed vegetated surfaces

Hamideh Nouri, Simon Beecham, Sharolyn Anderson, Ali Morad Hassanli & Fatemeh Kazemi



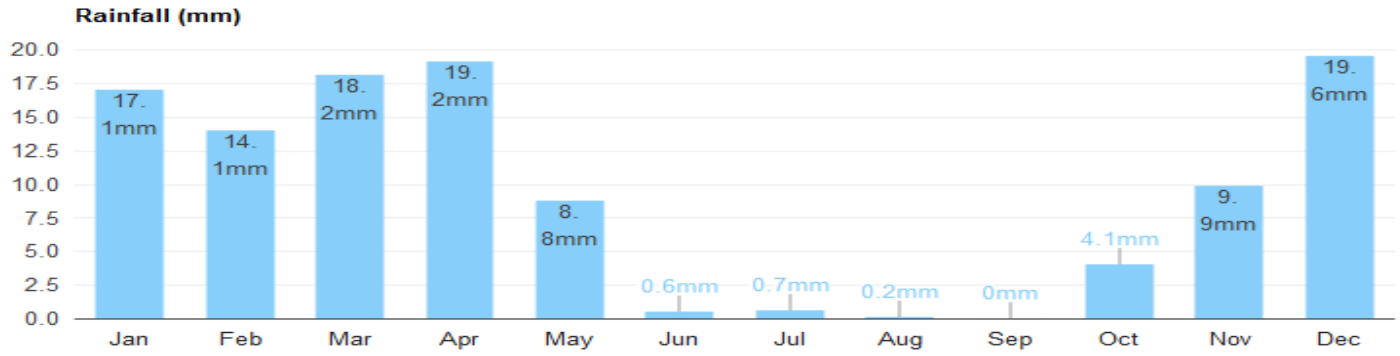
Esfahan, Iran

Adelaide, Australia

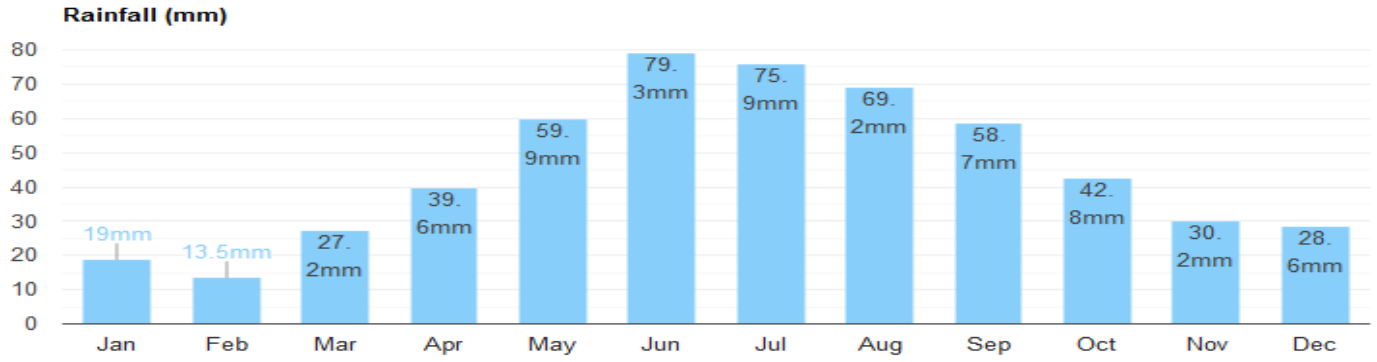


Fuzhou city, China

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)

$$\mathrm{ET_L} = \mathrm{ET_0} \times K_{\mathrm{c}} \times K_{\mathrm{st}}$$

- Plant Factor (PF)

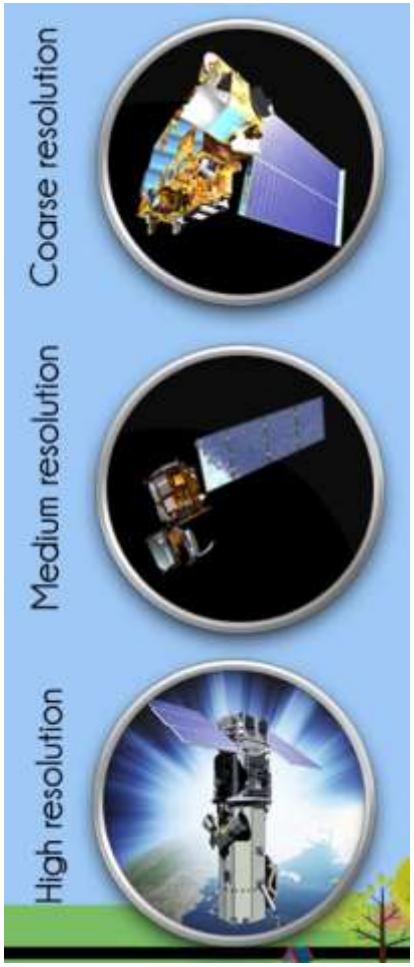
$$ET_L = PF \times ET_0$$

- Landscape Irrigation Management Program (LIMP)

$$ET_l = ET_0 K_{mc} K_v K_d K_{sm}$$

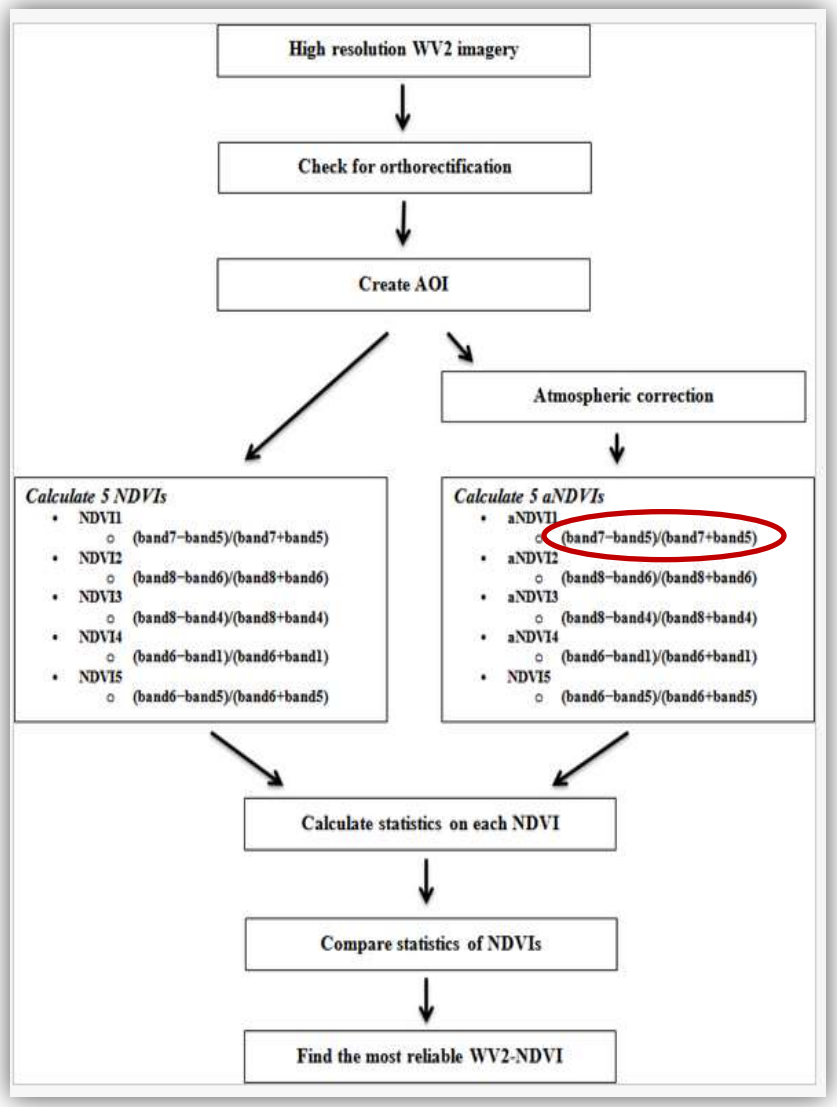
Nouri et al., Water requirements of urban landscape plants: a comparison of three factor-based approaches, *Ecological Engineering*, Elsevier, 2013, 57, 276-284.

