Application of the multiple correspondence analysis for the evaluation of rain event characteristics influence on rainfall interception

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INTRODUCTION

Trees are an important element of the ecohydrological cycle due to rainfall partitioning. Precipitation (P), falling above the canopies, does not directly reach the ground, as it is divided into three components, namely throughfall (TF), stemflow (SF), and interception (I). The amount of intercepted rainfall is influenced by different meteorological and vegetation variables. Meteorological variables describe the characteristics of a rainfall event such as the amount of rainfall, duration and intensity, wind speed and direction, air temperature and humidity, raindrop number, size, and velocity. Vegetation variables describe the properties of the trees, for example, tree height, projected area of the canopy, diameter at the breast height, leaf area index, canopy openness, branch inclination and phenoseasons. In the presented research multiple correspondence analysis (MCA) was used to identify the co-dependant influence of various variables on rainfall interception by birch (*Betula pendula*) and pine (*Pinus nigra*) trees in small urban park in Ljubljana, Slovenia.

MATERIALS AND METHODS

Location

- small urban park (600 m^2) in city of Ljubljana, Slovenia
- two groups of trees (pine trees *Pinus nigra* in north-east and birch trees *Betula pendula* in south-east) and a clearing

Measurements

from January 2014 to July 2017 (176 rainfall events, snow excluded)

rainfall

- on the clearing, using a tipping bucket (0.2 mm/tip) rain gauge (Onset RG2-M) with an automatic data logger (Onset HOBO Event)
- on the rooftop, using OTT Parsivel optical disdrometer

throughfall (under each group of trees)

- a steel through gauge (0.75 m^2) connected to a tipping bucket flow gauge (Unidata 6506G; 50 ml/tip) with an automatic data logger (Onset HOBO Event)
- a steel through gauge (0.75 m^2) connected to a polyethylene containers (10 + 50 L), manually gathered after each event
- ten manually read roving funnel-type gauges (78.5 cm^2)

stemflow

- rubber collar, spirally wrapped around the stem and connected to a 20 l manually read polyethylene container

Multiple correspondence analysis (MCA)

MCA is a multivariate statistical method for descriptive rather than quantitative variables. It can be used to estimate the relationship between the variables. The results are presented using diagrams, in which the proximity of the variables corresponds to their interdependence and the location of the variables (positive or negative domain) corresponds to their positive or negative correlation. The relationship between rainfall interception of birch and pine trees and rainfall amount, duration and intensity, wind speed and direction, drop number and median volume diameter (MVD), expressing raindrop size was analysed.

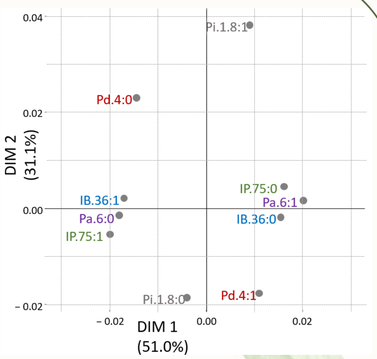
Variable's Acronym	Threshold Value	Less than Threshold	More than Threshold
Rainfall amount Pa	6 mm	Pa6:0	Pa6:1
Rainfall duration Pd	4 h	Pd4:0	Pd4:1
Rainfall intensity Pi	1.8 mm/h	Pi1.8:0	Pi1.8:1
Wind speed Ws	1.3 m/s	Ws1.3:0	Ws1.3:1
Wind direction Wd	S, N, E, W, SE, NE, SW, NW	WdS, WdN, WdE, WdW, WdSE, WdNE, WdSW, WdNW	
Median volume diameter MVD	1.5 mm	MVD1.5:0	MVD1.5:1
Number of raindrops NrD	10,000 50,000 100,000	NrD10:0 NrD10-50 NrD50-100 NrD100:1	

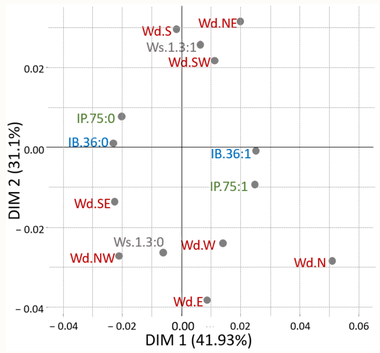
The numerical values of the variables were transformed to the descriptive ones using classes regarding the threshold values of the variables (more or less than threshold), which was determined through sensitivity analysis. The thresholds were 6 mm for rainfall amount, 4 h for duration and 1.8 mm/h for intensity, 1.3 m/s for wind speed, 8 cardinal directions for wind direction, 1.5 mm for MVD and 10,000, 50,000 and 100,000 raindrops for their number.

RESULTS

Rainfall amount (Pa), intensity (Pi), and duration (Pd)

The two dimensions expressed 75.7% of statistical inertia and both of them indicated the highest influence of the rainfall amount on interception. The dimension 1 displays that the rainfall interception for birch (IB36:1) and pine trees (IP75:1) was higher when the rainfall amount, intensity, and duration were lower than the threshold values. But according to dimension 2, the rainfall interception by birch tree decreases (IB36:0) during the events with intensity less than 1.8 mm/h, but with more than 6 mm of rainfall during the events longer than 4 h. For the pine tree, the decrease in rainfall interception (IP75:0) can be observed also during shorter and intense events with less than 6 mm of rainfall.



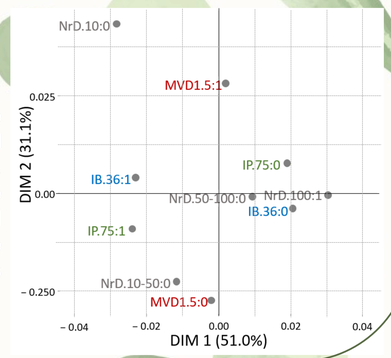


Wind speed (Ws) and direction (Wd)

The two dimensions expressed 73.0% of statistical inertia. In this case the diagram showed a very interesting influence of wind direction and speed. The decrease of rainfall interception by birch and pine trees can be observed in two cases: for wind speed higher than 1.3 m/s, the wind corridor appears from south and south-west towards north-east; for wind speed lower than 1.3 m/s, the corridor appears from south and south-east towards north-west. Both directions arises on the edges of the surrounding buildings and not in between them. However, the influence of the wind corridors seems to be minor. The test observations of the rainfall resulted in Pearson correlation coefficient between the measured values from the two gauges equal to 0.99. No statistically significant differences in the measured rainfall amount at the two locations in each individual wind corridor were observed.

Number of raindrops (NrD) and the median volume diameter (MVD)

The two dimensions expressed 82.1% of statistical inertia. Both dimensions indicated the number of raindrops as the more influential variable. According to dimension 1 rainfall interception by birch and pine trees was larger for smaller and less numerical raindrops. The dimension 2 expressed the influence of the size of the raindrops. Interception by the birch tree decreases (IB36:0) regardless of the large number of small raindrops, and increases (IB36:1) for the small number of large raindrops. In a case of a pine tree, the small number of large raindrops decreases the interception (IP75:0), whereas it increases it (IP75:1) for smaller raindrops regardless of their number.



CONCLUSIONS

The analysis with the MCA proved the dominant influence of the rainfall amount, as previously used methods and numerous past studies did. The ratio of rainfall interception to rainfall amount decreases with increasing rainfall amounts. MCA including the wind characteristics gave a new insight into its influence on rainfall interception. The results expressed two new directions of occasional wind corridor according to the nearby buildings which were not visible using other methods of data analyses. The presented analysis, using MCA, confirmed results of previous analyses and offered a new insights into the process.

REFERENCES

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