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Spatio-temporal variation of throughfall in a hyrcanian plain forest stand in Northern Iran

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Abstract: Elucidating segregation of precipitation in different components in forest stands is important for proper forest ecosystems management. However, there is a lack of information on important rainfall components viz. throughfall, interception and stemflow in forest watersheds particularly in developing countries. We therefore investigated the spatio-temporal variation of important component of throughfall for a forest stand in a Hyrcanian plain forest in Noor City, northern Iran. The study area contained five species of *Quercus castaneifolia*, *Carpinus betulus, Populus caspica* and *Parrotia persica*. The research was conducted from July 2013 to July 2014 using a systematic sampling method. Ninety-six throughfall collectors were installed in a 3.5 m × 3.5 m grid cells. The canopy covers during the growing/leaf-on (i.e., from May to November) and non-growing/leaf-off (i.e., from December to March) seasons were approximately 41% and 81%, respectively. The mean cumulative throughfall during the study period was 623±31 mm. The average throughfall (*TF*) as % of rainfall (*TFPR*) during leaf-on and leaf-off periods were calculated 56±14% and 77±10%, respectively. *TF* was significantly (R^2 = 0.97, p = 0.00006) correlated with gross precipitation. Percent of canopy cover was not correlated with *TF* except when gross precipitation was <30 mm. A comparison between leaf-off and leaf-on conditions indicated a significantly higher *TFPR* and corresponding hotspots during leaf-on period. *TFPR* also differed between seasons with a maximum amount in winter (82%). The results of the study can be effectively used by forest watershed managers for better perception of hydrological behavior of the Hyrcanian forest in the north of Iran under different silvicultural circumstances leading to getting better ecosystem services.

Keywords: Caspian Hyrcanian Forest; Deciduous forest; Forest hydrology; Interception storage; Precipitation loss.

INTRODUCTION

To understand the hydrological cycle and ecosystem services, it is necessary to quantify the role of vegetation in partitioning rainfall resulting in water balance at pedon, slope and watershed scale, and correspondingly the runoff, sediment, nutrients, contaminants and even biota redistribution (Buendia et al., 2016; Cao et al., 2008; Celentano et al., 2016; Cox et al., 2006; Davudirad et al., 2016; Gabarrón-Galeote et al., 2013; García-Fayos et al., 2010; Hosseini et al., 2016; Keesstra et al., 2009; Keesstra et al., 2012; Lal, 1997; Novara et al., 2013; Pereira et al., 2013; Sadeghi et al., 2015; Yousefi et al., 2016; Vega et al., 2005). Improving our understanding about rainfall partitioning in forests ecosystems is very important for studies that focus on forest hydrology to better management and decision making on this vital ecosystems (Ajami et al., 2011; Brecciaroli et al., 2012; Davudirad et al., 2015; Dohnal et al., 2014; Frot et al., 2007; Holko et al., 2009; Xu et al., 2014). Such eco-hydrological studies lead to a proper hydrological balance analysis and therefore have been well considered in forest hydrology studies during last few decades (Adriaenssens et al., 2012; Bosch and Hewlett, 1982; Carlyle-Moses, 2004; Devlaeminck et al., 2005; Gurav et al., 2012; Marin et al., 2000; Llorens and Domingo, 2007; Mitchell et al., 1986; Molina and Campo, 2012; Nanko et al., 2006; Park and Cameron, 2008; Rahmani et al., 2011; Shachnovich et al., 2008; Tcherepanov et al., 2005; Xu et al., 2014).

Net rainfall reaches the forest floor through the tree canopy by throughfall and stem flow (Aikawa et al., 2006; Deng et al., 2013; Hinko-Najera et al., 2015; Rahmani et al., 2011; Zhang et al., 2009). Throughfall is the part of rainfall that reaches forest floor either through dripping from the tree canopies and after fulfilling initial interception storage or direct passing the canopy gaps (Chappell and Bidin, 2001; David et al., 2011; Díaz et al., 2007; Guswa and Spence, 2012; Huber and Iroumé, 2001; Rahmani et al., 2011; Roberts and Rosier, 2005; Wuyts et al., 2008; Zhang et al., 2006; Zimmermann and Zimmermann, 2014).