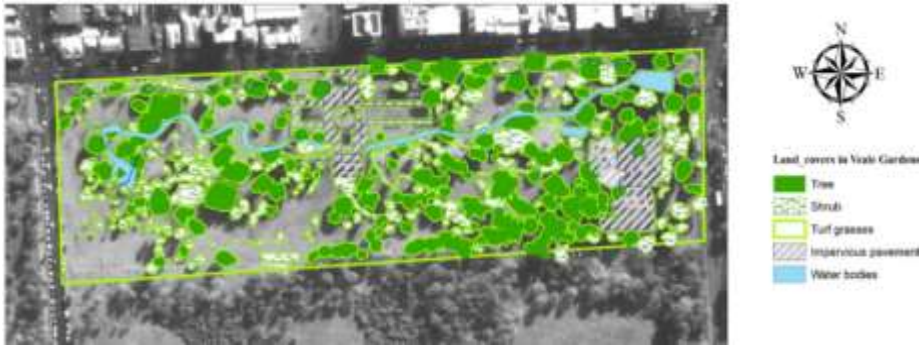
Remote sensing-based

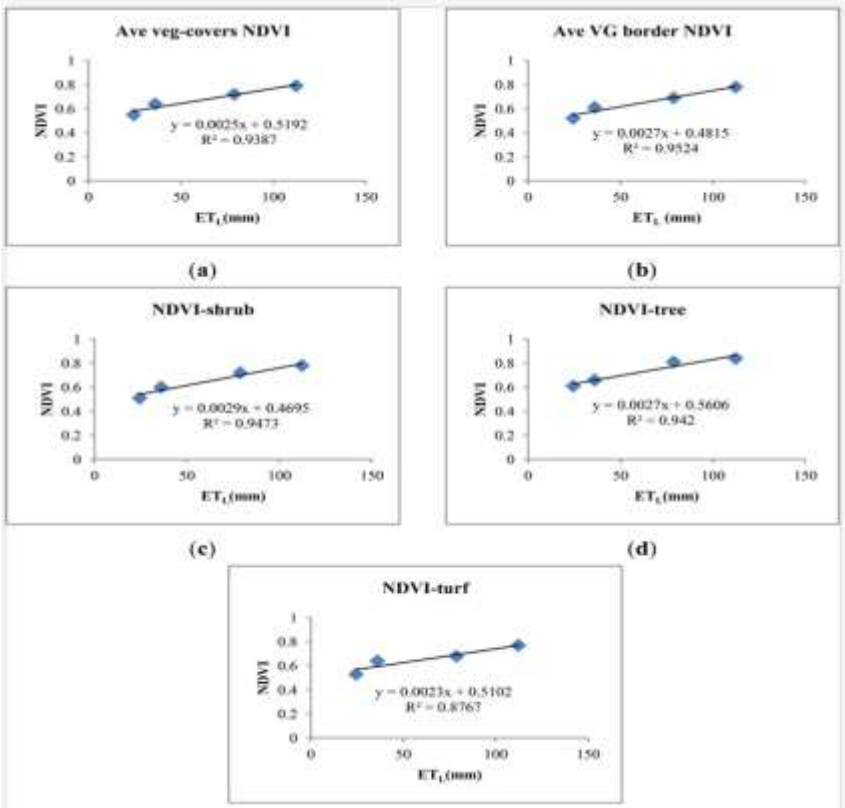


- **EOS-1, Aqua** (MODIS sensor with 36 bands, spatial resolution of 250m for the red and NIR bands, 500m for the remaining land bands, and 1km for all other bands)
- **Landsat** (ETM+ and OLI sensors with 11 bands, spatial resolution of 30m)
- **WorldView 2** (8 bands, spatial resolution of 0.46m panchromatic and 1.85 m multispectral)

