J. Agr. Sci. Tech. (2011) Vol. 13: 1105-1120

Rainfall Redistribution by an Oriental Beech (*Fagus orientalis* Lipsky) Forest Canopy in the Caspian Forest, North of Iran

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ABSTRACT

Gross rainfall (GR) partitioning into throughfall (TF), stemflow (SF) and interception loss (I) was studied in a pure oriental beech (*Fagus orientalis* Lipsky) forest located in the central Caspian region of northern Iran. Measurements were performed on a rainfall event basis in a 5625 m^2 plot of the Kheyrud Forest Research Station of Tehran University during 2008 and 2009 growing seasons. GR was measured with three rain gauges located on the ground in an open area approximately 160 m apart from the study plot. Thirty-six manual gauges were used to collect the TF and were placed randomly underneath the canopy. SF was collected with spiral type SF collection collars from six selected beech trees. Interception losses were calculated as the difference between GR and the sum of TF and SF. Over the measurement period, 53 GR events were recorded. Cumulative GR depth was 1,001.5 mm; TF amount was 728 mm; SF was 32.3 mm, and I was 241.2 mm. The average of TF/GR, SF/GR, and I/GR ratios for each rainfall events were 69.4%, 2.5% and 28.1%, respectively. TF, SF, and I were found to be closely related to GR amounts. A strong positive correlation was found between SF/GR and GR (R^2= 0.9). Significant correlations were also observed between I/GR and GR (R^2= 0.581) as well as between TF/GR and GR (R^2= 0.414). It was observed that for small GR events a large portion of the incident GR wetted the canopy and, subsequently, contributed to the evaporation losses of the intercepted rain. Results of the study demonstrate how I represents a remarkable percentage of the incident GR and how TF and SF are both strongly affected by GR itself.

Keywords: Canopy Interception Loss, Oriental Beech, Stemflow, Throughfall.

INTRODUCTION

Forest canopy in terrestrial ecosystems serves as a receptive stratum against incident rainfall. In forested ecosystems, gross rainfall (GR) is redistributed into throughfall (TF), stemflow (SF), and interception loss (I). Knowledge of this redistribution and its influence on the forest microclimate is of great importance in understanding the ecological processes and in forest hydrology research (Marin *et al.*, 2000; Iida *et al.*, 2005).

Net rainfall (NR) reaches the forest floor through the canopy via two main pathways, i.e. SF and TF (Manfroi *et al.*, 2004; Levia and Herwitz, 2005 André *et al.*, 2008a). TF is the portion of rainfall that reaches the forest floor by passing directly through or dripping from tree canopies. SF is the fraction of rainfall that reaches the forest floor by flowing down the stems of trees after the incident rainfall is intercepted by leaves and branches and, subsequently, diverted to the trunks of the trees (Staelens *et al.*, 2008).

[DOR: 20.1001.1.16807073.2011.13.7.14.9]

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The total loss of water, called canopy interception (I), is equal to the sum of the evaporation that occurs during the rainfall as well as the evaporation that occurs after the rainfall ceases due to the water retained on the canopy. Interception is the fraction of the incident rainfall that does not reach the forest floor (Samba *et al*., 2001). Interception is commonly measured indirectly as the difference between GR, measured above the canopy or in a neighboring open area, and the sum of TF and SF sampled simultaneously on the forest floor (Staelens *et al*., 2008).

The interactions between vegetation and rainfall are of considerable significance from the physiological, ecological, and hydrological points of view (Aboal *et al*., 1999). In particular, rainfall redistribution by forest canopies plays an important role in water balance on local and catchment scales due to the control that forest canopies exert by modifying both evaporation and the redistribution of the incident rainfall (Herbst *et al*., 2006; Herbst *et al*., 2007; Llorens and Domingo, 2007; Sraj *et al*., 2008).

Both TF and SF have remarkable influence on the hydrological budget of forest ecosystems. Moreover, several studies have indicated how TF and SF amounts and their solute composition play a significant hydrogeoecological role in forest ecosystems, because they affect soil chemistry and nutrients as well as soil pollutants (Parker, 1983; Skrivan *et al*., 1985; Price and Watters, 1989; Falkengren-Grerup, 1989; Tanaka *et al*., 1991; Farmer *et al*., 1991; Takamatsu *et al*., 1997; Kolka *et al*., 1999; Chang and Matzner, 2000; Moreno and Gallardo, 2002), soil moisture gradients, and groundwater recharge (Durocher, 1990; Taniguchi *et al*., 1996; Roberts, 1999; Abrahams *et al*., 2003), generation of runoff and soil erosion processes (Gonza´lez Hidalgo *et al*., 1997), location of epiphytes, spatial patterns and rate of seepage fluxes, population dynamics of insect species (Carpenter, 1982) and, as a direct result, spatial distribution of understory vegetation (Crozier and Boerner, 1984; Andersson, 1991; Awasthi *et al*., 1995; Roberts, 1999; Chang and Matzner, 2000).

Rainfall redistribution in forests is a function of many factors: rainfall characteristics, meteorological conditions, vegetation structure as well as the interactions of these factors (Hall, 2003; Toba and Ohta, 2005; Deguchi *et al*., 2006; Staelens *et al*., 2008).