Many important factors viz. rainfall characteristics, canopy architecture, branch angle, canopy cover, tree age, leaves shapes, types and dimensions, phonological stages, and even silvicutural practices affect hydrologic behavior of forest stand against input rainfall (Brandt, 1987; Bruijnzeel, 2005; Davudirad et al., 2015; Davudirad et al., 2016; Gay et al., 2015; Guswa and Spence, 2012; Huber and Iroumé, 2001; Molina and Campo, 2012; Nanko et al., 2006; Onozawa et al., 2009; Pérez-Suárez et al., 2008; Pypker et al., 2005; Staelens et al., 2007; Van Stan et al., 2012; Xu et al., 2014). Due to dynamic variability of affecting factors in space and time, the throughfall as an important component of hydrologic cycle in forest ecosystems (Sadeghi et al., 2008) varies temporally and spatially (Forti and Neal, 1992; Staelens et al., 2006). Previous research signified the effects of canopy gaps on spatio-temporal variability of throughfall (Forti and Neal, 1992; Keim et al., 2005; Loescher et al., 2002; Zirlewagen and von Wilpert, 2001). The importance of spatio-temporal variation in throughfall in forest ecosystems has also been reported in water balance modeling studies in forest watersheds (Zirlewagen and von Wilpert, 2001), forest lands nutrients exchange (Vernimmen et al., 2007; Zimmermann et al., 2008), soil erosion processes (Sadeghi et al., 2008) and fauna and flora studies (Xiao et al., 2000).

The Hyrcanian forest near the southern shores of the Caspian Sea of Iran and Azerbaijan (from –25 m to +10 m above mean sea level) is a unique ecosystem due to having a markedly different climate compared to other parts of Iran, and is very important in different ecological and hydrological aspects (Ebrahimpour et al., 2011; Rahmani et al., 2011). The location of the Caspian Sea and the Alborz Mountains mainly control the climate and the hydrology of the Hyrcanian forest. The average annual precipitation is around 1000 mm; three times more compared to the average precipitation in Iran (Rahmani et al., 2011). Most of the tree species in the Caspian Hyrcanian Forests are deciduous means their leaves falling off at maturity or tending to fall off during cold season. Therefore, two main phenological stages of leaf-on and leaf-off can be defined. Unfortunately, the Hyrcanian plain forests are drastically threatened by human encroachment and overexploitation, despite their importance in ecological stability, and the hydrological balance.

Scrutinizing available literature showed that only a few studies have been conducted to quantitatively determine the vital role of the Hyrcanian forest on hydrological conditions. While the positive roles of Hyrcanian forest in decreasing frequency and intensity of floods and even regulating hydroclimatical conditions of the region are qualitatively known. It is necessarily needed to obtain precise estimations on hydrological components of the Hyrcanian forest to properly develop and calibrate hydrological models (Sadeghi and Mizuyama, 2007; Sadeghi et al., 2007; Sadeghi and Saeidi, 2010) in the area where the input rainfall is potentially erosive and offensive compared to other parts of Iran (Sadeghi et al., 2011). The present study has been therefore planned to investigate the spatio-temporal variations of throughfall as a main factor in rainfall partitioning in a part of the Hyrcanian plain forests. The present study aimed i) to determine the throughfall in a mixed Hyrcanian stand forest; ii) to identify the relationship between canopy cover and throuhfall and iii) to investigate the spatio-temporal variations of the throughfall in different seasons and leaf-off and leaf-on periods. The results of the present study may justify decision makers and planners to appropriately preserve the precious heritage of Hyrcanian plain forests as an important unique ecosystem in the world for the next generations due to vital services of this ecosystem in regulation of hydrological regimen of the area.

MATERIAL AND METHODS

Study site

The study area has been located in the Hyrcanian plain forest at International Campus of Tarbiat Modares University at Faculty of Natural Resource in Noor City, Iran. The site was chosen due to accessibility, possibility of accurate monitoring and controlled conditions. The study site is not threatened by anthropogenic activities and therefore is representing all original Hyrcanian plain forest situated in southern Caspian Sea shores. Average annual precipitation in the study site is 1030 mm according to the data (1968–2013) from the nearest meteorological (i.e, Noor Station just 2 km away). The study area was confined to an area of 943.25 m^2 (38.5 m x 24.5 m) covered by different species viz. *Carpinus betulus* (55%), *Quercus castaneifolia* (10%), *Parrotia persica* (10%) and *Populus caspica* (7%) with respective number of trees of 35, 5, 2 and 2; also 18% is covered by grass and bare soil. The measured mean breast height diameter at the beginning of the study was measured as 26±7.5 cm for *Quercus castaneifolia,* 31±7.82 cm for *Carpinus betulus,* 104±16.5 cm for *Populus caspica* and 33±6.5 cm for *Parrotia persica*. No border effects could be recognized and therefore considered in the study, since the study area is just a small piece which has been surrounded by a similar forest stand.

