Species specific temporal patterns of throughfall and stemflow in deciduous and coniferous forests with implications for unsaturated zone and groundwater recharge processes

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1 Research Questions

What is the impact of forest structural parameters on rainfall redistribution, especially for stemflow infiltration and groundwater recharge amounts?

What are the differences in stemflow and infiltration patterns between seasons and tree species?

2 Background & Approach

- rainfall is redistributed by forest canopies
- species specific temporal patterns of throughfall (TF) and stemflow (SF) determine groundwater recharge distribution & timing
- canopy structure is likely to have a major influence on TF & SF distribution

Therefore, we:

- investigate forest structural parameters e. g. leaf-area-index (LAI), tree species and sizes
- monitor with high temporal resolution
- cover all important tree species and ages

3 Research Area

Fig.1: Research area with positions of the 7 monitoring sites (reddish areas: pine dominated forest, greenish areas: beech dominated forest)

4 Equipment

Fig.2: Trough system in a beech stand with tipping bucket gauge for TF measurements (dip angle = 10°, tube length = 5m)

Throughfall:

- 7 TF plots with 6.6 m² collecting area per plot
- 5 tipping buckets with 100 mL volume per plot

Fig.3: Stemflow collection system with tipping bucket

Stemflow:

- tipping buckets allow for continuously high temporal resolution compared to event or cumulative measurements
- 5 mL tipping volume for small and 100 mL for bigger trees
- 5 trees on single and 10 on mixed species plots
- SF collected with covered PVC-collar

LAI:

- ground-based LAI measurements with LICOR LAI-2000
- estimates LAI based on measured diffuse sky radiation .

Fig.4: LICOR LAI-2000 plant canopy analyzer (source: http://www.licor.com)

5 Monitoring Results

Fig.5: SF time series for all trees sorted by diameter at breast height DBH (color scales consistent within tree species, darkgrey=NA, black frames indicate data used for modeling)

Fig.6: Gross rainfall and TF events in September & December 2014 (black frames indicate data used for modeling)

Fig.7: Interception calculated from the difference between gross rainfall and throughfall of events in September & December 2014 (grey= no interception calculated, black frames indicate data used for modeling)

- all data shown for two large example events in September and December 2014 with 18.5 mm and 33 mm of total gross rainfall

Stemflow:

- SF mainly influenced by tree species and tree diameter at breast height (DBH) (Fig. 6)
- however, other factors such as crown structure and forest composition have to be considered for detailed analyses
- SF of beech higher than oak and pine by one order of magnitude

Stand	Late Summer	Winter
Beech young	5.8	2.2
Beech old	4.8	1.0
mixed Pine-Beech	5.8	2.2
Pine young	NA	4.7
Pine old	1.2	1.2
mixed Oak-Beech	4.5	1.7

Tab.1: LAI of all stands during example events

LAI:

- highest seasonal LAI variation in beech stands, least in pine forests

Throughfall:

- highest TF rates in old beech, lowest in young pine stands
- smallest winter TF fraction in young pine stand due to dense canopy

6 Modeling

Fig.8: Stemflow infiltration patterns under 3 representative trees and 1 canopy gap per site simulated with HYDRUS (blue: soil moisture close to saturation, red: soil moisture close to field capacity), TF infiltration visible as homogeneous background pattern

Question:

- modeling should reveal spatio-temporal patterns of stemflow infiltration in relation to homogeneous throughfall input

Model:

- HYDRUS 2D finite-element model used to simulate unsaturated zone for events presented in chapter 5
- TF is the measured plot mean value applied to non-tree surface nodes, SF as measured stemflow per tree applied to a number of surface nodes representative for tree diameter
- model domain consists of 4 layers with breaks in 0.33, 1 , 1.5 m depth
- soil parametrization based on inverse modeling with measured soil moisture for 7 depths between 0.1 and 2m; first permeameter tests lead to comparable saturated hydraulic conductivity (K_{sat}=0.2 m/h in top soil, increasing with depth)
- preferential flow in macropores and along roots not accounted for
- model fit might be improved by using dual-porosity / dual-permeability approaches

7 Conclusions

- beech: highest stemflow amount and therefore highest and fastest GW recharge pulse
- if there is enough rainfall to reach saturated conditions pines and oaks are able to contribute substantially to GW recharge
- winter infiltration patterns more pronounced due to higher pre-event soil moisture
- outlook: quantitative assessment of groundwater recharge

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