Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/forestsystems
doi: http://dx.doi.org/10.5424/fs/2014232-03410

Forest Systems 2014 23(2): 300-303
ISSN: 2171-5068
eISSN: 2171-9845

Short Communication. Simulation of gash model to rainfall interception of *Pinus tabulaeformis*

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Abstract

Aim of study: In order to test the adaptability of revised Gash analytical model to canopy interception of *Pinus tabulaeformis* plantation, determine local parameters in the model, and analyze the sensitivity of the parameters to the simulated interception.

Area of study: The throughfall experiment has been completed in Hebei province of China during 2010.

Material and methods: During the experiment process, rainfall, throughfall and stemflow were measured and canopy interception was simulated with the revised Gash analytical model.

Main results: The results show that the rate of measured throughfall, stem flow and canopy interception occupied to rainfall were 67.08%, 3.10% and 29.82%. Canopy storage capacity, stem storage capacity and Stemflow partitioning coefficient was 2.68 mm, 1.22mm and 0.03. Evaporation rate varied from 0.01 to 0.37 mm · h^{-1} and the ratio of evaporation and rainfall (E/R) ranged from 0.01 to 0.19 in rainfall periods.

Research highlights: The revised gash model was able to accurately simulate the weekly canopy interception of *Pinus tabulaeformis* forest.

Key words: Gash analytical model; Throughfall; Canopy interception; *Pinus tabulaeformis* plantation.

Introduction

Partition of rainfall into throughfall, stemflow and interception loss it is the first interaction between water cycle and forest (Limousin *et al*. 2008). The interception of precipitation by vegetation canopies is a major component of the surface water balance (Link *et al*. 2004) and it has been extensively studied. A large number of interception studies have been studied in tropical rainforest (Hutjes *et al*. 1990; Jetten 1996), seasonal temperate rainforest (Link *et al*. 2004), temperate broadleaf (Hörmann *et al*. 1996) and temperate conifer forests (Rutter *et al*. 1972; Valente *et al*. 1997). The majority of interception studies in temperate conifer canopies have been research in relatively young plantation forests in Europe (Ford and Deans, 1978; Gash and Stewart 1977; Gash *et al*. 1980; Johnson 1990; Kelliher *et al*. 1992; Rutter *et al*. 1972; Viville *et al*. 1993). Most interception studies in temperate conifer canopies have been studies in Europe. However, the interception studies about *Pinus tabulaeformis* which is universally distributed in East Asia and especially the modeling of canopy inspection of *Pinus tabulaeformis* with revised Gash analytical model has seldom been reported worldwide in China.

Material and methods

Study site description

The study site is located at Mulan forestry management bureau in Hebei province (41°49'35.8" N, 117°35'31" E and elevation 1270 m), north of China. In this study, measurements of rainfall, throughfall, stemflow and a suite of meteorological variables were conducted for the period of June to October, 2010.

Investigation of sample plot

Ten *Pinus tabulaeformis* sample plot of 30 m × 30 m was chosen and it was investigated in June, 2010. In

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Received: 07-08-12. Accepted: 15-01-14.

these plots, vegetation is dominated by *Pinus tabulaeformis* plantation and understory species compose a sparse grass-shrub layer, Herb cover is less than 35% and the height is lower than 0.6 m. Mean tree height and canopy were 12.4 m and 6.3 m respectively and the crown diameter was 2.5m × 2m in average in the plot. Stems with diameters at breast height were DBH < 10 cm and DBH > 22 cm accounted for 2.22% and 1.48% respectively of the total stems, which represented a very small percentage.

Throughfall

In the experiment, throughfall (TF) was collected with self-produced iron rain gauges (0.78 m long and 0.2 m wide) during the growing season, and was measured manually using graduated cylinders with an accuracy of 1 ml. TF collected by each of the gauges was measured directly after an event or at sunrise if the event occurred during or extended into the night.

Stemflow

To attain more accuracy, a stratified random sampling design representative of the beech forest was used for the selection of sampling trees for SF measurement. All trees inside the study plot with DBH > 10 cm were divided into three groups: DBH < 14 cm, DBH = 14-18 cm, and DBH = 18-22 cm. DBH was measured to the nearest centimeter using a caliper. For each of the above mentioned DBH group. SF was collected from 6 selected beech trees using spiral-type SF collection collars installed at the level of the breast height during the measurement period.