Sampling design

The study was planned in a grid design of 3.5 m × 3.5 m according to the canopy cover distribution and density, for which 96 throughfall collectors were installed at all corners of the squares (Lloyd, 1988; Rahmani et al., 2011). Since the measurement of throughfall in the entire selected area was concerned, the distribution pattern of the collectors was set systematically to try to mimic natural conditions where dense and sparse canopy covers, and clear areas are all together. The study design along with corresponding details has been depicted in Figure 1. The study was carried out for all incidents (24 events) during one year from July 2013 to July 2014.

Gross precipitation was directly measured at the nearest open area 200 m from the study site to minimize the introduction of errors (Holder, 2003, 2004; Rahmani et al., 2011). Cylindrical rainwater collectors with diameters of 9 cm were mounted on iron rods 35 cm above the forest floor to measure throughfall after each rainfall event and one collector was used to measure gross precipitation. Since there was no automatic rain gage in the study area, just the depth of rainfall was recorded after each individual storm event. Since there was no automatic rain gage in the study area, just the depth of rainfall was recorded after each individual storm event. The spatial distribution of gross precipitation was assumed to be homogeneous over the small study site. The volume of the collected rainwater was determined using weighting method with the help of a portable digital scale with an accuracy of ±0.1 g (≈ 0.017 mm of water in collector). The depth of the throughfall was consequently determined for each collector by dividing the volume of water by the collection area (63.59 cm^2). All 96 throughfall collectors (Figure 1) were inspected and cleaned after each instant measurement. Some data were missed for some collectors, since they have been destructed due to passing wild animals or blowing wind. The throughfall as % of rainfall (*TFPR*), as the principal factor of the present study, was calculated using the following equation and applying gross precipitation (*Pg*) and throughfall (*TF*), both in mm.

$$TFPR = \frac{TF}{Pg} \times 100 \qquad (1)$$

The values of *TFPR* more than 100 indicate that the depth of throughfall was more than gross rainfall and therefore denote throughfall hotspots. In addition, the hotspots were detected using Getis Ord Hot-spot analysis in Arc GIS 10.2 at three significant levels ($\alpha = 0.10$, 0.05 and 0.01) and using an Inverse-Distance spatial relationship concept (Getis and Ord, 1992).

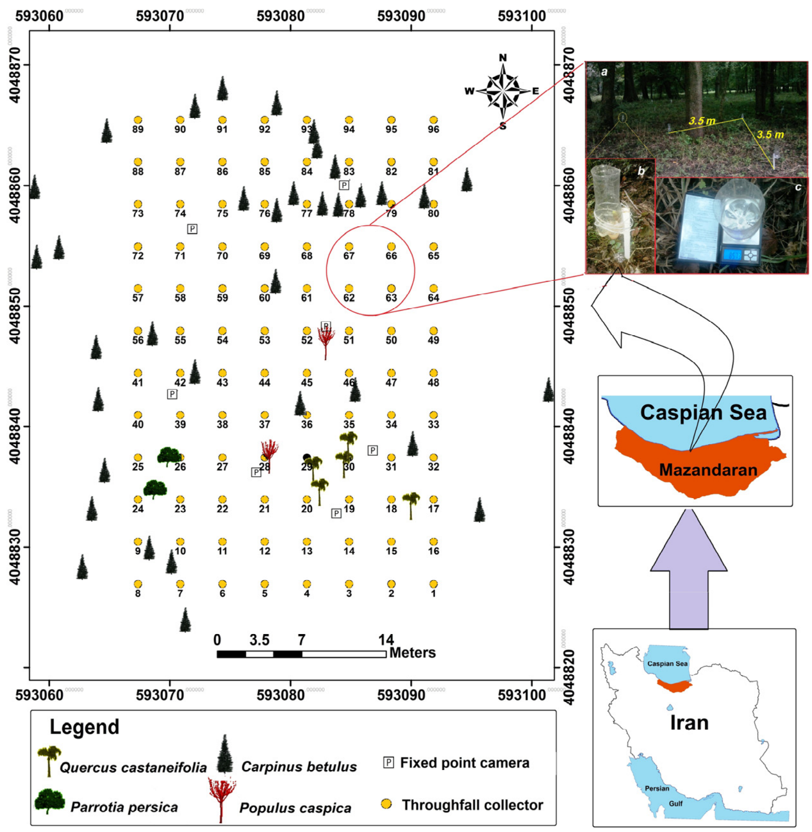

Fig. 1. General location of the study area and a ground view of the study site (a), throughfall collector (b) and weighting stage of collected throughfall (c).