High resolution-WorldView2 & 3



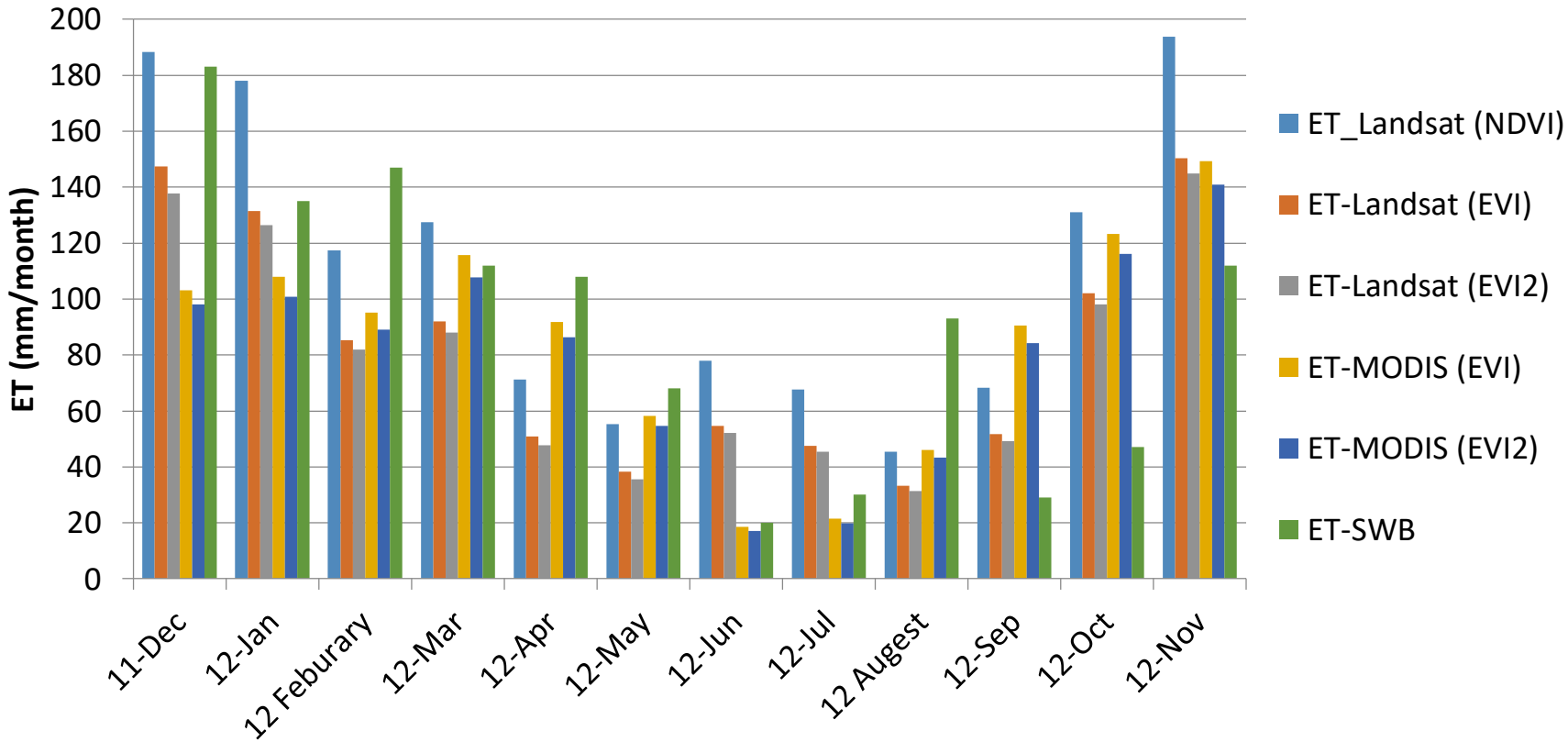




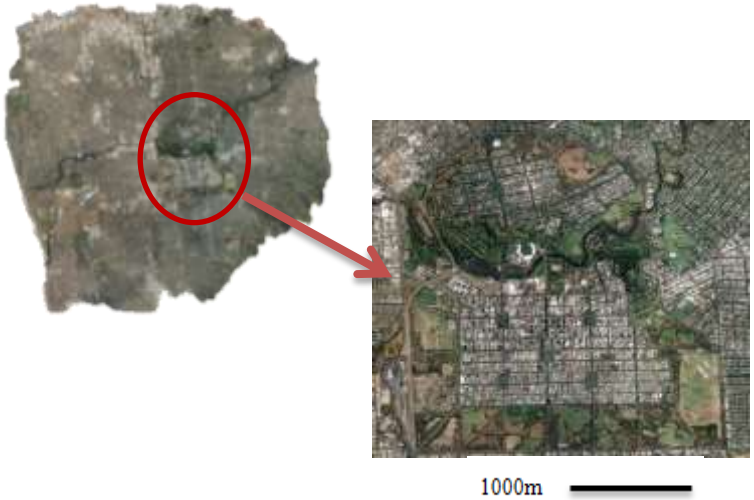
Nouri, et al.,High spatial resolution WorldView-2 imagery for mapping NDVI and its relationship to temporal urban landscape evapotranspiration factors, *Remote Sensing,* 2014, *6*(1), 580-602.

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

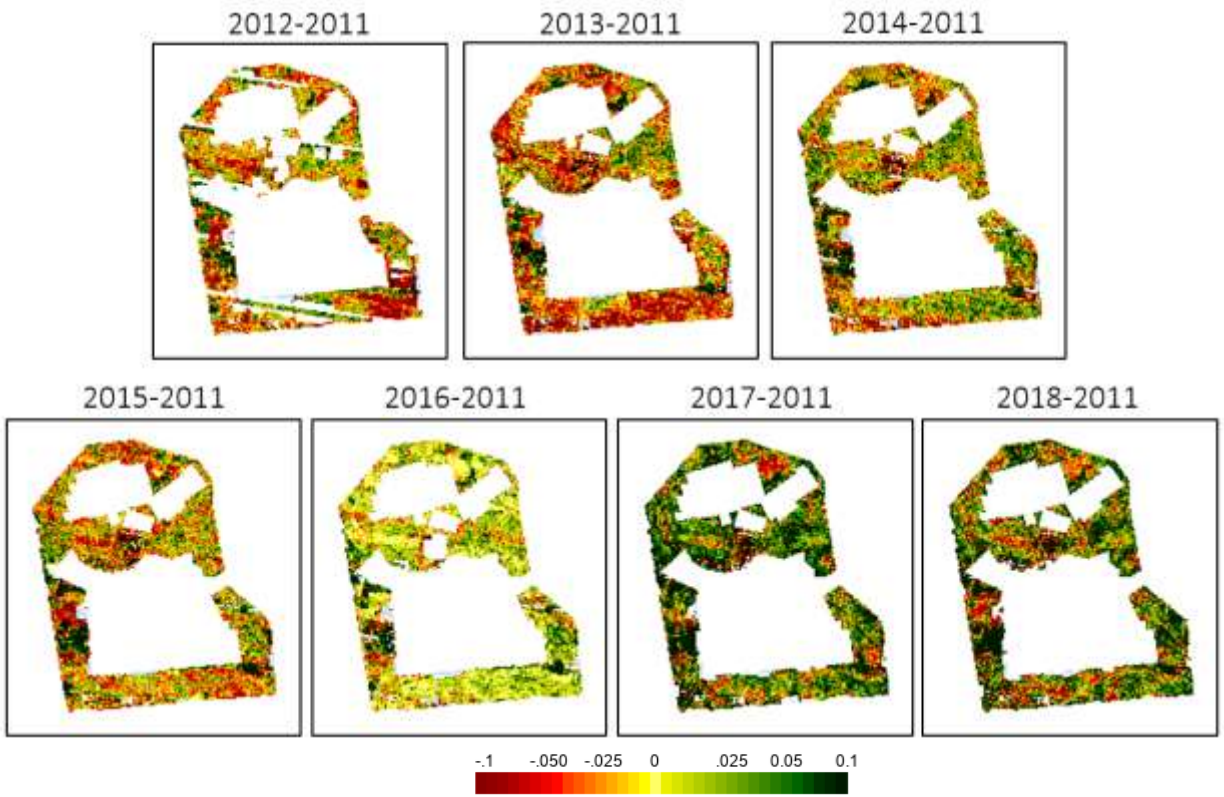
$$\mathbf{NDVI} = \frac{\mathrm{NIR-Red}}{\mathrm{NIR+Red}} \qquad \boldsymbol{EVI} = \mathrm{G} \times \frac{\mathrm{NIR-Red}}{NIR+C1(Red)-C2\,(Blue)+L} \qquad \boldsymbol{EVI2} = 2.5 \times \frac{\mathrm{NIR-Red}}{NIR+2.4\,(Red)+1}$$