Method for Modeling

Revised analytical model

The revised Gash analytical model calculates interception losses over a period of time from the evaporation rate to precipitation rate of each individual rainfall event (Limousin *et al*. 2008). In this model, interception of canopy was calculated by the function as follows.

$$\sum_{j=1}^{n+m} I_j = c\sum_{j=1}^{m} P_{Gj} + \sum_{j=1}^{n}\left(cE_{ci}/R_j\right)\left(P_{Gj} - P'_G\right) + +c\sum_{j=1}^{n} P'_G + qcS_{tc} + cp_{ct}\sum_{j=1}^{n-q}(1-(E_{cj}/R_j))\left(P_{Gj} - P'_G\right) \quad [1]$$

In the model, P'_G which is the amount of precipitation to fill storage capacity of canopy is calculated by the equation following (Gash *et al*. 1995).

$$P'_G = (-R/E_c)S_c \ln(1-(E_c/R)) \quad [2]$$

P''_G is the amount of precipitation necessary to fill the trunk storage capacity, and given by the following equation (Valente *et al*. 1997).

$$P''_G = (R/(R-E_c))(S_{tc}/P_{tc}) + P'_G \quad [3]$$

Results

Coefficients relate to rainfall and evaporation

In this study, Rainfall and evaporation related coefficients such as number of times of measured rainfalls, mean evaporation rate, mean precipitation rate and ratio of E_c versus R in each week were given in Table 1.

Parameters relate to canopy and stem

In the studied *Pinus tabulaeformis* plot, throughfall and stemflow were linearly correlated with incident rainfall (Fig. 1). Total of throughfall was 140.85 mm and total of stemflow was 6.51 mm. By subtracting throughfall and stemflow from incident rainfall, interception loss was found to be 62.62 mm in the plot, occupied 29.82% of total precipitation.

$$TF = 0.8189 \cdot RF - 2.1973,\ R2 = 0.9855,\ p < 0.0001 \quad [4]$$

$$SF = 0.0286 \cdot RF9 - 0.1304,\ R2 = 0.911,\ p < 0.0001 \quad [5]$$

Simulation on condition that E/R was varied

In the study, rainfall interception on condition that value of Ec/R was constant or stimulated respectively. The measured and simulated canopy interceptions were

Table 1. Rainfall and evaporation related coefficients

Order of experiment weeks	Time of measured rainfalls	Average evaporation rate, E_c	Average precipitation rate, R	Ratio of E_c versus R
1	4	0.0984	3.0104	0.0322
2	10	0.0635	6.5671	0.0099
3	7	0.1980	4.4639	0.0422
4	8	0.2135	1.2001	0.1864
5	2	0.3561	4.0010	0.0916
6	8	0.2795	2.0916	0.1376
7	11	0.3689	2.2535	0.1680
8	10	0.1494	4.8010	0.0319
9	8	0.1693	3.3002	0.0520
10	3	0.2880	2.8003	0.1035
11	1	0.4280	4.2381	0.1009
12	6	0.1451	2.1079	0.0710

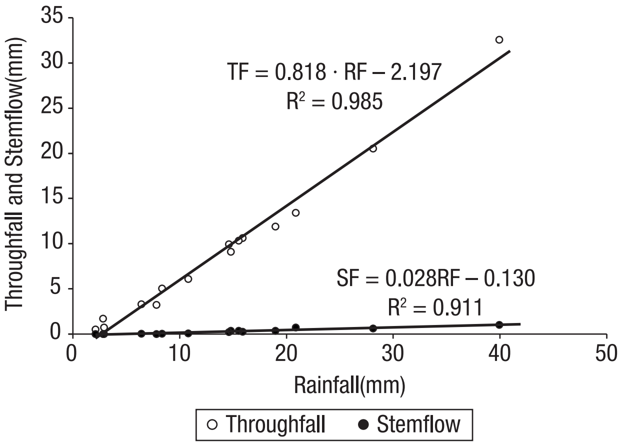

Figure 1. Relationships between throughfall or stemflow and incident rainfall in the studied plots.
Note: TF stands for throughfall; SF stands for stemflow; RF stands for rainfall.