The temperate deciduous forests of northern Iran, known as the Caspian forests, cover an area of around 2 million hectares of a narrow strip 800 km long and 20-70 km wide, ranging from the level of the Caspian Sea up to 2,200 m. Oriental beech (*Fagus orientalis* Lipsky) is the most important broad-leaved deciduous species in the Caspian region and natural pure and mixed oriental beech forests are located across a wide range of elevation between 700 and 1,800 m a.s.l.

Ahmadi *et al*. (2009) discussed the rainfall partitioning in an oriental beech forest of the northern Iran measured during the 2008 growing season. This paper, however, reports the rainfall redistribution beneath the oriental beech forest during the 2008 and 2009 growing seasons in relation to GR size.

MATERIALS AND METHODS

Study Site Description

The study was carried out in the Kheyrud Forest Research Station of Tehran University, located approximately 7 km east of Nowshahr City, Mazandaran Province, northern Iran (Figure 1).

Measurements were made in a 5,625 m^2 plot of a pure and natural oriental beech forest. The experimental area is situated in the central Caspian forests (36°35′N, 51°37′E, and 1,410 m above the Caspian Sea level) and it is representative of the Kheyrud Forest Research Station, in terms of topography and forest structure. Measurements were made during 2008 and 2009 growing seasons (here, growing season

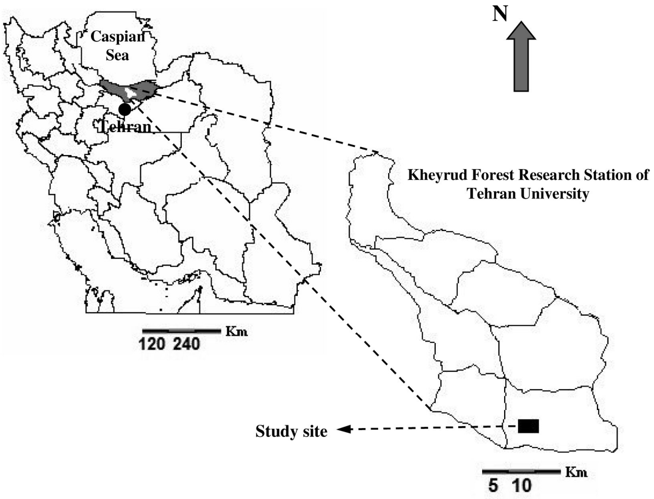

Figure 1. The experimental area located at the Forest Research Station of Tehran University, Iran.

refers to the period of the year during which the deciduous leaf cover was approximately at the maximum level, i.e. canopy cover was more than 95%); specifically, from 24 June to 5 December in 2008 and from 5 May to 30 November in 2009.

Plot tree density was 112 trees ha^{-1} and the total basal area was 86.2 m^2 ha^{-1}. Mean tree height and diameter at breast height (DBH) were 31.5 m and 49.5 cm, respectively, while mean tree crown depth was 18.5 m (Figure 2). The experimental plot was a north facing slope with a slope angle of 20°.

The experimental plot cover was an unmanaged and unevenly aged forest in which tree trunk diameters ranged from 7.5 to 100 cm. Tree diameter distribution was as follows: 30% of trees had DBH< 30 cm, 45% had DBH= 30-60 cm, and 25% had DBH> 60 cm (Figure 2). No tree harvesting or silvicultural practices were carried out in the studied area.

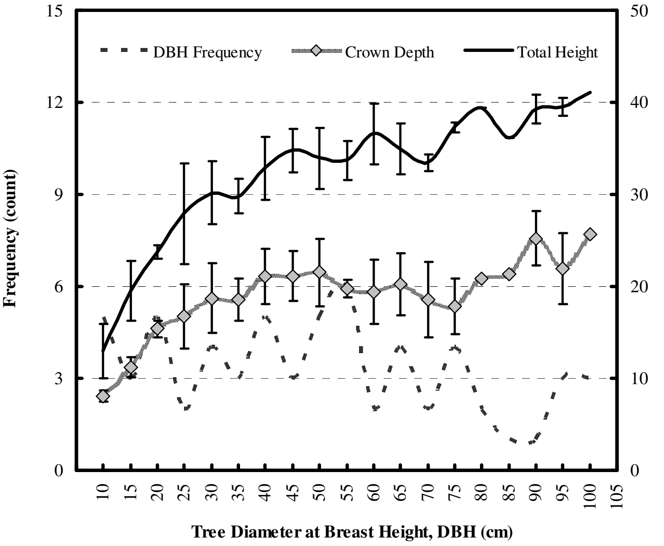

Figure 2. Frequency distribution of tree diameters at breast height (DBH), mean tree crown depth, and mean tree total height in the experimental area of Kheyrud Forest Research Station of Tehran University. Error bars show the standard deviation (±SD).

Meteorological parameters (precipitation, air temperature, and pan evaporation) reported here are those of the Nowshahr Meteorological Station (36° 39'N, 51° 30'E; 7.5 m above the Caspian Sea level), which is the nearest station to the study site. Mean annual rainfall (1985-2008) reached 1,303 mm with high variations (CV%: 15.4); October being the wettest month (mean rainfall amount equal to 235 mm) and August the driest (mean value equal to 42 mm) as shown in Figure 3.

Mean annual air temperature is 16.2°C (CV%: 3.3), and February (7.1°C) and August (25.1°C) were respectively the coldest and the warmest months (Figure 3).

According to Nowshahr Meteorological Station, mean annual pan evaporation (E) was 1,031.2 mm (CV%: 5.9), with the highest average monthly E value of 155.4 mm in August and the lowest value of 26.2 mm in January (Figure 3).

