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Research Paper

Measuring and modelling Stemflow in an Oriental beech stand of the Hyrcanian region, Iran.

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Abstract: Stemflow as a hydrologic process is often considered to be an insignificant contributor to the hydrologic budget. This is most likely because of the relatively small percentage of the gross rainfall (approximately 1%-5%, in most cases) contributed by stemflow . In this study, measurements stemflow fluxes was conducted from November 2005 through November 2006 within a natural stand of oriental beech (Fagus orientalis Lipsky) in district 1, Shastkalateh, Hyrcanian forests. The main objectives of this study were to determine and model stemflow using allometric characteristics of beech trees. Furthermore, to represent a forecast model of stemflow, allometric parameters of beech trees, i.e., diameter, cross area, height and volume of tree and area height and volume of canopy were measured. A strong correlation was observed between stemflow and allometric characteristics of beech trees. The regression model was parameterised to predict the values of stemflow by the value of allometric characteristics of beech trees.

Keywords: Precipitation; Stemflow; Oriental beech; Hyrcanian region, Modeling

Introduction

Precipitation is the main input to the catchment water balance in most forest ecosystems (Barnes et al., 1997; Herbst et al., 2006). Precipitation and climate characteristics as well as canopy structure are the main influencing factors on Rainfall partitioning (Herwitz, 1985; Gash et al., 1995; Hormann et al., 1996; Crockford and Richardson, 2000; Zeng et al., 2000; van Dijk and Bruijnzeel, 2001; Link et al., 2004; Pypker et al., 2005; Herbst et al., 2006; Cuartas et al., 2007). Leaf shape (broadleaf/conifer), stem density(e.g., Swank and Douglass, 1974; Vertessy et al., 2001; Komatsu et al., 2008),Canopy height, canopy architecture, and stand characteristics such as basal area commonly have some influences on interception process and its values (Ford and Deans, 1978; Stogsdill et al., 1989; Cape et al., 1991). Rainfall is partitioned into throughfall, stemflow and interception by forest canopies, and this partitioning is a very important part of forest hydrology(Alizadeh 2007, Nasiri et al.,2012). Quantification and understanding of the interactions among these three hydrological components, the vegetation and soil of a watershed, are of great importance for the rational management of these natural resourses (Newson, 1992).
Quantification of interception losses is very important due to its significant impact on the watershed’s water balance (Ward and Robinson, 2000). Interception losses influence the water yield and the other water components of forested watersheds relative to non-forested watersheds (Calder, 1976; Asdak et al., 1998). Continuous rainfall causes water to saturate tree foliage, and then additional water is conducted to the ground via the stem of trees. The stemflow is defined as the amount of water which moves as flow from foliage to stem and down to the ground. Throughfall is defined as the amount of rainfall which comes through the leaf canopy via the empty spaces between the leaves to the ground (Alizadeh 2007). Total interception loss can not be measured directly but must be estimated from samples of gross rainfall, throughfall, stemflow. The amount of interception by the canopy, including leaves, branches and stems, was evaluated by the following water balance equation:

$$I=P-(TF+SF)$$

where I, P, TF and SF are interception, gross rainfall, throughfall and stemflow, respectively.
Stemflow is rainfall which, having been caught on the canopy, reaches the litter or mineral soil by running down the stems. Both climate and phytomorphological factors control rainfall interception by forests. Previous studies carried out in forests reported SF values that were less than 2% of Pg (Rothacher, 1963; Hutchinson and Roberts, 1981; Rowe, 1983; Cuartas et al., 2007). Morphological differences among trees have been quantified to explain stemflow variability. During precipitation, the morphology and distribution of trees and, collectively the forest, control the fate of the water. The morphology of the vegetation can influence the quantity and distribution of water descending from the canopy to the ground surface (Schroth *et al.* 1999). Crown area is a significant factor in predicting variability in stemflow (Lawson 1967; Aboal *et al.* 1999).Based on trunk projected area 1.5 m above ground, Durocher (1990) found that rainfall input at the base of some trees was 30 to 40 times larger than the mean throughfall. Essentially, throughfall is distributed over a very large area while stemflow is not. Cape et al. (1991) conducted a study in a forest in northern Britain consisting of Pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst), Sitka spruce (*Picea sitchensis* (Bong.) Carrière), larch (*Larix decidua* L.), Oak (*Quercus petraea* Matt.), and Alder (*Alnus*

subcordata (L.) Gaerta). They concluded that the branching habit of each species was the main determinant of stemflow, and also noted that the provenance of a species affects the branching habit and, therefore the stemflow of that species.
A very limited number of studies and publications are found on the partitioning of precipitation by forest canopy for the Oriental beech forest, which is a widespread forest species in the Hyrcanian region (Ghorbani, 2007). This paper focuses on how an Oriental beech forest affects precipitation. More specifically, the objectives of this study were to:(1) measure the total precipitation and SF; (2) establish an appropriate model to estimate Sf using allometric parameters of beech trees.

