Preliminary results on uncertainties in rainfall interception estimation

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ABSTRACT
This work deals with some aspects of rainfall interception estimation uncertainty in a deciduous forest. The importance of interception loss measurement error is stressed. Confidence limits of Rutter original and sparse interception model parameters obtained from regressions for leafed and leafless period are presented, as well as free throughfall coefficient variability with event weather conditions.

Keywords: uncertainty, parameters, interception, measurement error

INTRODUCTION

Rainfall partitioning is a hydrological process by which rain water retained on leaves, branches and stems is redistributed within the canopy. Part of retained water drains down to the soil and part is evaporated to the atmosphere as interception loss. For this reason, interception loss quantification and modelling requires water fluxes and meteorological data to be gathered in the field. However, these variables are uncertain because of measurement errors and for being variable in time and space.
The scientific efforts on rainfall interception loss quantification and modelling in rainforest are counterbalanced with studies on temperate forests, but within this last group markedly less attention is devoted to deciduous forest (Muzylo et al., 2009). This lack of information should be stressed and completed since seasonal changes of deciduous forest will probably cause the seasonal changes in water balance in the catchments covered with this type of vegetation. Apart of that, seasonal changes in forest structure will change forest parameters, making interception modelling more complex than in coniferous forest. The objective of this work is to determine measurement uncertainties, and to analyse uncertainties related to parameterization in a deciduous forest plot.

METHODS

Water fluxes measurement uncertainty

Data used for this study was obtained from 7 stemflow gauges and 3 sets of 2 troughs, with a total surface, ca 6 m^2, both devices equipped with tipping buckets. These instruments were installed in a small experimental forest plot (Vallcebre research catchments, pre-Pyrenees, Spain; Latron et al., 2009), covered principally with *Quercus pubescens.* Rainfall measurements were obtained in a nearby clearing with a standard rainfall gauge. All measurements were stored each 5 minutes on a DT 500 data logger. Rainfall partitioning measurements were complemented with meteorological variables measured above the forest canopy.

Statistical properties of measured variables were calculated to estimate data uncertainty of 100 rainfall events registered in the studied plot (Beven, 2009). No random or statistical errors were considered, but the standard error of the mean was used to express the uncertainty of mean throughfall and stemflow values. The measurement error of interception loss was derived as the square root of the sum of throughfall and stemflow variances and a correlation factor between these two variables.

Rutter original and sparse models

Rutter original model (Rutter et al., 1971), which was the first rainfall interception physically based model, predicts interception loss, throughfall and stemflow by a running balance of the canopy water storage, evaporation, rainfall and drainage. Detailed rainfall and meteorological data are indispensable inputs to run the model. All model parameters and calculations are done on the plot surface basis and the rate of drainage form the canopy is assessed by means of empirical equation. Valente et al., (1997) proposed improvements to the Rutter model adapting it for sparse vegetation. The sparse model version divides the plot into two sub-areas, an open area and an area that comprises canopy and trunks, so that the evaporation rate and values of parameter describing trunk and canopy storage are expressed on the covered area basis. By introducing important conceptual changes to the models' structure, the sparse model version is expected to describe better the evaporation loss in both: closed and sparse canopies.

Determination of parameter's ranges

Free throughfall coefficient (p) was obtained from hemispherical photographs as percentage of uncovered sky and its variability with rainfall intensity and wind speed was assessed.

Over 60 hemispherical photographs were taken in growing season and were analyzed with Gla V2 software. Mean free throughfall coefficient values were obtained for different rainfall incident angles (Herwitz and Slye, 1995) derived from changing wind speed in the range of 0 - 3.5 m/s and rainfall intensity in the range of 0.5 – 30 mm/hour

Trunk storage (St, Stk) and drainage parameters (pt, pd) were obtained as coefficients from the linear regressions of stemflow on precipitation or throughfall - (1-canopy cover)* rainfall, for original and sparse model, respectively (Valente et al., 1997). The uncertainty of regression coefficients was assessed by means of standard deviation of the slope and of the intercept (Coleman, 1999). Form these, the confidence intervals for the parameters' values were obtained.

Saturation storage capacity (S) was calculated as an intercept of the regression of throughfall versus gross rainfall according to the Leyton's et al (1967) method adapted by Valente et al., (1997). As this method involves drainage parameters, their confidence limits were considered and confidence limits for storage capacity were derived.

RESULTS AND DISCUSSION

Throughfall and stemflow measurement errors decrease with increasing the rainfall amount, both in leafed and leafy period (Figure 1). Contrarily, there is not a decrease in interception loss measurement errors as rainfall increases (Figure 2).