Table 1. Precipitation and throughfall in a Hyrcanian forest stand during the study period.

Temporal scale	Date	No. of events	Gross precipitation (mm)	No. of correct samples	No. of hotspot points	Throughfall as % of rainfall				Canopy cover (%)
						Mean	Minimum	Maximum	Standard Deviation	
Event	30-Jul-2013	24	18.95	64	10	73.1	21.2	160.4	27	85.0
	6-Aug-2013		8.81	94	12	75.9	25.6	165.8	27	86.0
	9-Aug-2013		36.17	94	0	58.3	29.5	118.5	14	87.5
	10-Aug-2013		12.38	95	0	46.4	13.7	89.5	13	87.5
	22-Aug-2013		23.18	94	2	59.1	21.2	116.1	16	87.8
	9-Sep-2013		124.65	90	2	55.5	21.5	112.6	18	89.6
	27-Sep-2013		27.94	92	9	74.9	35.4	114.3	18	87.0
	5-Oct-2013		12.58	92	2	54.2	18.3	157.5	20	85.0
	9-Oct-2013		92.32	93	2	62.1	33.0	136.4	16	84.0
	21-Oct-2013		89.33	64	7	82.9	60.0	230.4	26	83.5
	24-Oct-2013		26.01	91	3	67.5	32.8	139.2	17	83.0
	2-Nov-2013		79.45	71	6	72.4	15.2	248.6	27	78.0
	23-Dec-2013		178.66	42	1	68.5	29.2	112.5	15	76.0
	4-Jan-2014		44.82	90	3	62.4	35.4	134.5	16	70.0
	8-Jan-2014		30.53	88	8	70.7	24.6	169.8	26	67.5
	15-Mar-2014		65.27	84	12	79.9	41.9	172.9	26	57.8
	9-Apr-2014		3.33	89	2	47.6	11.6	105.3	21	34.1
	8-May-2014		4.74	92	2	51.6	19.3	127.1	21	68.8
	4-Jun-2014		8.33	94	5	48.8	5.2	163.8	32	83.8
	22-Jun-2014		23.71	94	6	58.5	17.2	124.4	17	84.0
	4-Jul-2014		11.08	95	1	47.8	15.9	107.0	22	84.5
	8-Jul-2014		4.43	92	7	52.4	18.8	136.1	21	85.0
	14-Jul-2014		5.53	94	4	48.9	15.0	120.4	20	85.3
	21-Jul-2014		6.10	95	4	49.7	20.6	115.0	21	86.5
Seasons	Spring	3	5.4	91	3	51.3	15.2	111.9	20	62.2
	Summer	9	24.9	91	4	57.5	24.4	99.7	14	86.2
	Fall	8	68.9	77	4	58.5	24.3	130.4	17	82.3
	Winter	4	46.8	87	8	82.4	41.9	172.9	24	65.1
Growth periods	Leaf-on	19	44.7	89	6	56.6	18.1	103.9	15	83.9
	Leaf-off	5	22.4	86	4	77.2	42.4	138.2	21	62.4

The *TFPR* spatial distribution was investigated for each individual storm event using ordinary kriging method in Arc GIS 10.2 (Staelens et al., 2006) and corresponding maps were also developed in four seasons and two growth conditions. Rain events in this study were categorized in three classes of gross precipitation <10 mm*,* 10–30 mm and >30 mm as already suggested by Hosseini Ghaleh Bahmani et al. (2012).

The canopy cover of the forest stand was determined by 119 photos taken during 17 date (times) to consider intra variation of canopy cover (Sadeghi et al., 2007) at seven fixed points randomly distributed throughout the study area. The photography localities and other details have been shown in Figure 1. A Nikon Coolpix camera (20 megapixels) mounted on an wooden stack stand at 50 cm above the forest floor was applied to take vertical pictures to be further processed based on K-mean classification method (Vattani, 2011) and ultimately to determine percent of canopy cover (*PCC*).

All the statistical analyses were applied by IBM SPSS Statistics 22 software in 95% confidence level ($P < 0.05$). The influence of vegetation cover situations i.e. leaf-on and leaf-off periods on amount of TFPR and frequency of hotspot points were analyzed by paired t-test. Influence of seasonality on amount of TFPR was also analyzed by one-way ANOVA on the basis of Duncan's multiple comparison test (Rahmani et al., 2011; Ritter et al., 2005). The relation between *PCC* and *TFPR* was additionally determined by Pearson correlation test (Rahmani et al., 2011; Staelens et al., 2006).