According to USDA soil classification, the soil in the study site is Alfisol without any diagnostic horizon. Soil humidity and temperature regimes are Udic and Mesic, respectively, and the organic matter accumulation, LFH layers, is higher than 5 cm.

Field Measurements

Gross Rainfall (GR) Measurement

GR was collected in the 2008 and 2009 growing seasons, using 3 hand-made cylindrical plastic rain gauges (collector diameter of 9 cm), which were installed in an adjacent open area free of vegetation at a distance of 160 m from the study plot. Using a graduated cylinder with an accuracy of 1 ml, GR was measured manually either immediately after an event or at sunrise following nighttime precipitation (Carlyle-Moses *et al.*, 2004).

GR depths reported here refer to the mean values calculated taking into account, for each event, the measurements recorded by the 3 pluviometers.

Our literature review suggested that a period of 2- to 10-hours was long enough to completely dry out the canopy for different species and different climates. Therefore, we included no-rain periods of 10 hours or less, which is the upper end of the no-rain periods reported by interception studies (e.g. Lloyd *et al.*, 1988; Asdak *et al.*, 1998; Schellekens *et al.*, 2000; Kume *et al.*, 2006). In other words, each rainfall event was preceded by a

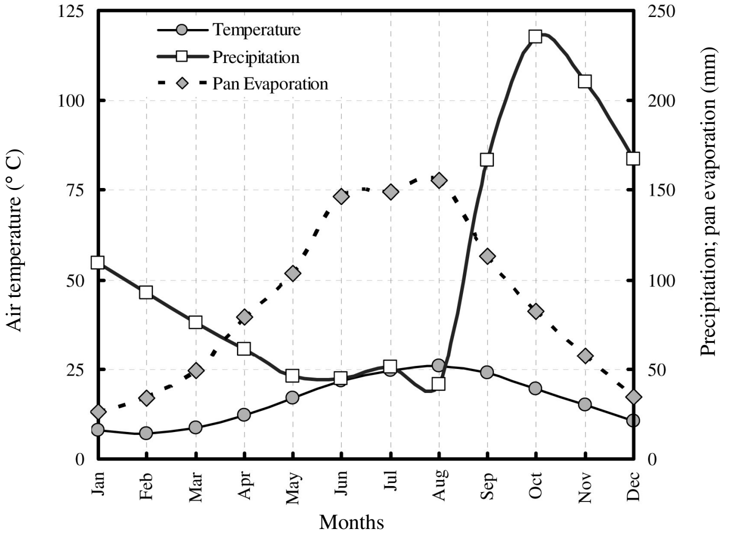

Figure 3. Monthly mean air temperature, precipitation, and pan evaporation recorded in the Nowshahr Meteorological Station, the nearest synoptic weather station to the study site, (mean 1985-2008). Dry spells occurs during the growing season, from May to November, when P ≤ 2T.

[DOR: 20.1001.1.16807073.2011.13.7.14.9]

dry period of at least 10 hours.

Throughfall (TF) Measurement

TF was collected using the same type of manual gauges described for GR measurements. Thirty-six collectors were randomly placed (Carlyle-Moses *et al.*, 2004) underneath the canopy to completely cover the study area (Figure 4).

TF measurements were made for the corresponding GR event durations. Mean TF depths were calculated from the 36 TF measurements.

Stemflow (SF) Measurement

A stratified random sampling design was applied in order to select the trees for SF measurement (Hanchi and Rapp, 1997; Lewis, 2003). This was an attempt to ensure that the chosen trees were representative of the entire study plot population. All trees of the plot with DBH > 7.5 cm were measured and then grouped into three classes: DBH < 30 cm, DBH = 30-60 cm, and DBH > 60 cm. For each DBH class, two individual trees were selected randomly.

SF was collected from 6 selected beech trees (Figure 4) using spiral-type collars installed at breast height (Toba and Ohta, 2005).

The SF collection collars were made of halved plastic hose-pipe (3 cm in diameter), which were sealed with silicone rubber and pegged around the trunk of each tree to form a watertight junction between the collar and the tree bark itself to trap water flowing down. The spiral collectors encircled the trunk at least 1.5 times. The SF water collected by the collar was conveyed to a 20-liter collection bin via a plastic pipe.

SF volumes were measured on single event basis as done for GR and TF.

Crown Projection Area (CPA)

In order to calculate the SF depth, the crown projection area (CPA) must be known. The CPA is determined by measuring the area of the projection of the edge of the tree crown on a horizontal plane (Delphis and Levia, 2004).