Materials & Methods

Description of the study site

This study was conducted in the Shastkola experimental forest station located on the northern foothills of the Alborz Mountains in northern Iran. The study was carried out for 1 year from November 2005 to November 2006. The study site has an area of 16 ha and is located at 36_440N latitude, 54_230E longitude, with an elevation of approximately 900 m. According to the data from the nearest meteorological station, Gorgan, the mean annual precipitation is approximately 601 mm (IRIMO, 2007). Oriental beech is the most dominant species in the Hyrcanian forests, and this is also the case within the study site. The site contains a mixed-aged stand of Oriental beech which exhibits a range of natural characteristics. The stand was characterised by a closed canopy, a tree density of 244 trees/ha (with Diameter at Breast Height of greater than 10 cm), and a basal surface area of 34.5 m2. On average, 53% of the basal surface area was formed by Oriental beech. The mean height of the trees was 22.5 m and the height of canopy was estimated to be 30 m, indicating that the stand had a thick canopy. Other tree species in the study site include: hornbeam (Carpinus betulus Linnaeus), Persian ironwood (Parrotia persica C.A. Meyer), Caucasian maple (Acer cappadocicum Gleditsch), maple (Acer insigne Boissier), Italian alder (Alnus subcordata C.A. Meyer), and date plum (Diospyros lotus Linnaeus) (Ghorbani, 2007).

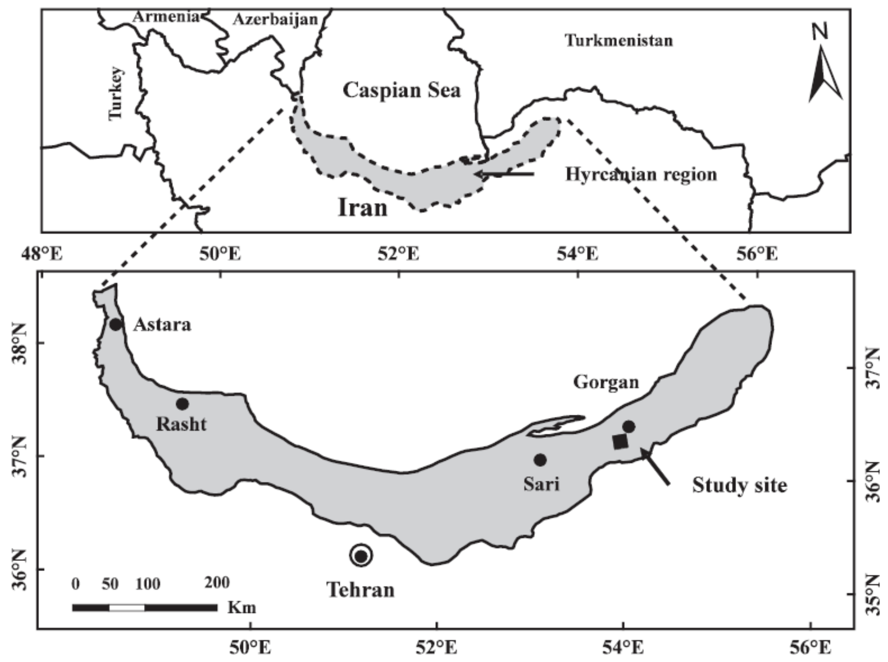

Fig.1. location of the study site in the Hyrcanian region.

Measurements

Gross precipitation was directly measured by a manual rainfall gauge (20 cm diameter) was installed 1.5 m above the tree canopy. The value of Pg was calculated after each precipitation event. In order to measure the stemflow, firstly 31 beech trees were selected randomly. For each tree, the rate of stemflow was measured using a stemflow collector. The stemflow collectors were made of a rubber channel of 2.5 cm diameter that was moulded around the stem to form a single, closed-loop collar. Stemflow was calculated by dividing the volume of the collected water by the crown area and was measured for each precipitation event during the study. The collected data were analysed using ANOVA implemented in SPSS. Furthermore, to represent a forecast model of raining elements, allometric parameters of beech trees, i.e., diameter, cross area, height and volume of tree and area height and volume of canopy were measured and then prepare The most accurate prediction models by application of the allometric characteristics of beech trees.

Result

Results show that During the 12-month study (November 2005–2006), The total precipitation recorded during this period was approximately 827 mm. Approximately, 2.4 mm of the total precipitation (0.3%) was considered as SF. The most accurate prediction models were prepared by application of the allometric characteristics of beech trees. The result of allometric characteristics measurement of trees are shown in Table 1.