RESULTS

Throughfall

A total of 938 mm of rain consisted of 24 events excluding a snow event was recorded between July 2013 and July 2014 (Table 1). A rare snowfall event of 120 cm occurred on 3 and 4 February 2014. The heavy snow covered all collectors at the study site, therefore no throughfall data were collected for this period.

The mean cumulative throughfall during the study period was 623±31 mm (≈ 66% of total rainfall). The average values of throughfall as % of rainfall (*TFPR*) were also found 56±14% and 78±10% for leaf-on and leaf-off periods, respectively. The difference was due to changes in canopy cover of the trees in the study area during leaf-on (growing) and leaf-off (non-growing) seasons as shown in Figure 2. The corresponding variations of mean canopy cover percentage of the study forest stand have also been presented in Figure 3.

According to the results, the average percent of canopy cover site for the entire study period was 66% varied from 41% to 81% for leaf-off and leaf-on periods, respectively. The minimum and maximum canopy covers were also recorded as 34% for 14 April 2014 and 89% for 8 September 2013.

Statistical analyses

The relationship between gross precipitation and *TF* both normally distributed attested by Kolmogorov-Smirnov test was considered by Pearson correlation test whose corresponding results have been summarized in Table 2. The results showed that there was a significant correlation between TF and gross precipitation at 99% confidence level.

The percent of canopy cover was determined for all storm events and correlated with *TF*. The results of Pearson correlation showed that there was no significant correlation ($P = 0.144$) between *PCC* and *TF* for gross precipitation data set >30 mm. However, this correlation was significant ($P < 0.04$)

Fig. 2. Canopy pictures taken from seven photography fixed points (P1–P7) during leaf-on (right) and leaf-off (left) periods.

Table 2. Results of Pearson correlations ($p<0.001$) among main study variables.

Factor	Statistical factor	Canopy cover (%)	Through-fall (mm)
Gross precipitation	No. of data Correlation coefficient Significant level	–	24 0.987** 0.00006
TF (gross precipitation <10 mm)	No. of data Correlation coefficient Significant level	7 0.960** 0.00004	–
TF (10> gross precipitation <30 mm)	No. of data Correlation coefficient Significant level	8 0.882** 0.004	–
TF (gross precipitation >30 mm)	No. of data Correlation coefficient Significant level	9 0.529 0.144	–

** Significant at 99% level of confidence

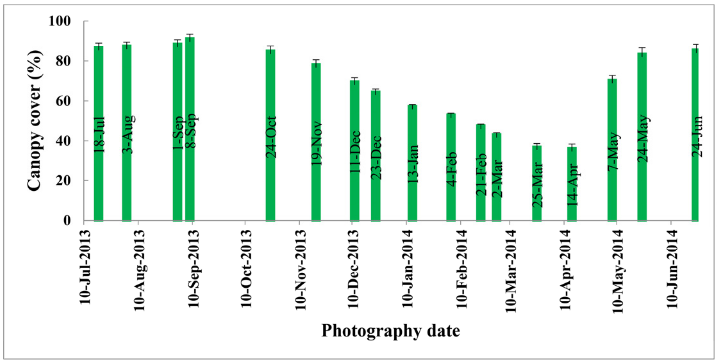

Fig. 3. Mean canopy cover variation during study period for a small Hyrcanian forest in Northern Iran.

Table 3. Results of paired t-test (p < 0.001) in leaf-on and leaf-off conditions in view point of throughfall as % of rainfall (*TFPR*) and hotspot frequency.

Study variables	Paired Differences					t-value	Degree of freedom	Significant level (2-tailed)
	Mean	Standard deviation	Standard error mean	95% Confidence interval of the difference				
				Lower	Upper			
TFPR	19.3	23.1	2.3	14.6	24.07	8.19	95	0.00005
Hotspot frequency	1.87	2.12	0.38	1.091	2.65	4.90	30	0.00003

Table 4. Results of ANOVA for comparison among *TF* in different seasons in study forest.

Source	Sum of squares	Degree of freedom	Mean squared	F-value	Significant level
Between Groups	47965.285	3	15988.4	41.7	0.0003
Within Groups	145594.736	380	383.1		
Total	193560.021	383			

for gross precipitation <10 mm and 10–30 mm at 99% confidence level.