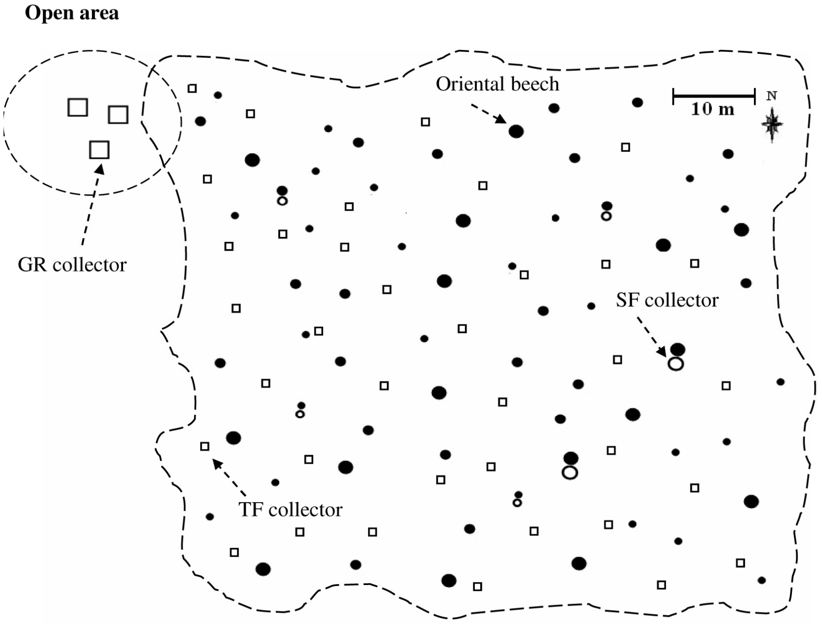

Figure 4. Disposition of oriental beech trees (filled circles), gross rainfall (GR), throughfall (TF) and stemflow (SF) collectors in the experimental plot of Kheyrud Forest Research Station of Tehran University.

Table 1. Gross rainfall (GR), throughfall (TF), stemflow (SF), interception losses (I) and net rainfall (NR= TF+SF) depths and percentages based on the data of 53 rainfall events recorded during the two growing periods of 24 June-5 December 2008, and 5 May-30 November 2009.

	GR		TF		SF		I		NR	
	mm	%	mm	%	mm	%	mm	%	mm	%
Cumulative	1001.5	100	728	72.7	32.3	3.2	241.2	24.1	760.3	75.9
Mean	18.9	100	13.7	69.4	0.6	2.5	4.6	28.1	14.3	71.9
Minimum	2.8	100	1.7	52.1	0.01	0.4	0.8	12.4	1.8	54
Maximum	48.6	100	40.4	85	2.1	5	8.8	46.1	42.6	87.6
CV (%)	62.4	-	70.3	11.6	95.8	50.7	46	35.2	71	12.5

Assuming the shape of the CPA was a circle, 4 main directional crown radii were measured for each tree subject to SF measurements. The CPA was then calculated taking the radius of the circle as the average of the 4 measurements performed (the mean value of the CPA was 31 m^2).

The SF depth for each selected tree was then calculated dividing the SF volume by the CPA (Shachnovich *et al.*, 2008). Finally, the SF depths of the 6 selected trees were averaged to determine the mean SF referring to the single GR event.

RESULTS

Gross Rainfall (GR)

During 2008 and 2009 growing seasons, 53 rainfall events were recorded. The cumulative GR amount was 1,001.5 mm; mean GR was 18.9 mm $event^{-1}$, but GR depths showed high variability (CV= 62.4%) ranging from 2.8 mm to 48.6 mm (Table 1).

In order to better understand the relationships among GR, TF, SF and I, and also taking into account frequency and extremes of rainfall, GR events were grouped into 5 classes of 7.5 mm interval: GR≤ 7.5 mm, 7.5 mm≤ GR≤ 15 mm, 15 mm≤ GR≤ 22.5 mm, 22.5 mm≤ GR≤ 30 mm, and GR≥ 30 mm (Figure 5). Of the 53 total GR events, 13, 10, 11, 9, and 10 GR events were, respectively, assigned to the previously mentioned classes. Cumulative depths of GR classes were 68.6 mm (6.9% of cumulative GR), 117.1 mm (11.7% of GR), 205 mm (20.5% of GR), 233.8 mm (23.3% of GR), and 377 mm (37.6% of GR), respectively (Figure 5).

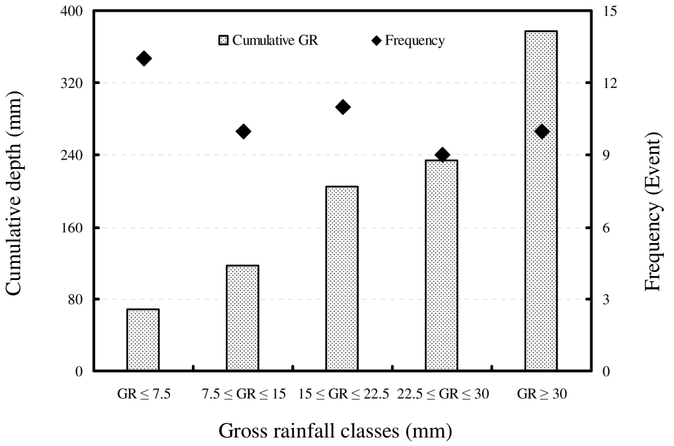

Figure 5. Frequency distribution of gross rainfall (GR) events and cumulative gross rainfall depth for different GR classes, during the two growing seasons, 24 June-5 December 2008 and 5 May-30 November 2009.

Rainfall Partitioning

Throughfall (TF)

Cumulative TF depth represented 72.7% (728 mm) of the cumulative GR (53 rainfall events in the 2008 and 2009 growing seasons). Mean TF depth was 13.7 mm (CV= 70.3%) or 69.4% of the corresponding GR, and ranged from 1.7 mm (52.1% of the corresponding GR) to 40.4 mm (85% of the corresponding GR), as shown in Table 1.

TF was found to be closely related to GR amount. A very strong positive polynomial relationship (Figure 6-a) was observed between TF and GR depths (R^2= 0.990; P≤ 0.01).

