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Relation of influencing variables and general weather conditions on response of rainfall partitioning by birch and pine trees

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Introduction

The hydrological cycle is influenced by multiple natural and artificial elements. As part of vegetation, the trees significantly influence the cycle through the process of rainfall partitioning. The components of rainfall partitioning are rainfall interception (I), describing the amount of rainfall, captured by the canopy and evaporating to the atmosphere, throughfall (TF), reaching the ground by dripping from the branches or falling through the openings, and stemflow (SF), precipitation trickling down the stem. How the precipitation is distributed after its interaction with a tree depends on multiple interconnected parameters (Staelens et al., 2008; Šraj et al., 2008; Zabret et al., 2018). Usually, they are divided on meteorological properties of an event (e.g. rainfall amount, intensity, wind speed) (Van Stan, 2014) and vegetation variables of a tree (e.g. tree height, canopy characteristics, bark absorption) (Zabret, 2013). As the variables are interdependent, it is hard to understand these processes. The complex interactions were addressed in multiple previous studies, taking into account different combinations of variables and presenting different viewpoints (Staelens et al., 2008; Šraj et al., 2008; Van Stan et al., 2014; Zabret et al., 2018; Zabret and Šraj, 2019). Therefore, the objective of this study is to contribute to the understanding of complicated processes with an analysis of a long term data set with advanced statistical model, including different tree species (deciduous and coniferous) and phenophases.

Methodology

The data on rainfall events and interception were collected on a study plot (600 m^2), located in a small urban park in the city of Ljubljana, Slovenia (46.04^0 N, 14.49^0 E), characterized by continental climate. It consists of a clearing and of two separate groups of trees, the birch trees (*Betula pendula* Roth.) and the pine trees (*Pinus nigra* Arnold). On the study plot the measurements are ongoing since January 2014. Rainfall was measured on the clearing with a tipping-bucket rain gauge (Onset RG2-M, 0.2 mm/tip) and with a disdrometer on the rooftop of a nearby building (OTT Parsivel). Throughfall (TF) was measured under each group of trees with ten roving wedge gauges (78.5 cm^2) and with two steel through gauges (0.75 m^2), one connected to manually-read polyethylene containers and the other one equipped with tipping bucket flow gauge (Unidata 6506G, Onset HOBO Event, 50 ml/tip). Stemflow (SF) was captured by halved rubber hose, spirally wrapped around the stem of one tree of each group and connected to a tipping bucket (Onset RG2-M, 0.2 mm/tip). Data on additional meteorological variables were obtained from the nearest meteorological station Ljubljana-Bežigrad.
The statistical analyses were performed in R software (R core team, 2020), with the boosted regression tree analysis (BRT) and with correlation matrices. The variables, taken into account, were rainfall amount (Ra), duration (Rd) and intensity (Ri), median volume diameter of raindrops (MVD), number of raindrops (Nr), air humidity (H) and temperature (T), wind speed (Ws) and duration of dry period between the events (DrP).

Results

The analyzed data were collected in the period from 1 January 2014 to 30 June 2017, when 415 rainfall events were considered. The selected rainfall events delivered 4,111.6 mm of rainfall in total. The events were on average 8.5 hours long and the rainfall intensity per event was on average equal to 2.5 mm/h. Under the birch trees the observed TF was on average equal to 54% (± 44%) per event, SF was observed during 188 events and was on average equal to 1.2% (± 2.4%). Therefore, rainfall interception by birch tree was on average equal to 31% in leafless and 51% in leafed period (Fig. 1). Under the pine trees, TF on average accounted for 29% (±36%) per event, while SF was observed during 124 events and on average represented 0.02% (± 0.09%) of rainfall in the open. Pine tree intercepted on average 73% of rainfall in the open, with minimal difference between the phenoseasons (69% and 74% in leafless and in leafed period, respectively).