The *TF* in two forest conditions (leaf-off and leaf-on) was also compared using paired t-test. The results showed that there was a significant difference (P < 0.007) between lower amounts of *TF* in leaf-off and higher amounts of *TF* in leaf-on season at 99% confidence level. The hotspots frequency in leaf-on and leaf-off conditions was also assessed by paired t-test and reported in Table 3. The results further showed that there was a significant difference (P < 0.01) between frequency of hotspots in leaf-on and leaf-off conditions, and the frequency of hotspots in leaf-on conditions was obviously more than those of leaf-off season.

One-way ANOVA on the basis of Duncan's multiple comparison test (p < 0.05) was also used to compare *TF* in different seasons whose results have been given in Table 4. Results showed that the amounts of *TF* in different seasons had significant difference at 99% confidence level as the maximum *TFPR* occurred in winter (82.36%) and the minimum *TFPR* was in spring (51.29%). The results of Duncan's test also showed that there was no significant difference between *TFPR* in autumn (58.49%) and summer (57.43%) seasons.

Spatio-temporal analysis of throughfall

The spatial distribution of throughfall as % of rainfall was mapped for the seasonal and growing/non-growing periods as shown in Figure 4. Results of spatio-temporal variations for *TFPR* showed there were miscellaneous patterns of *TFPR* distribution in different seasons, especially between leaf-on and leaf-of periods.

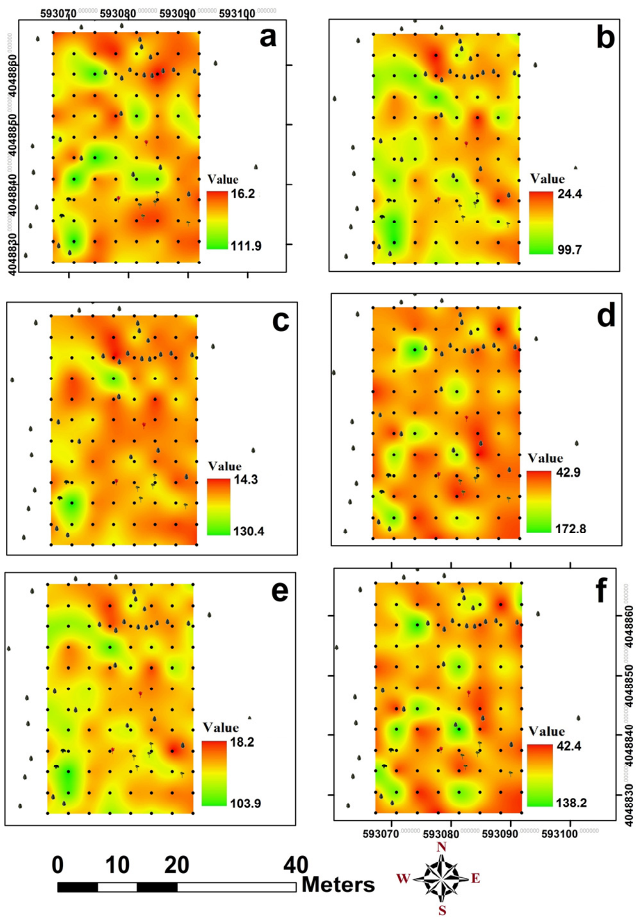

Fig. 4. Spatial variations in throughfall as % of rainfall for spring (a), summer (b), autumn (c), winter (d), leaf-on (e) and leaf-off (f) for a representative Hyrcanian forest stand, northern Iran.

In forest floor during rainfall, *TFPR* in some points was more than the gross rainfall, signifying hotspots (Figure 5). These hotspots occurred through directing rainfall to spatial points by leaves and branches of trees. In addition and based on anecdotal evaluation, the hotspot frequency in collectors located