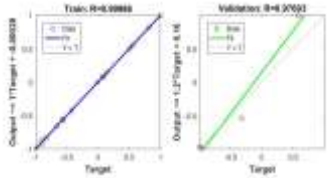
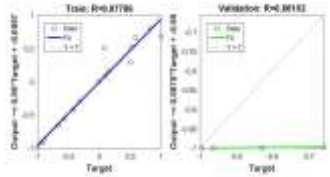
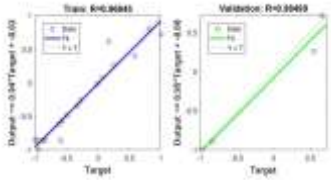
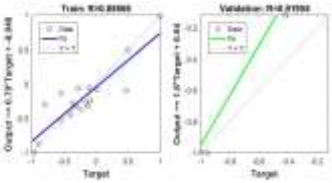
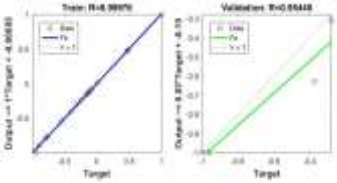
Nouri, et al., Effect of Spatial Resolution of Satellite Images on Estimating Urban Green Spaces Evapotranspiration, *Hydrological Processes* (in-review).

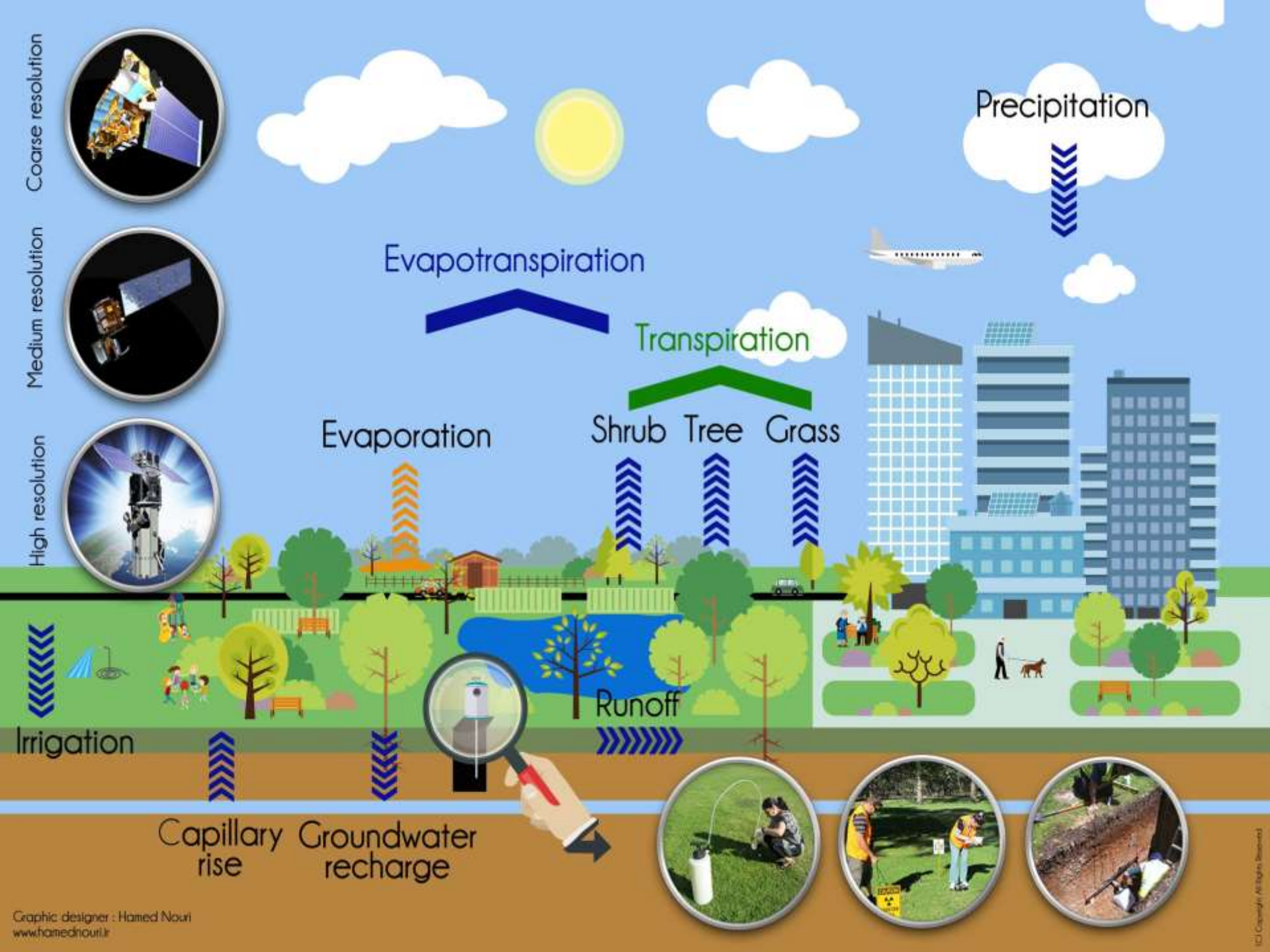


Variation of NDVI compared to the year 2011



Black-box models

Scenario	Performance
1	
2	
3	
4	
5	


Coarse resolution
Medium resolution
High resolution
Precipitation
Evapotranspiration
Transpiration
Evaporation
Shrub
Tree
Grass
Runoff
Irrigation
Capillary rise
Groundwater recharge
Graphic designer : Hamed Nouri
www.hamednouri.ir

Soil Water Balance (SWB)

precipitation runoff drainage

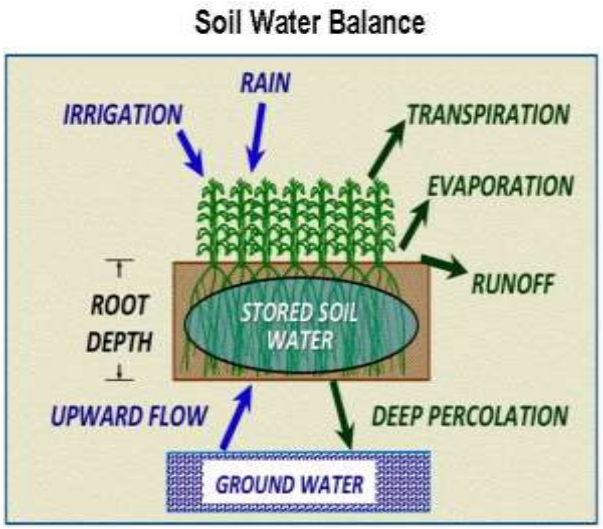
$$P + I + W - ET - R - D = \pm [\Delta S]$$

irrigation

soil water storage

water table upward evapotranspiration

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.



