SAP FLOW MEASUREMENTS IN HYDROLOGY – OPTIMIZING TREE TRANSPIRATION MAPPING AT LARGE SCALES

Maciek W. Lubczynski (m.w.lubczynski@utwente.nl),
Chandra P. Ghimire (c.p.ghimire@utwente.nl)

a Department of Water Resources (WRS), International Institute for Geo-Information Science and Earth Observation (ITC), University of Twente (Netherlands)
Presentation plan

- Aim;
- Principle;
- Accuracy needed;
- Sapwood area;
  - Allometric equations for scaling sapwood area;
  - RS scaling;
- Sap flux density;
- Tree Impact Area (TIA) - partitioning ET;
- Conclusions & remaining ‘to do’!
Aim

Driving Forces
(hydrological model input)

- Rainfall
- Evapotranspiration

   - Transpiration
   - Evaporation

Distributed, hydrological, numerical model
Tree transpiration mapping by RS scaling of sap flow measurements - principle

\[ Q = J_p \cdot A_x \]

Plot size: stem scalar

\[ A_s \text{ vs. } A_x \]

Catchment: canopy scalar

\[ A_c \text{ vs. } A_x \]

Limitation of the method and accuracy required

- Areas where individual canopies can be identified from space
- Accuracy required
  - RS solution of energy balance - not acceptable for tree transpiration mapping;
    - Low accuracy of RS solution of energy balance;
    - Lack of sufficiently high resolution of satellite thermal bands;
    - Impossible determination of TIA (tree impact area)
- Tolerance for large scale approaches - larger than for example for plot scale assessment
Scaling sapwood area by canopy area

Linearized relation \( Ac \sim Ax \) by allometric equations

Accuracy dependent on dispersion of the points (in Kalahari case \( R^2 > 0.82 \))

Eventual improvement:
- Use of non-invasive \( Ax \) methods such as e.g. NMR
- Use of canopy volume instead of \( Ac \);

RS scaling of Ax

- RS, automated species classification, i.e. identification of species types;
  - multispectral or even better hyperspectral,
  - object-oriented image classification;
  - multi-temporal image classification
- RS definition of geometry of canopies;
  - Spatial resolution
  - Canopy overlapping
- Perspectives;
  - satellites with more spectral bands and higher resolution
  - Drones as carriers of sensors
Tree species classification (eCognition)

After Kimani et al. 2007
Multi-temporal, remote sensing classification of tree canopies for tree transpiration

Sap flux density

- Temporally variable
- Characteristic for a species but...
- Pretty uniform per-species even between different sizes of trees and trees at different locations
  - Low dispersion around the mean of \( J_p = f(Ax) \) among trees of different sizes;
  - \( J_p \) measured in one plot is reasonable estimator of \( J_p \) in another plot despite even different soil water condition
- For large scale tree transpiration mapping one \( J_p \) per species is good enough
Quercus ilex and Quercus pyrenaica, Spain

Sources of uncertainty of the tree transpiration mapping method

- Dispersion in allometric equations ($A_c \sim A_x$)
  - Accuracy of $A_x$ estimates;
- RS species classification;
- RS evaluation of the geometry of the canopies
- Sap flux density (sap velocity) per-species
  - Accuracy of $J_p$ measurements;
  - $J_p$-mean representativeness;
Tree impact area ???

- Larger, smaller or approx. equal to the canopy size?
- Tree-size, environment and species-dependent

What is most efficient experimental method to define tree impact area (TIA) to be applied in hydrological models?

Is relation between Ac and TIA linear? If so when?

Assuming relation with canopy size, how many per-species TIA are needed to derive allometric equation of Ac vs TIA?
Conclusions

- RS scaling of tree transpiration in large scales requires: i) allometric equations defining $A_x$ as a function of selected scalar (e.g. canopy area or volume); ii) RS identification of species type and geometry of a scalar; iii) mean sap flux density per species;

- With such data, tree transpiration can be defined at any scale of a given environment and at any instant of time, at certain, definable accuracy;

- To be able to adapt the proposed method as input of hydrological management models, per-species allometric equations defining $TIA$ as a function of selected scalar (e.g. canopy area or volume) need to be developed; this task need further scientific development
THANK YOU