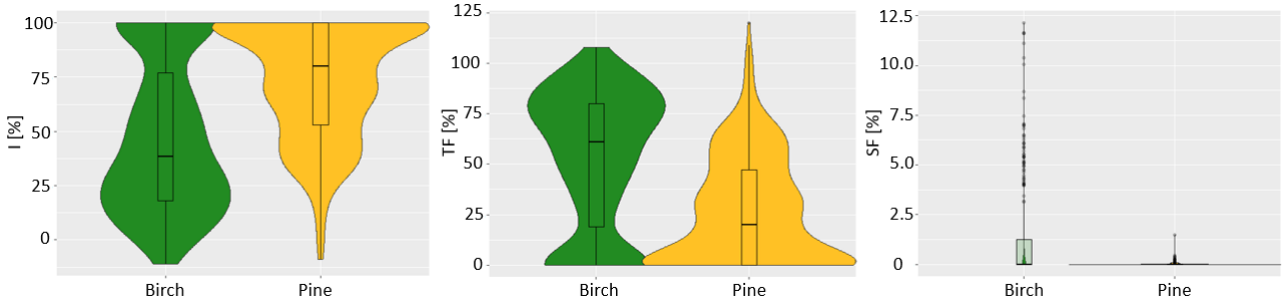
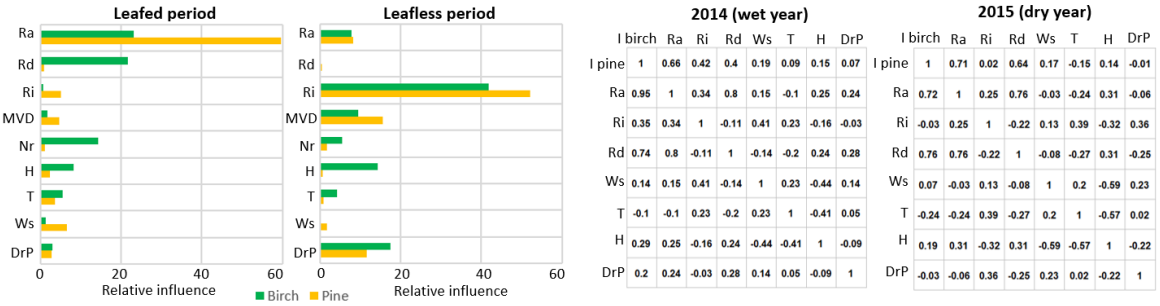


Fig. 1 Measured rainfall interception (I), throughfall (TF) and stemflow (SF) by birch and pine trees per rainfall event

The amounts of rainfall partitioning correspond to different combinations of influencing variables. To analyze proportions of rainfall interception by birch and pine trees, the influence of numerous variables per phenoseasons and per dry and wet years were modelled by generalized boosted regression tree models (BRT) and correlation matrices. Year 2014 was treated as a wet and year 2015 as a dry year according to the comparison of the annual rainfall amounts per long term average (Zabret and Šraj, 2019). The results of BRT show, that rainfall interception by both, birch and pine trees is the most influenced by rainfall amount in leafed period and by rainfall intensity in leafless period (Fig. 2). According to the meteorological characteristics during the phenoseasons we can compare leafed season with drier and leafless season with wetter conditions. Similarly, during the wet year of 2014, rainfall interception by both tree species was the most influenced by rainfall amount, intensity and duration, while in year 2015 (dry year) influence of rainfall intensity was negligible (Fig. 2).



2014 (wet year)

	I birch	Ra	Ri	Rd	Ws	T	H	DrP
I pine	1	0.66	0.42	0.4	0.19	0.09	0.15	0.07
Ra	0.95	1	0.34	0.8	0.15	-0.1	0.25	0.24
Ri	0.35	0.34	1	-0.11	0.41	0.23	-0.16	-0.03
Rd	0.74	0.8	-0.11	1	-0.14	-0.2	0.24	0.28
Ws	0.14	0.15	0.41	-0.14	1	0.23	-0.44	0.14
T	-0.1	-0.1	0.23	-0.2	0.23	1	-0.41	0.05
H	0.29	0.25	-0.16	0.24	-0.44	-0.41	1	-0.09
DrP	0.2	0.24	-0.03	0.28	0.14	0.05	-0.09	1

2015 (dry year)

	I birch	Ra	Ri	Rd	Ws	T	H	DrP
I pine	1	0.71	0.02	0.64	0.17	-0.15	0.14	-0.01
Ra	0.72	1	0.25	0.76	-0.03	-0.24	0.31	-0.06
Ri	-0.03	0.25	1	-0.22	0.13	0.39	-0.32	0.36
Rd	0.76	0.76	-0.22	1	-0.08	-0.27	0.31	-0.25
Ws	0.07	-0.03	0.13	-0.08	1	0.2	-0.59	0.23
T	-0.24	-0.24	0.39	-0.27	0.2	1	-0.57	0.02
H	0.19	0.31	-0.32	0.31	-0.59	-0.57	1	-0.22
DrP	-0.03	-0.06	0.36	-0.25	0.23	0.02	-0.22	1

Fig. 2 Results of BRT (left) and correlation matrices (right) on influence of meteorological variables on rainfall interception

Conclusions

Long-term continuous measurements of TF, SF and meteorological variables was analyzed with two statistical methods to show which variables influence the rainfall partitioning the most and how is their impact connected to general weather conditions. The comparison of results for wet and dry year and wet and dry phenophase showed that in wetter conditions rainfall intensity play significant role while in drier conditions it has negligible impact as rainfall amount and duration were recognized as the most influential. The comparison of the results indicate that the influence of general weather conditions dominates the properties of tree canopy.

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