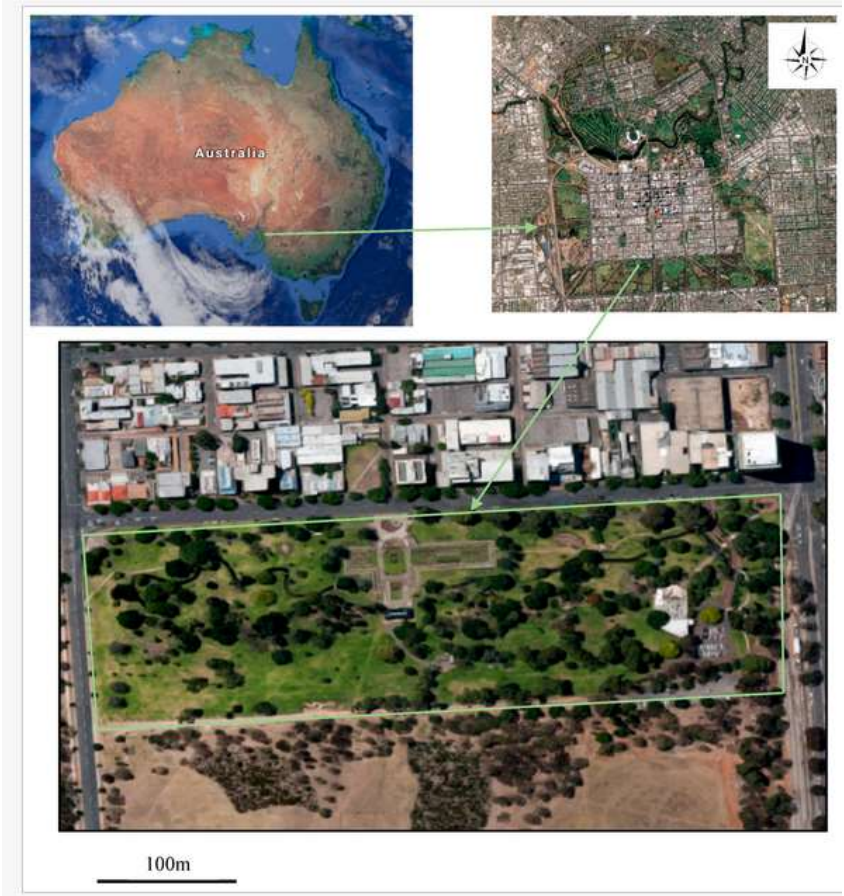
Weather data

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

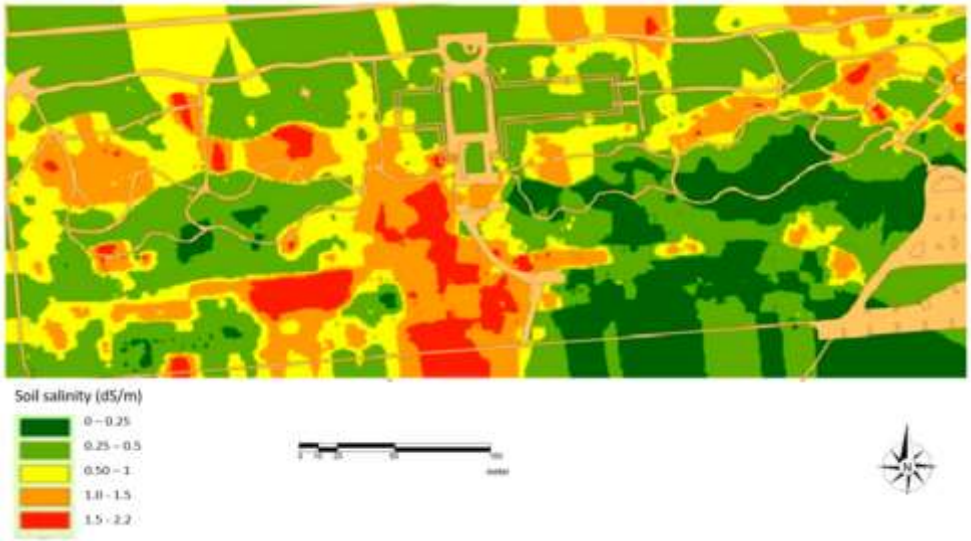
Australian Government

Bureau of Meteorology

Sampling points

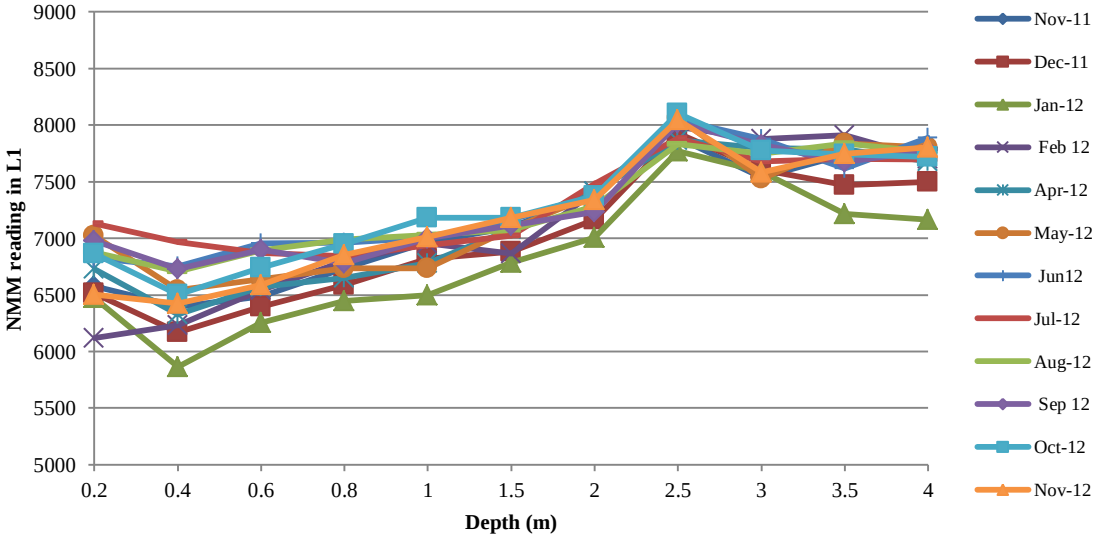


Proximal sensing – EM38



Soil moisture status (12 tubes down to 4 m depth)