Figure 6-b shows the relative importance of TF (the ratio TF/GR) in relation to GR. TF/GR was correlated with the GR amount and a weak positive exponential relationship (R^2= 0.414; P≤ 0.01) could describe the relation between the two parameters.

For rainfall event classes of GR≤ 7.5, 7.5≤ GR≤ 15, 15≤ GR≤ 22.5, 22.5≤ GR≤ 30, and GR≥ 30 mm, the TF/GR ratios were 64.1% (CV= 11%), 65.2% (CV= 8.4%), 68.9% (CV= 12.4%), 72.7% (CV= 7%), and 78.3% (CV= 4.5%), respectively (Figure 7).

Stemflow (SF)

Cumulative SF depth of 53 rainfall events was 32.3 mm or 3.2% of the cumulative GR. Average SF amount was 0.6 mm (SF presented a very high variability; CV= 95.8%) corresponding to 2.5% of the mean GR, but ranging from 0.4% to 5% of the GR (Table 1).

A very strong positive correlation (R^2= 0.980; P≤ 0.01) was found between SF and GR (Figure 8-a). Figure 8-b shows that the higher the GR the bigger the fraction of SF which can be generated; in fact, there is a strong positive power relationship (r^2= 0.9; P≤ 0.01) between SF/GR and GR.

For the rainfall event classes of GR≤ 7.5, 7.5≤ GR≤ 15, 15≤ GR≤ 22.5, 22.5≤ GR≤ 30, and GR≥ 30 mm, the average SF/GR values were 1% (CV= 27.7%), 1.8% (CV= 20%), 2.5% (CV= 15.8%), 3.6% (CV= 16%), and 4.2% (CV= 14.9%), respectively (Figure 7).

Interception Loss (I)

The cumulative interception loss was 241.2 mm corresponding to 24.1% of total GR. On the average, the I expressed as percentage of GR (I/GR) was 28.1% (4.6 mm), but I/GR ranged widely from 12.4% (0.8 mm) to 46.1% (8.8 mm), as shown in Table 1.

A positive power correlation (R^2= 0.817; P≤ 0.01) was observed between I and GR amount. Interception increased with an increasing amount of GR (Figure 9-a), while I/GR decreased with increasing rainfall heights as shown by the exponential regression (R^2= 0.581; P≤ 0.01) reported in Figure 9-b.

For the rainfall event classes of GR≤ 7.5, 7.5≤ GR≤ 15, 15≤ GR≤ 22.5, 22.5≤ GR≤ 30, and GR≥ 30 mm, the average I/GR values were 34.9% (CV= 20.3%), 33% (CV=16.5%), 28.6% (CV= 29.7%), 23.7% (CV= 22.1%), and 17.5% (CV= 21.8%), respectively (Figure 7).

Net Rainfall (NR)

NR amount was 760.3 mm or 75.9% of the cumulative GR (1001.5 mm), which means that this amount of water reached the forest floor partially as TF (728 mm) and partially as SF (32.3 mm). The remaining 241.2 mm or 24.1% of the total GR was intercepted by the oriental beech canopies and then lost through evaporation. The average amount of NR was 14.3 mm or 71.9% of the mean GR (Table 1).

A very strong positive polynomial relationship (R^2= 0.99; P≤ 0.01) was found between the NR and GR values and also a polynomial regression (R^2= 0.50; P≤ 0.01) was observed between NR/GR and GR.

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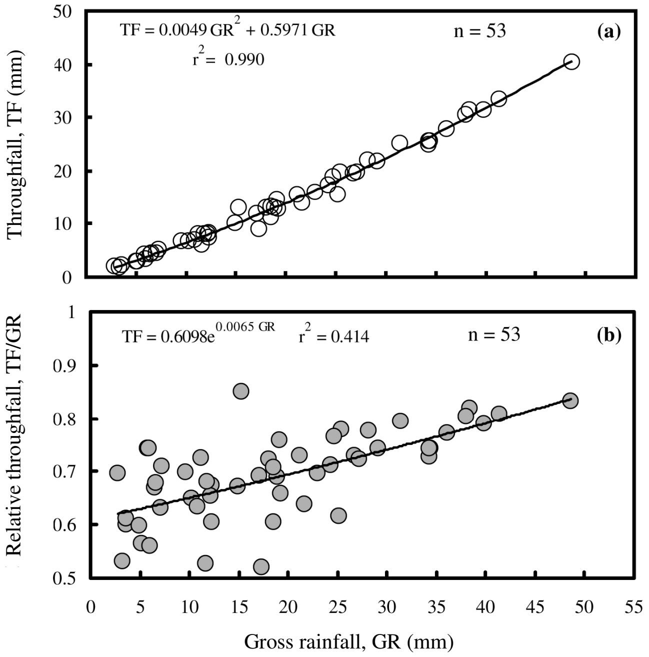

Figure 6. (a) Correlation curve of throughfall (TF) vs. gross rainfall (GR), **(b)** Correlation curve of relative throughfall (TF/GR) vs. gross rainfall (GR). Both graphs refer to the two growing periods, 24 June-5 December 2008, and 5 May-30 November 2009. Each circle refers to a rainfall event. n shows the number of rainfall events.