Throughfall relative errors are higher in leafed period than in the leafless one and smaller than 20% for rainfall events larger than 5mm. Stemflow is more variable flux and its relative standard errors are about 30% for events larger than 10mm of rainfall. Finally, interception loss errors are in general smaller than 50 %, but for some events can reach up to 100 %.

Results show that measurement errors are important source of uncertainty and should be taken into account in model calibration and validation, both in leafless and leafed period.

For all three fluxes the relationship between rainfall amount and the considered flux is quite similar in leafless period (correlation coefficient ρ 0.75-0.82). Contrarily, this relationship shows larger differences in the leafed period, with stemflow error highly related to Pg amount (ρ 0.99), compared to the other fluxes (interception ρ 0.69, throughfall ρ 0.56).

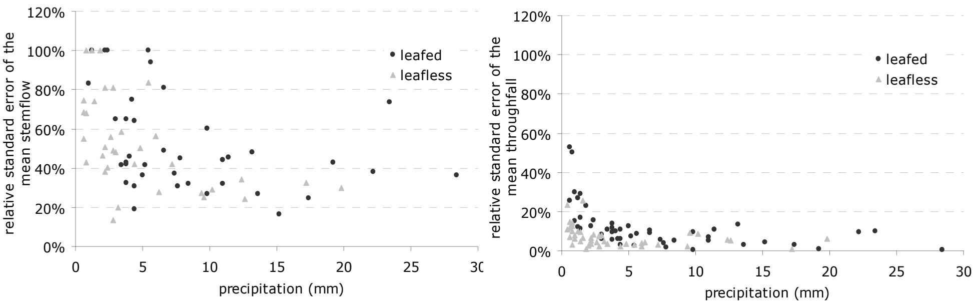

Figure 1. Stemflow relative error of the mean for leafed and leafless periods (left). Throughfall relative error of the mean for leafed and leafless periods (right).

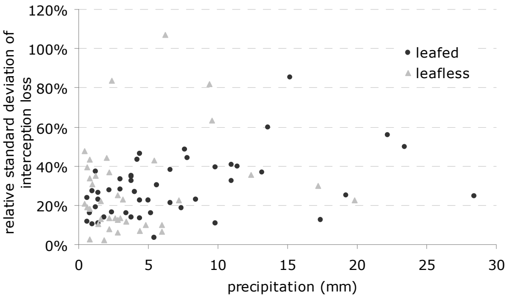

Figure 2. Interception loss relative standard deviation for leafed and leafless periods.

Obtained confidence intervals of canopy and trunk storage and drainage parameters were much wider than expected and are reported in the table 1. Relative standard deviation values up to 100% for storage capacities should be highlighted. Important differences in standard deviation of parameters were found between leafless and leafed period, having the leafless period higher values.

Free throughfall coefficient was found to vary up to 5 % depending on the meteorological conditions during rainfall in growing season. This confidence limit is assumed to be valid also for the leafless period as any similar analysis was performed for leafless period.

Table 1. Confidence intervals of parameters used in Rutter original and sparse rainfall interception models

Parameter	Rutter original		Rutter sparse	
	Leafed	Leafless	Leafed	Leafless
Canopy storage (S)	0. 36-0.46	0.01-0.15	0.38-0.55	0.01-0.22
Stem storage (St, Stk)	0.10-0.24	0.07-0.39	0.01-0.17	0.01-0.27
Drainage partitioning (pt, pd)	0.02-0.04	0.05-0.08	0.01-0.06	0.13-0.21
Free throughfall coefficient (p)	0.31-0.34	0.64-0.71	0.31-0.34	0.64-0.71

This analysis confirms that uncertainty of parameters calculated from regressions is relevant, although only the regression adjustment was considered as a possible source of uncertainty, and no data measurement errors were considered in this analysis.

CONCLUSIONS

The preliminary results show that the event scale measured interception loss in the studied pubescent oak stand is considerably uncertain both in leafed and leafless period. The spatial variability of throughfall and stemflow clearly determine this uncertainty. In addition, parameters obtained for Rutter models following classical methods, especially canopy storage capacity in leafless period, show also significant uncertainty. For these reasons both, measurements and parameters estimation uncertainties should be taken into account in modelling exercises.

ACKNOWLEDGMENTS

This study was supported by the Project Probase CGL2006-11619/Hid, founded by the Spanish Ministry of Science and Innovation (MCIIN). The first author is benefited from a pre-doctoral FPU grant (MCIIN). Support provided by X. Huguet, J. Latron, G. Nord and M. Soler during fieldwork and data acquisition is acknowledged.

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