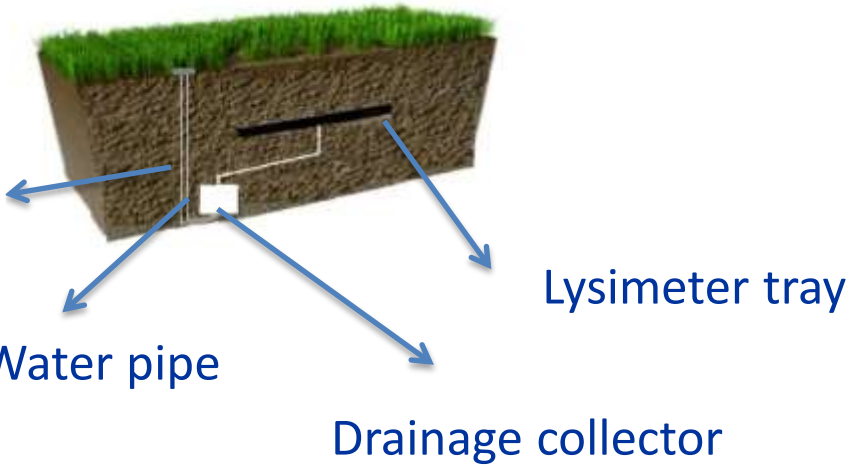
Neutron Moisture Meter (NMM)



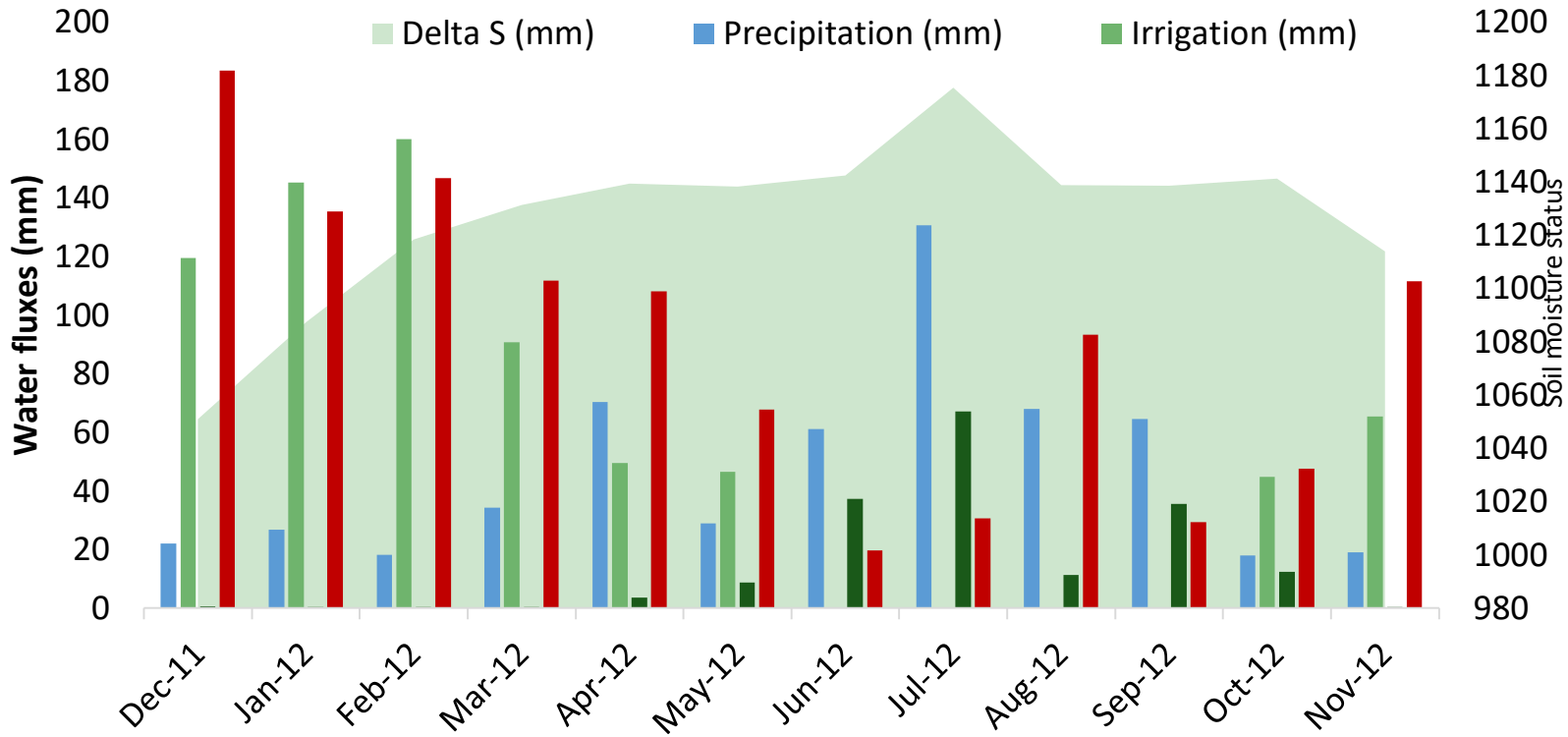
Soil moisture readings

CPN503 DR Hydro-probe and 32-sec count rates

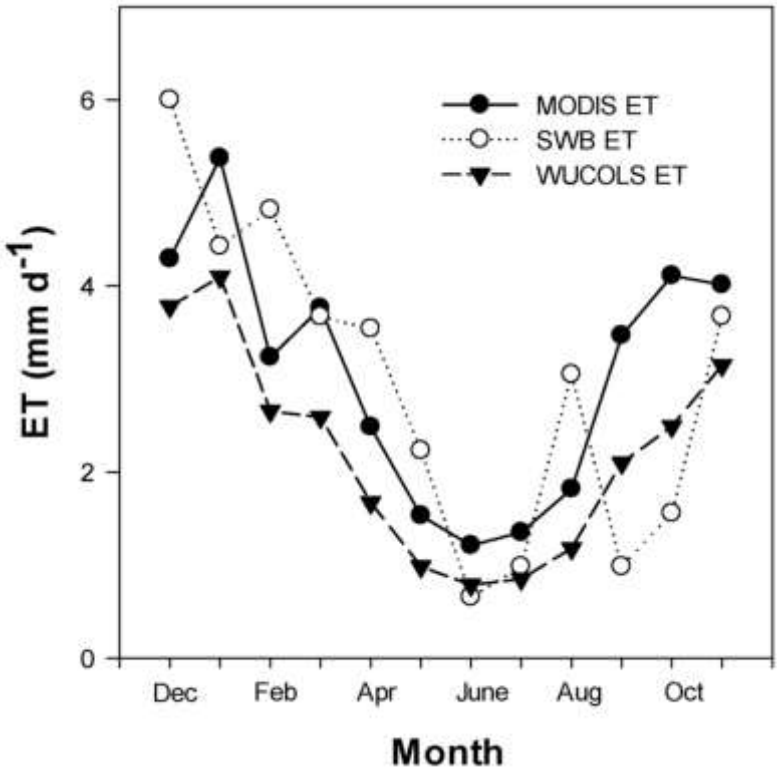
Drainage – lysimeters (4 lysimeters)