Table 1. allometric characteristics of beech trees

allometric characteristics	Minimum	Average	Maximum
DBH(cm)	31	78.7	130
Height(m)	20.3	36	44.3
Besal Area (cm²)	0.07	0.5	1.3
Volume(m³)	0.49	7.4	19.9
Crown Height (m)	7.8	19.9	32.4
Crown Area(m²)	27.4	125	277
Crown Volume (m³)	457.2	2610.3	8984.99

Pearson Correlation Coefficient between allometric characteristics of beech trees and volume and hight of SF was investigated(Table 2).

Table 2. Values of Pearson Correlation Coefficient between allometric characteristics of beech trees and volume and hight of SF

Allometric characteristics	Height of annual SF	Volume of annual SF
DBH	-0.683**	-0.419*
Crown Height	0.164	0.003
Height	-0.573**	-0.436*
Besal Area	-0.617**	-0.381*
Volume	-0.615**	-0.386*
Crown Area	-0.473**	0.010
Crown Volume	-0.367*	0.024

* Significant at 0.05 level.
** Significant at 0.01 level.

Due to result of Pearson Correlation Coefficient ,the most accurate prediction models were prepared by application of the allometric characteristics of beech trees.It's shown in Tables 3 and4.

Table 3 Predicted allometric model for height of annual SF

Variable	Models	R²	Standard error	Domain Reputation	Number of sampelling
DBH(cm)	Y = 169.885 / x	0.846	1.1665	31-130	31
Height(m)	Y=0.0795*x	0.996	0.55367	20.32- 44.30	31
Besal Area (cm²)	Y =0.6781 / x	0.912	0.91037	0.07-1.32	29
Volume(m³)	Y =5.1096 / x	0.902	0.92832	0.49-19.906	28
Crown Height (m)	Y =213.343 / x	0.788	1.42977	27.49-277.05	28
Crown Area(m²)	Y =10.3736 / x	0.678	1.62534	457.2-8984.1	29

Table 4 Predicted allometric model for volume of annual SF

Variable	Models	R^2	Standard error	Domain Reputation	Number of sampelling
DBH(cm)	Ln Y =305.962/x	0.881	1.58881	31-130	28
Height(m)	Ln Y =179.131/ x	0.963	1.05542	20.32- 44.30	31
Besal Area (cm^2)	Y =51.9859/ x	0.774	1.27799	0.07-1.32	28
Volume(m^3)	Y =382.003 / x	0.631	1.63436	0.49-19.906	28

Discution

However, further consideration reveals that the low and high values of this range may have been due to specific characteristics of the studied trees or of the rain events. On the other hand, the high value of experiment 1 could be attributed to heavy rain events. Also the difference of the tree structure, as characterized by crown size, leaf shape, branch angle, flow path obstruction and bark type are important factors which affect stemflow generation (Crockford and Richardson, 2000).

Rowe (1983) observed that Sf in deciduous forests can be a very small proportion of the Pg (1–2%), whereas in the present study, the averaged value of Sf measured across the all sample trees was 2.4 mm (0.3% of the total Pg . As reported by Ghorbani (2007), the site contains uneven-aged mixed stand of Oriental beech. In addition, the stand had a closed canopy, and was characterised by a thick and large canopy cover. The above mentioned characteristics of the stand lead to a reduction of Sf. This is in agreement with the findings of many studies (e.g., Helvey, 1967; Mitscherlich and Moll, 1970; Ford and Deans, 1978; Aston, 1979; Steinhardt, 1979; Aussenac and Boulangeat, 1980; Hutchings et al., 1988; Lloyd et al., 1988; Stogsdill et al., 1989; Cape et al., 1991; Ubarana, 1996; Tobon Marin et al., 2000; Iroume and Huber, 2002; Holscher et al., 2005). Furthermore, our observations of the site indicated that the existence of some cracked and decayed stems along with mosses covering the bark surface could lead to a reduction of the Sf measured by collar-type collectors. Lichens and mosses can absorb water roughly 6–10 times their dry weights (Link et al., 2004). These species probably play a very important role in rainfall interception, however the interception dynamics of these species are poorly understood (Link et al., 2004).

On the basis of the results of this study, for estimation purposes, the value of Sf can be averagely assumed to be 0.3% of the Pg for Oriental beech stands in the Hyrcanian region. However, it is difficult to presume Sf values from one forest to another even if they are the same forest type (Levia Jr. and Frost, 2003). Since measurement of precipitation components is labour-intensive and time-consuming, there have been some efforts to predict the component values through model development (Rutter et al., 1975; Gash, 1979; Mulder, 1985; Calder, 1986). As stated earlier, few values Sf have been published for Oriental beech stands (Ghorbani, 2007). The necessity of data for modelling purposes requires intensive data collection on the site prior to model development. The most accurate prediction models were prepared by application of the allometric characteristics of beech trees . Due to lack of synoptic weather station in the area, the models that forecast the percent of SF, based on allometric properties of trees can be practically applicable.

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