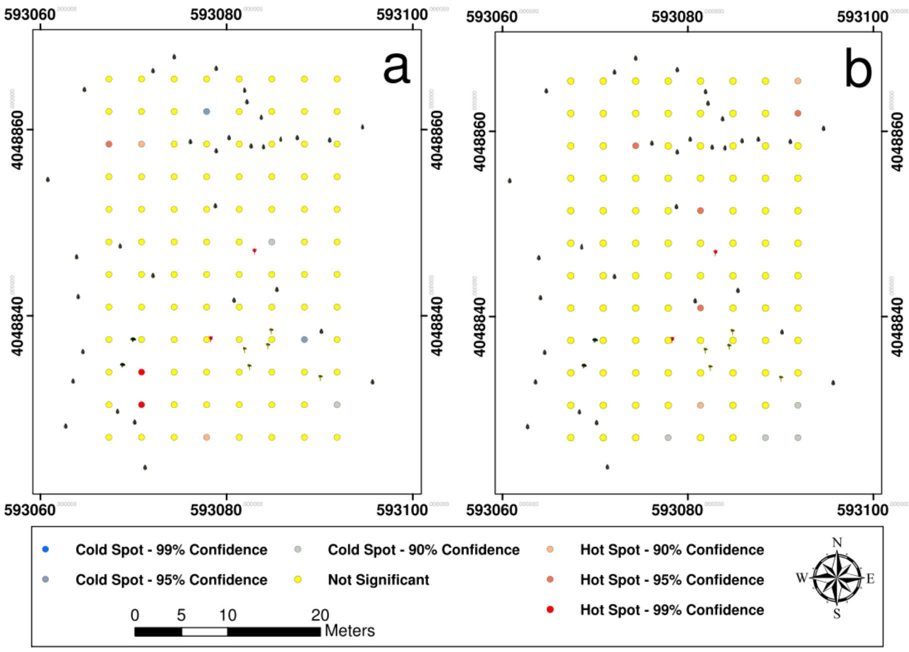

Fig. 5. Hot/cold spot analysis of *TFPR* for Leaf-on (a) and Leaf-off (b) periods.

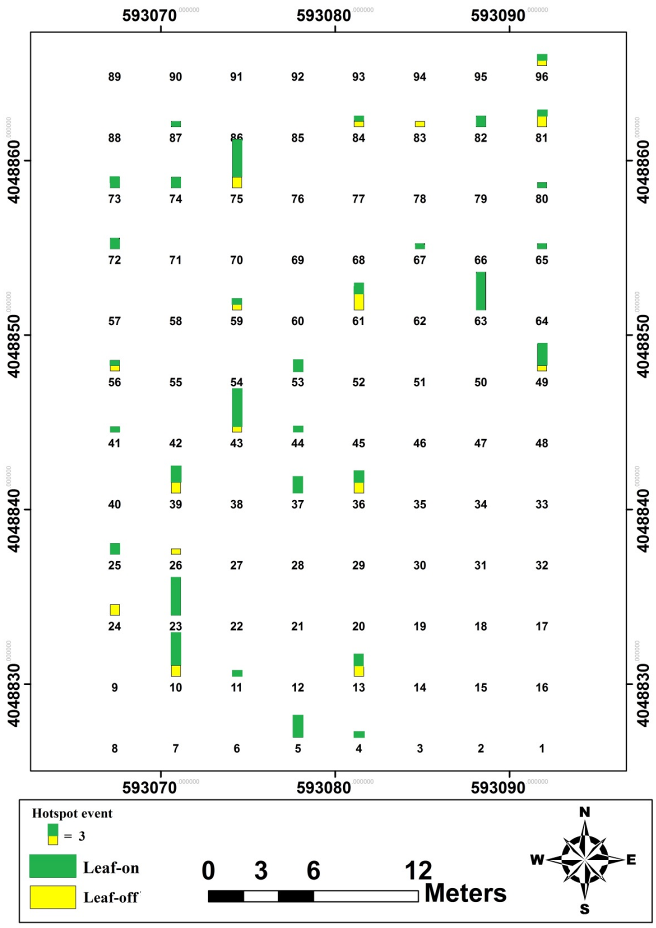

Fig. 6. Distribution of hotspot frequencies (No. of events with amounts of throughfall more than gross rainfall; the higher bar the more frequency of hotspots) during leaf-on and leaf-off periods.

in 2–6 m away from trees was more than collectors located closer than 2 m or beyond 6 m. The hotspot frequency around the *Quercus castaneifolia* and *Populus caspica* in the both study conditions (leaf-on and leaf-off seasons) was very low. Frequency of hotspots in the study time was determined during leaf-off and leaf-on periods represented in Figure 6.

DISCUSSION

The results of ANOVA confirmed that *TF* in different seasons had significant difference at 99% confidence level and PRT in spring was more than other seasons. However, Duncan's classification showed that there was no significant difference between summer and fall seasons in *TF*. The graphical comparison among maps developed for seasons and growing condition of the study stand (Figure 4) verified a general symmetric condition between *TF* distribution in summer and growing season as well as *TF* distribution in winter and non-growing season. It clearly verified that spring and autumn played a transitional situation in two other seasons and conditions. It was also implied from the results that the Hyrcanian plain forest did not have more variation in canopy cover during summer and fall seasons. The lack of leaves in forest decreased the value of interception and increased the throughfall (Nasiri et al., 2012; Xiao et al., 2000). Besides those, the results showed that in all maps around the *Parrotia persica* trees, the value of *TF* was higher than other species because of different morphologies among study species. This can be attributed to *Parrotia persica* having smooth leaves and branches and the frequency of grooves in this species is lower than other species leading to less interception and rain loss as reported by Nasiri et al. (2012).