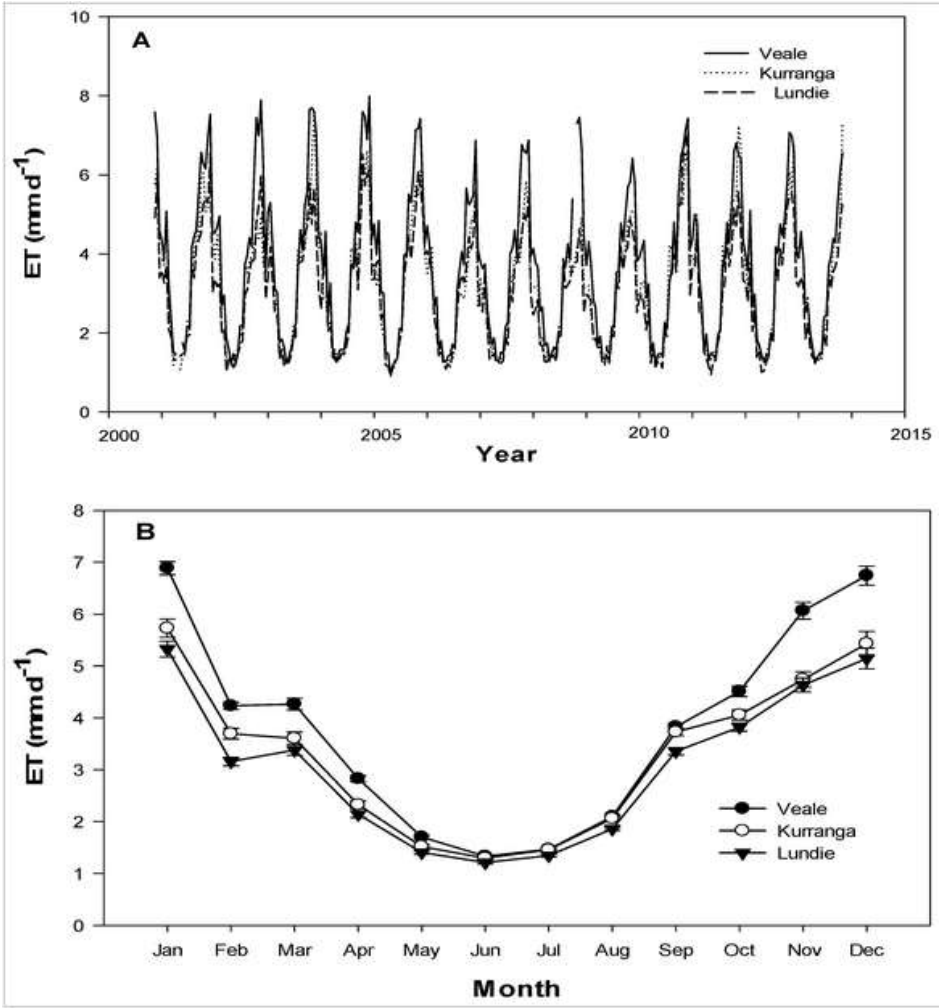


Soil Water Balance (SWB) results



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.





* Nouri et al., Comparing Three Approaches of Evapotranspiration Estimation in Mixed Urban Vegetation; Field-based, Remote Sensing-based and Observational-based methods, *Remote Sensing,* 2016, 8(6), 492.

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

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

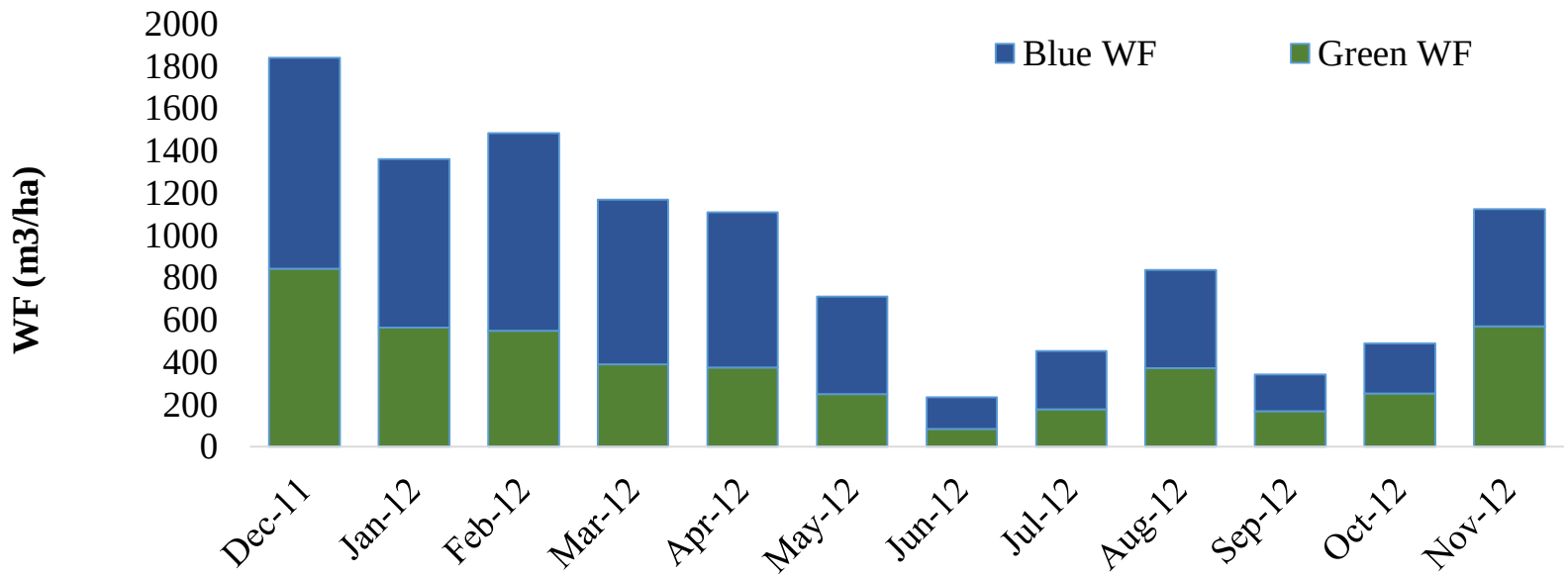
$$\frac{\Delta S_{b,I}}{\Delta t} = I - \left(\frac{S_{b,I}}{S}\right)(D + ET) - \left(\frac{I}{I+P}\right) RO$$