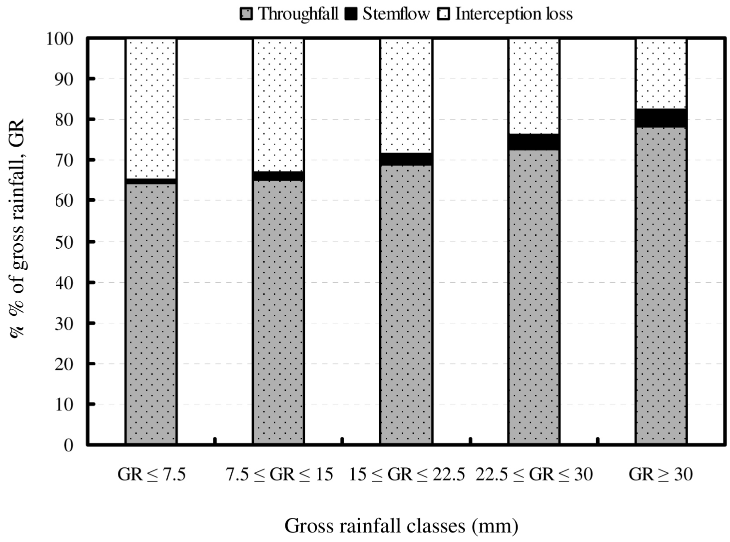

Figure 7. Mean percentages of throughfall (TF/GR), stemflow (SF/GR), and interception loss (I/GR) for five gross rainfall classes and for to the two growing periods, 24 June-5 December 2008, and 5 May-30 November 2009.

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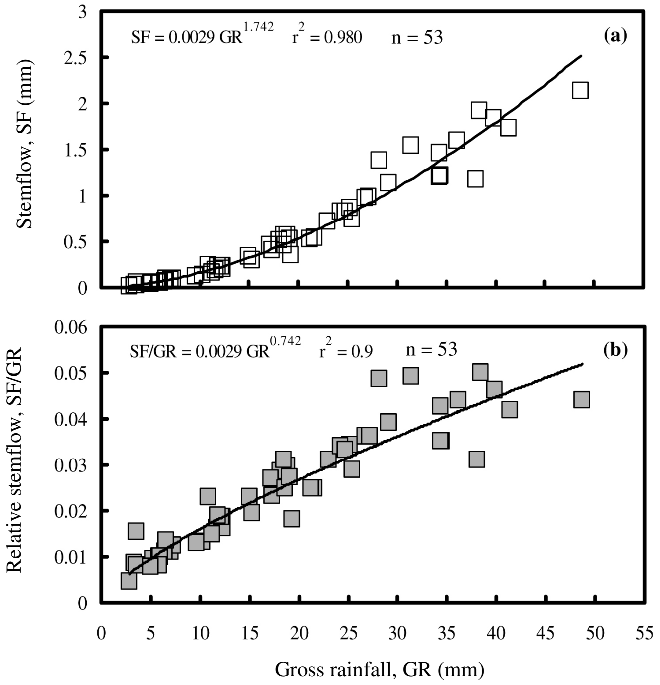

Figure 8. **(a)** Correlation curve of stemflow (SF) vs. gross rainfall (GR) during the measurement periods, **(b)** Correlation curve of relative throughfall (SF/GR) vs. gross rainfall (GR). Both graphs refer to the two growing periods, 24 June-5 December 2008, and 5 May-30 November 2009. Each square refers to a rainfall event. n shows the number of rainfall events.

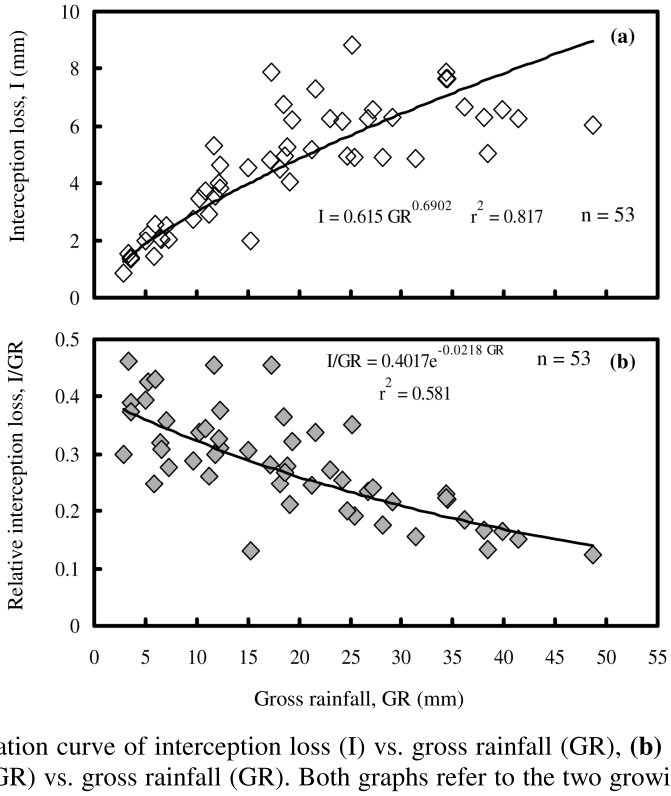

Figure 9. **(a)** Correlation curve of interception loss (I) vs. gross rainfall (GR), **(b)** Correlation curve of relative throughfall (I/GR) vs. gross rainfall (GR). Both graphs refer to the two growing periods, 24 June-5 December 2008, and 5 May-30 November 2009. Each diamond refers to a rainfall event. n shows the number of rainfall events.

