Variability of sap flow on forest hillslopes: Patterns and controls

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Poster-ID: EGU2013-3484

catchments as organised systems
DFG FOR 1598

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Objective

Sap flow in trees is an essential variable in integrated studies of hydrological fluxes. It gives indication of transpiration rates which is relevant for hydrologic and climate models, especially for the prediction of change in water fluxes in the soil-plant-atmosphere continuum.

Knowledge about both the response of sap flow to atmospheric forcing but also an understanding of main controls on its spatial variability is needed for these predictions.

Study site

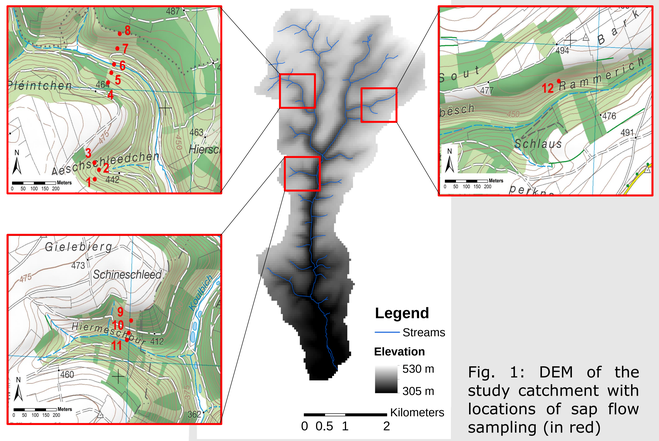

Fig. 1: DEM of the study catchment with locations of sap flow sampling (in red)

- Study catchment: subcatchment of the Attert basin in Luxemburg
- Geology: schists of the Ardennes massif
- Land cover: evergreen and deciduous forests
- Tree sampling distributed across the catchment and slopes of different exposition; information on nearby soil moisture available
- Tree species for sap flow measurements: Beech and oak (but also some hornbeam, maple and spruce trees are included)

Methods

Sensors:

- Heat-pulse velocity method
- East30 three-needle sap flow sensors:
  - Middle needle: heating source
  - Top and bottom needles contain three thermistor in 5, 18 and 30 mm depth (Fig. 2)

Installation (Fig. 4):

- Install on north-facing side of tree
- Drill holes with drilling guide for parallel orientation
- Lubricate sensors before inserting them in order to have good connection to sapwood and for recovery after measurement season
- Cover to protect the sensor against rain and radiation

Measurement principle:

- The middle needle is heated and temperature differences before and after heating are measured in all thermistors. From these differences between thermistor pairs in top and bottom needle, sap velocity can be calculated at the three depths.

Determining point of zero sap velocity (Fig. 3):

- From the values for the three needles a regression function can be fitted for trees showing decreasing sap velocity in all three thermistor pairs (e.g. beech, see Fig. 6).

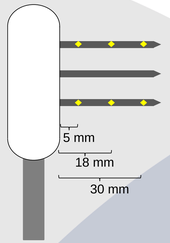

Fig. 2: Three-needle sap flow sensor, thermistors indicated in yellow

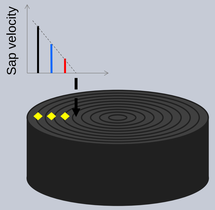

Fig. 3: Determination of zero sap velocity within the sapwood

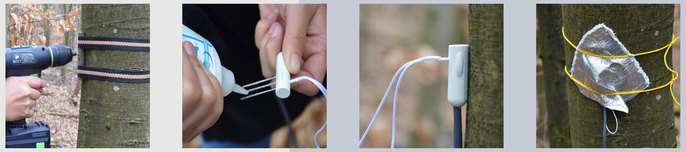

Fig. 4: Sap flow sensor installation, including rain and radiation protection

Results

1) Daily sap flow patterns and controls

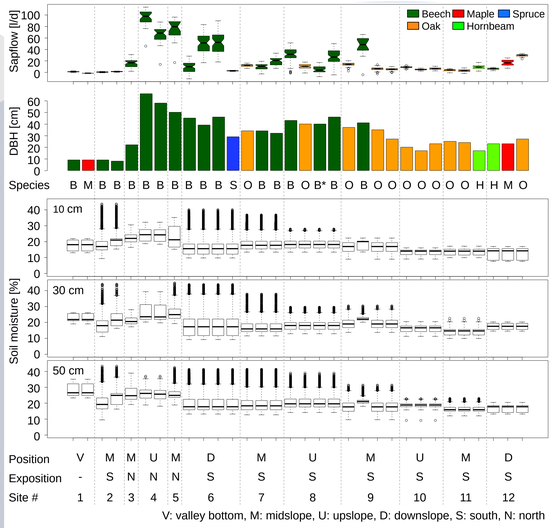

Fig. 5: Daily sap flows for all trees in the study from a period of one month in summer 2012, diameter at breast height (DBH) for the measured trees and soil moisture over the same period, excluding days of missing sap flow, slope position and exposition

- Inter-species differences in daily sap flow between trees of similar DBH (at same location)
- Relation of daily sap flow and DBH
- No relation to soil moisture in depths of 10, 30 or 50 cm
- Intra-species differences between slope positions (beech, sites 6, 7, 8)
- Intra-species variability within same DBH range at same location
- Trees not water-limited at these location, not even on south-facing slopes at upslope position

2) Sap velocities

- Differences in sap velocity profile between tree species are visible (Fig. 6)
- For beech, the determination of zero sap velocity via regression is plausible
- For oak, outer thermistor seems most important as it covers youngest tree rings; daily sap flow can be reasonably calculated from this information

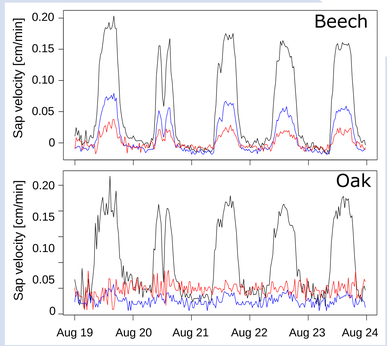

Fig. 6: Sap velocity profiles for the three thermistors (black: outer, blue: middle, red: inner) in a beech and an oak tree, for five days in 2012

Conclusions & Outlook

- Sensor type seems suitable for roughly assessing sap flow for meso-scale model input
- Especially for trees with deep sap velocity profile, simultaneous measurement at three depths is advantageous
- 2013: equipment of 19 additional sites on different geological units (sandstone, marls)
- Challenge: estimating stand transpiration

Acknowledgements

This study was funded by the DFG-FOR 1598 and supported by many helpers in the field.

HELMHOLTZ ASSOCIATION