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

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

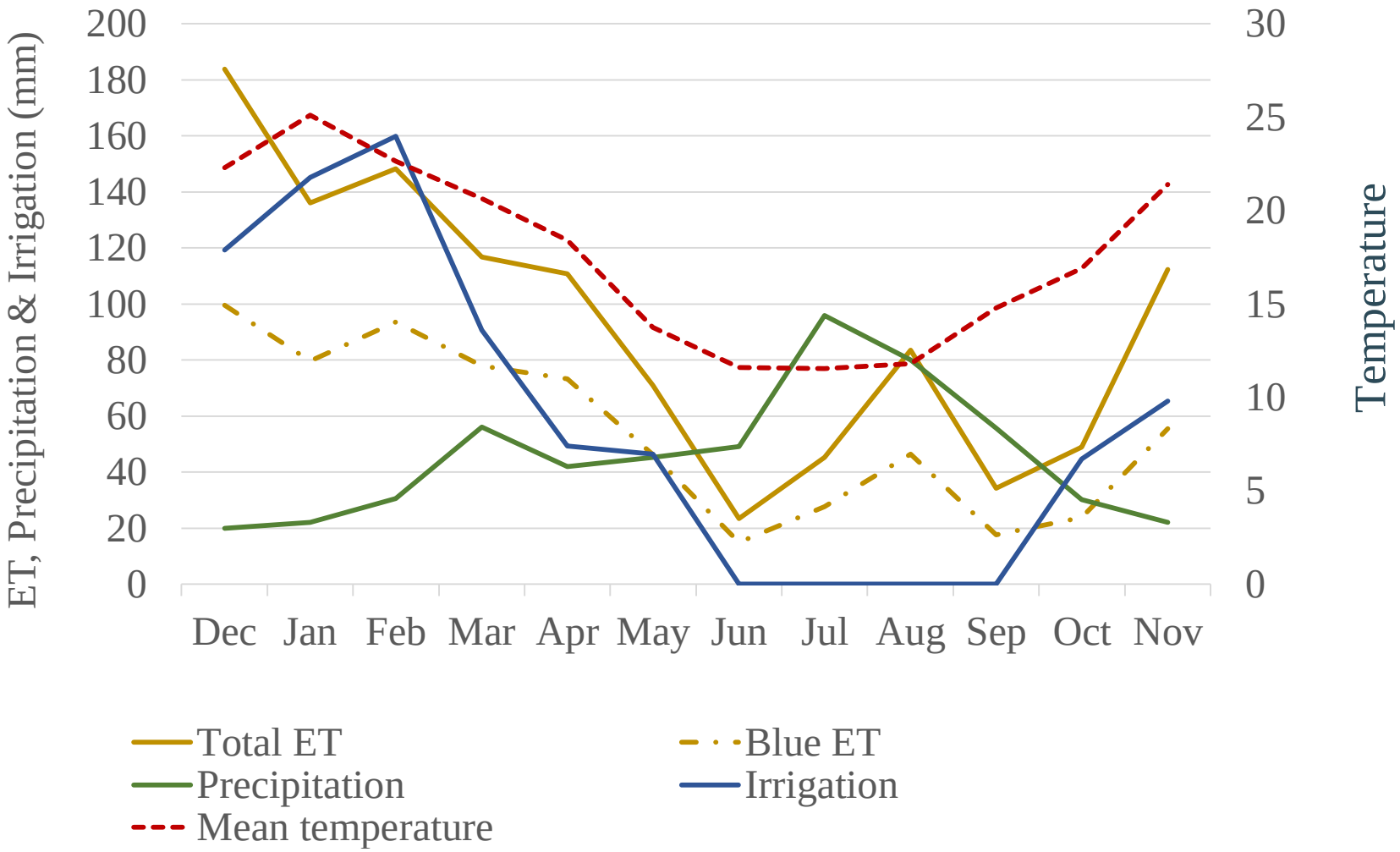
$$ET_{b,I} = \left(\frac{S_{b,I}}{S_g + S_{b,I} + S_{b,CR}}\right) ET$$

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



Total WF : 11,140 m^3/ha/year

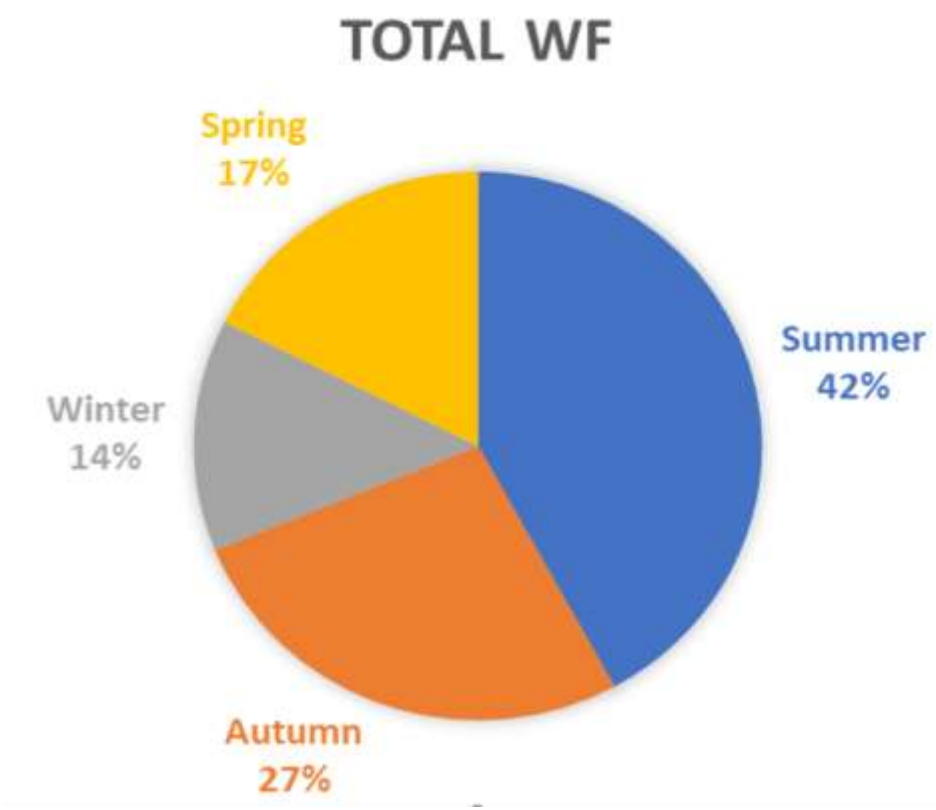
59% from blue water **41%** from green water



Nouri, et al., The blue water footprint of urban green spaces: An example for Adelaide, Australia, ***Landscape and Urban Planning***, 2019, 190-103690.

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.



سپاسگزارم

Terimah Kasih

Vielen Dank

谢谢
Xièxiè

Gracias

Dank je wel

MERCI

THANK YOU

ありがとうございました
Arigatōgozaimashita

EGU General Assembly 2020

Vienna | Austria | 3–8 May 2020

ABOUT AND SUPPORT ▾ ABSTRACTS & PROGRAMME ▾ REGISTER & VENUE ▾ EXHIBITION ▾ GUIDELINES ▾ LOGINS ▾

submission deadline is 15 January 2020, 13:00 CET.

HS6.1

Evapotranspiration estimation using remote sensing: modeling, mapping and evaluation

Convener: Hamideh Nouri | Co-conveners: Megan Blatchford[ECS], Pamela Nagler, Naga Manohar Velpuri

Abstract submission deadline: 15 November 2019

No:	044
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
Organizers	Pamela Nagler[1], Hamideh Nouri[2], Huade Guan[3] and Genxu Wang[4] *[1]U.S. Geological Survey, USA* *[2]University of Göttingen, Germany* *[3]Flinders University, Australia* *[4]Chinese Academy of Sciences, China*