The results of Pearson correlation showed that there was a significant correlation (r = 0.987) between *TF* and gross precipitation. The high correlations between *TF* and gross precipitation have already been reported by former researches (e.g., Carlyle-Moses, 2004; Gurav et al., 2012; Park and Cameron, 2008; Shachnovich et al., 2008) as 0.998, 0.988, 0.996 and 0.979, respectively for different forest stands throughout the globe. The correlation results also showed that the influence of canopy cover to absorb the rainfall was significant just for rain events smaller than 30 mm. This results additionally showed that the Pearson correlation coefficient for gross precipitation <10 mm was more than rain events for 10 mm < gross precipitation <30 mm. The amount of interception in rainfalls with high duration and low volume was high, while it was low in events with high intensity and more volume. This is consistent with other studies (Herold et al., 2005; Hosseini Ghaleh Bahmani et al. 2012; Nasiri et al., 2012; Rahmani et al., 2011; Xiao et al., 2000). Interestingly, the throughfall values obtained for the study area as a representative area for the Hyrcanian plain were similar to the findings for mountain ecosystems in Slovakia and the Czech Republic by Holko et al. (2009) and Dohnal et al. (2014).

Results of paired sample t-test showed that there was significant difference ($P = 0.007$) between leaf-on and leaf-off periods in TFPR and hotspot frequency. Canopy cover in leaf-on period prepared conditions to reduce the amount of rain by increasing leaves and branches soak. Hotspots frequency in leaf-on period was more than leaf-off condition. Hotspots in interception system show the behavior of canopy drainage pattern (Coenders-Gerrits et al., 2013; Hopp and McDonnell, 2011). Hence, the whole branches stand downward and therefore allow easy drainage of the throughfall during leaf-on conditions. Accordingly, the hotspot frequency in collectors located in 2–6 m away from trees was more than other far points. This was also noticed by (Coenders-Gerrits et al., 2013; Germer et al., 2006; Ziegler et al., 2007). In addition, results showed that the hotspot frequency around the *Quercus castaneifolia* and *Populus caspica* in the both leaf-on and leaf-off periods was very low (Figure 4). The main reason for this observation was the tall growth and contact acute angel of the tributaries to the main trunk of these species as reported by Nasiri et al. (2012).

Only 66 % of the annual rainfall was able to penetrate the canopy of the study forest on the study Hyrcanian plain, and the canopy spatially redistributed the precipitation reaching the forest floor. Rahmani et al. (2011), reported that an average of 43% of the total gross precipitation penetrated through the canopy as throughfall in another Hyrcanian mountain forest stand located in hilly areas (900 m above mean sea level). The maximum value of throughfall as % of rainfall in the study area and during study period was 248% at collector number 23 (Figure 1) for the rain (79.4 mm) on 3 November 2013. The *TF* was approximately 197 mm at this collector. The mean *TF* at the study site for this rain was 23%. Collector 23 was near a *Parrotia persica* tree. *P. persica* is a multi-branched tree with an earlier leaf-off period than other species. The minimum *TFPR* during the study was 6% at collector 85 during a rainstorm (8 mm) on 4 June 2014. Collector 85 was surrounded by *Carpinus betulus* trees. The mean *TFPR* for this storm was 49%. *C. betulus* has dense foliage, and raindrops cannot easily pass directly through the crown without interacting with the foliage, especially during the growing season.

CONCLUSION

The present study figured out an approximation for throughfall rates and its variability in a Hyrcanian plain forest, northern Iran. The relevances between spatio-temporal variations of throughfall with distribution and phonological and morphological characteristics of existing species, and rainfall properties were also elucidated in the study deciduous Hyrcanian forest. Hence, the seasonal and periodical changes of throughfall were revealed at respective tunes of 49, 43, 42 and 18% for spring, summer, autumn and winter. The study forest could also intercept some 43 and 23% of the rainfall in the leaf-on and leaf-off periods. The results of the present study can be effectively used by forest hydrologist to help decision makers, planner and foresters adopt appropriate silvicultural measures for better management of hydrological behavior of the Hyrcanian forest in the north of Iran. Though further insight studies with longer period and more extensive areas and even in different forest stands are essentially needed to allow drawing comprehensive conclusions.

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