DISCUSSION

To evaluate the effect of oriental beech forest canopy on gross rainfall (GR) redistribution, the authors measured TF, SF, and I in a natural oriental beech forest situated at the midland of the central Caspian forests during 2008 and 2009 growing seasons. At the event scale, average values of TF/GR, SF/GR, and I/GR accounted for 69.4%, 2.5%, and 28.1%, respectively.

A literature review on rainfall redistributions measured in a variety of beech forests in terms of age, structure, and genus, indicates that the values of TF/GR, SF/GR and I/GR obtained in our study are comparable with those measured in other environments.

In a European beech (*Fagus sylvatica*) forest cover in Toscana, Italy, the values of TF/GR, SF/GR, and I/GR measured during the leafed period were 61.6%, 13.6%, and 24.8%, respectively (Giacomin and Trucchi, 1992). For a European beech forest in southern England, Neal *et al.* (1993) reported the values of 82-83%, 1-2%, and 16%, respectively, for the parameter ratios mentioned above. According to Tarazona *et al.* (1996), the values were 64.4%, 6.6%, and 29% for a European beech forest in Spain. Values reported by Granier *et al.* (2000) were: 69%, 5%, and 26% for a European beech forest in France. According to Michopoulos *et al.* (2001), in a beech (*Fagus moesiaca*) forest of the Pindous Mountains of Greece, the percentages of TF/GR, SF/GR, and I/GR were 80.5%, 8%, and 11.5%, respectively.

The mean value of 69.4% for the ratio TF/GR obtained in the present research falls within the range of the values observed by other authors in different beech forests (Giacomin and Trucchi, 1992; Neal *et al.*, 1993; Tarazona *et al.*, 1996; Didon-Lescot, 1998; Granier *et al.*, 2000; Michopoulos *et al.*, 2001; Mosello *et al.*, 2002; Carlyle-Moses and Price, 2006; Staelens *et al.*, 2008).

In the present study, the SF represents a small percentage of GR (2.5% on average) and is strongly correlated with the GR size. Highly variable SF/GR values are documented in literature: whereas Mosello *et al.* (2002), working in a European beech forest in Calabria, Italy, found a SF/GR value of 1.1%, Didon-Lescot (1998) found a value of 20.4% in Lozere, France. For different beech covers, many other authors (Giacomin and Trucchi, 1992; Neal *et al.*, 1993; Tarazona *et al.*, 1996; Granier *et al.*, 2000; Michopoulos *et al.*, 2001; Carlyle-Moses and Price, 2006; Staelens *et al.*, 2008) have indicated SF/GR values that are compatible with those of the present research.

Different I/GR percentage values ranging from 11.5% for a beech (*Fagus moesiaca*) forest in Pindous MTS, Greece (Michopoulos *et al.*, 2001) up to 31% for a European beech forest in Ghent, Belgium (Staelens *et al.*, 2008) are reported in literature. The 28.1% value determined in our study is comparable to the upper I/GR values reported for different beech forests by others researchers (Giacomin and Trucchi, 1992; Neal *et al.*, 1993; Tarazona *et al.*, 1996; Didon-Lescot, 1998; Granier *et al.*, 2000; Michopoulos *et al.*, 2001; Mosello *et al.*, 2002; Carlyle- Moses and Price, 2006; Staelens *et al.*, 2008) and also for other broad-leaved deciduous forests, typically between 15% and 25% (Dolman, 1987; Bruijnzeel, 2000).

Redistribution of rainfall into TF, SF, and I in forest ecosystems depends on incident rainfall characteristics (amount, intensity, duration, and temporal event distribution), meteorological conditions (air temperature, relative humidity, wind speed and direction) and forest structure (species composition, stand age and density and canopy morphology and architecture) as reported by many authors (Marin *et al.*, 2000; Xiao *et al.*, 2000; Hall, 2003; Fleischbein *et al.*, 2005; Toba and Ohta, 2005; Deguchi *et al.*, 2006; Staelens *et al.*, 2008). It is most likely that the differences among the magnitudes of TF/GR, SF/GR, and I/GR reported in this

[DOR: 20.1001.1.16807073.2011.13.7.14.9]

study and those found for other beech forests were the result of differences in the above mentioned factors.

The dissimilarities in SF/GR values of the oriental beech and other beech species are probably due to differences in morphological species traits such as canopy structure and morphology (Price and Watters, 1989; Levia and Herwitz, 2002; André *et al*., 2008c), crown projection area (Lawson, 1967; Aboal *et al*., 1999; Carlyle-Moses and Price, 2006), bark roughness, and structure (Helvey and Patric, 1965; Johnson, 1990; Levia and Frost, 2003; Odair *et al*., 2004; Levia and Herwitz, 2005), inclination angle of the branches (Van Elewijck, 1989; Návar, 1993; Martinez-Meza and Whitford, 1996; Levia and Herwitz, 2002) and presence of canopy lichens and mosses (Levia, 2004). Moreover, literature reviews agree on the ability of high SF production in tree species with a funneling canopy shape, large CPA, smooth bark, and low presence of lichens and mosses (Johnson, 1990; Návar, 1993; Aboal *et al*., 1999; Levia and Herwitz, 2002; Levia, 2004; Carlyle-Moses and Price, 2006; André *et al*., 2008b).