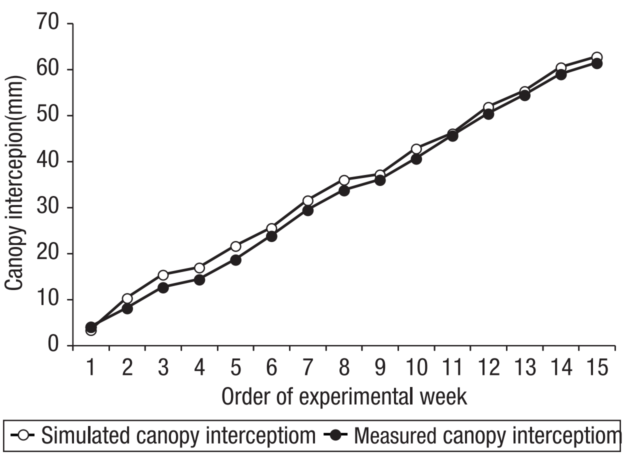

Figure 3. Comparison of measured and simulated weekly cumulative canopy interception when E/R varies.

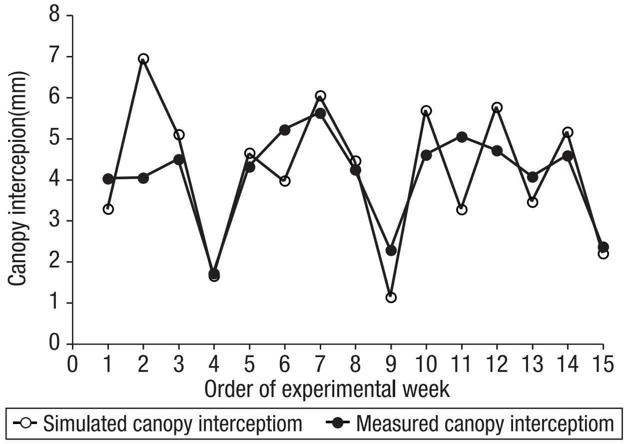

Figure 2. Comparison of measured and simulated weekly single canopy interception when E/R varies.

compared weekly by the way of both single rainfall and cumulative rainfall (Fig. 2 and Fig. 3). When E_c/R was varied, sensitivity analysis of the canopy parameters showed that the model is sensitive to changes in S in highest degree: a change of S of 25% changes canopy interception loss by 12.9%. The model is relatively sensitive to S_t and c: an increase of S_t and c of 25%, produces an increase of 5.8% and 3.4% in interception loss respectively. The model is insensitive to p_t: a change of p_t of 25% only changes interception loss by 0.03%.

Discussion and conclusion

Revised Gash model related to many coefficients and the accuracy of them was highly affected by many environmental factors. The variation of interception was caused by different coefficients. Some scholars (Deguchi *et al*.2006; Link *et al*.2004.) found that E_c/R generate biggest effect to canopy interception, while it was maintain that c makes the largest influence. In this study, the change of S made the largest variation in all the parameters. Compared with this study, the 25% S caused interception variation were 8.6% and 5.2% (Limousin *et al*.2008) respectively. Similar to Other studies, interception variation caused by p_t and S_t were relatively small in this study.

E_c and R are important weather parameters that make large influence to canopy interception. In most studies, the effect of E_c and R was studied by researching of the ratio of E and R (Deguchi *et al*. 2006; Link *et al*. 2008). In this study, the influence of E_c/R was analyzed comprehensively to study the influence of rainfall and evaporation factor to the model of studied area so as to analyze E_c/R influence basing on two premises: E_c/R varies and E_c/R was constant, and compares the simulation effect of the model. The result indicates that both the two situations show advantages in different aspect. When E_c/R varies, total error (2.11%) of simulated value to measured value was smaller than that when E_c/R was constant (5.19%). When E_c/R was constant, Pearson correlation coefficient of simulated and measured canopy interception was 0.85 for weekly single rainfall, which is much higher than that when E_c/R varies, 0.76. Otherwise, no matter E_c/R value varies or not, simulated cumulative canopy interception fit to the measured well.

Acknowledgements

This work was supported by Commonweal Project of State Forestry Administration of P. R. China (200804022A).

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