Our results confirmed how the GR amount has a major impact on rainfall redistribution into TF, SF, and I in the oriental beech forest. The higher the GR, the greater the TF and SF amounts, as well as the TF/GR and SF/GR ratios as reported by many authors (Marin *et al*., 2000; Llorens and Domingo, 2007; Staenles *et al*., 2008). During the study period, interception losses increased as the size of GR events increased; however, as expected, higher I/GR values were observed for the smaller GR events as reported by many authors (Rowe, 1983; Xiao *et al*., 2000; Marin *et al*., 2000; Fleischbein *et al*., 2005). The magnitude of I/GR for small events is a result of a large portion of incident rainfall retained on the canopy, which evaporates during and after the rainfall.

The present study shows that interception loss contributes a remarkable amount of incident rainfall and its measurement, therefore, is a significant element in the assessment of water balance in the natural oriental beech forests of Iran. Interception loss, which was not included in any previous water balance and hydrological studies of forest ecosystems in Iran, needs to be considered in the future water balance research.

CONCLUSIONS

The study of rainfall redistribution in a natural oriental beech forest in the central part of the Caspian region indicated that, at the event scale, the mean proportions of TF, SF and I were 69.4%, 2.5%, and 28.1% of GR, respectively. TF accounted for more than 95% of the net rainfall and, obviously, controlled the water input beneath the oriental beech forest canopies during the growing season. Moreover, it was observed that rainfall redistribution into TF, SF, and I was strongly affected by the size of GR.

If the data collected in this 2-year study demonstrate how TF and I are the main components of GR partitioning, other factors regarding the vegetative cover (percentage of canopy cover, LAI, tree density, etc.) as well as climatic factors (rainfall duration, intensity and distribution; relative humidity, wind speed, etc.), should be monitored to better define the role of a forest cover on the water balance. However, the initial results demonstrate how, in oriental beech of the Caspian forests, interception losses constitute an important component of the gross rainfall that reduces the amount of water that reaches the ground.

ACKNOWLEDGEMENTS

The authors thank Marzban and Abbasi, forest guards at the Kheyrud Forest Research Station of Tehran University, for their assistance with data collection and rain gauges installations.

[DOR: 20.1001.1.16807073.2011.13.7.14.9]

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توزیع مجدد باران توسط تاج پوشش توده راش شرقی (*Fagus orientalis* Lipsky) در جنگل های خزری شمال ایران

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چکیده

توزیع مجدد بارندگی کل به اجزاء بارش (تاج بارش، ساقاب و باران ربایی) در توده راش (*Fagus orientalis* Lipsky) خالص واقع در ارتفاعات میان بند جنگل های خزری مطالعه گردید. اندازه گیری های مربوط به اجزاء بارش در طی فصول رویش ۱۳۸۷ و ۱۳۸۸ در داخل توده راش با مساحت ۵۶۲۵ متر مربع واقع در جنگل خیرود صورت گرفت. بدین منظور، بارندگی کل با استفاده از سه جمع آوری کننده باران در منطقه بازی در فاصله ۱۶۰ متری از توده مورد مطالعه، جمع آوری گردید. به منظور جمع آوری تاج بارش، تعداد ۳۶ عدد جمع آوری کننده به صورت تصادفی در سطح توده قرار گرفتند. ساقاب تولیدی شش اصله درخت راش از قطر های مختلف با استفاده از جمع آوری کننده های مارپیچی ساقاب جمع آوری شد. میزان باران ربایی از تفاوت میان بارندگی کل و بارندگی خالص (مجموع تاج بارش و ساقاب) محاسبه شد. در طول دوره مورد مطالعه تعداد ۵۳ بارندگی (عمق تجمعی: ۱۰۰۱/۵ میلی متر) ثبت گردید، که ۷۲۸ و ۳۲/۳ میلی متر از این مقدار به ترتیب به تاج بارش و ساقاب اختصاص یافت و ۲۴۱/۲ میلی متر از آن به صورت باران ربایی تبخیر شد. همچنین متوسط تاج بارش، ساقاب و باران ربایی در طی هر بارش به ترتیب ۶۹/۴، ۲/۵ و ۲۸/۱ درصد از بارندگی کل برآورد گردید. این مطالعه نشان داد که تقسیم بندی بارندگی کل به اجزاء بارش به شدت تحت تاثیر مقدار بارندگی قرار دارد. بین نسبت ساقاب به بارندگی کل و بارندگی کل همبستگی مثبت و قوی وجود داشت (R^2= ۰/۹). همچنین روابط معنی داری بین نسبت باران ربایی به بارندگی کل و بارندگی کل (R^2= ۰/۵۸۱) و بین نسبت تاج بارش به بارندگی کل و بارندگی کل (R^2= ۰/۴۱۴) مشاهده گردید.

[DOR: 20.1001.1.16807073.2011.13.7.14.9]

نتایج نشان میدهد که در طی بارندگی‌های کم، بخش عظیمی از بارندگی صرف اشباع تاج می‌شود و سپس این مقدار آب باران تبخیر و به صورت باران‌ربایی از دسترس جنگل خارج می‌گردد. توزیع مجدد باران در جنگل راش وابستگی زیادی به مقدار بارندگی داشته و سهم قابل توجهی از بارندگی در توده راش به صورت باران ربایی از دسترس جنگل خارج می‌شود.

[DOR: 20.1001.1.16807073.2011.13.7.14.9]