Journal of Hydrology 561 (2018) 187–199

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Effects of forest structure on hydrological processes in China

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ARTICLE INFO

This manuscript was handled by Emmanouil Anagnostou, Editor-in-Chief, with the assistance of Qiang Zhang, Associate Editor

Keywords:
Forest
Structure
Rainfall partitioning
Evapotranspiration
Factor

ABSTRACT

There are serious concerns between forest and water quantity, Chinese extensive land area makes the relationship more complicated, thus, the effects of forest structure on hydrological processes in China were not fully comprehended. In this research, forest's hydrological functions, including rainfall partitioning, litter interception, evapotranspiration (ET), were analyzed in China. The results showed that throughfall was the largest proportion of gross precipitation with fraction between 69.3 ± 8.8% and 84.4 ± 5.6%. Then was canopy interception which varied from 14.6 ± 1.4% to 29.1 ± 3.3%. Throughfall was correlated with gross precipitation, canopy thickness and canopy density. Canopy interception was correlated with gross precipitation, LAI, canopy density, biomass, mixed degree, uniform angle index, aggregation index. Stemflow accounted for only 1.2 ± 0.32% of gross precipitation, with the greatest fraction of 2.1 ± 0.2% in XBH site and the least fraction of 0.3 ± 0.1% in DB site. Gross precipitation was the main factor in determining stemflow. DB site had the greatest litter interception (7.7 ± 0.8 mm) and HB site had the least (0.9 ± 0.3 mm). Litter interception had closer correlation with undecomposed litter mass (0.66) than total litter mass (0.46). Path-coefficient analysis showed that stand density, Shannon-Wiener index, litter mass, size ratio had greater impact on litter interception than other factors. ET was mainly influenced by precipitation, and it also correlated with LAI, canopy density and biomass. In north China, ET percentage (the ratio of ET and precipitation) was 82.7–109.5%, while it decreased to 63.1–88.5% in south China, ET demand in XBS site was larger than precipitation. ET percentage increased with increasing latitude and elevation, decreased with increasing temperature.

1. Introduction

Forests have impacts on improving water availability at regional and global scale (Ellison et al., 2012), they were also considered as the main measure for soil and water conservation due to their positive functions in reduce erosion (Komatsu et al., 2008). However, forests reduced water supply for they evaporated greater rainwater than other land use type (Beschta et al., 2000). The controversy between forest and water has attracted considerable attention for more than 200 years (Andréassian, 2004). The complexity of hydrological process caused the fruitless debate, multiple factors, such as climatology, geography, forest type, structure, etc., influence the process (Liu et al., 2001). Among all the influence factors, forests were the most prominent factor, due to human beings had great effect on forests distribution (Benyon and Doody, 2015). It is an important step to characterizing the roles of forests played in hydrological cycle, in terms of rainfall partitioning, evapotranspiration (ET), infiltration, and runoff generation (Love et al., 2010; Siles et al., 2010).

Forest structure re-routed vertical precipitation pathways by canopy, canopy partitioned rainwater into interception, throughfall and stemflow (Fig. 1). Rainfall partitioning is the first and most important process that forests act on water cycle (Livesley et al., 2014), while the interactions between forest structure and rainwater pathway are difficult to find out (Herwitz, 1985; Zimmermann et al., 2007). During rainfall events in summer, raindrops are intercepted by canopy. Other raindrops fall through the canopy directly to the ground which is called throughfall (Crockford and Richardson, 2000; Brauman et al., 2010). Most of the interception rainwater (10–50% of gross precipitation)

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https://doi.org/10.1016/j.jhydrol.2018.04.003
Received 24 September 2017; Received in revised form 29 March 2018; Accepted 1 April 2018
Available online 03 April 2018

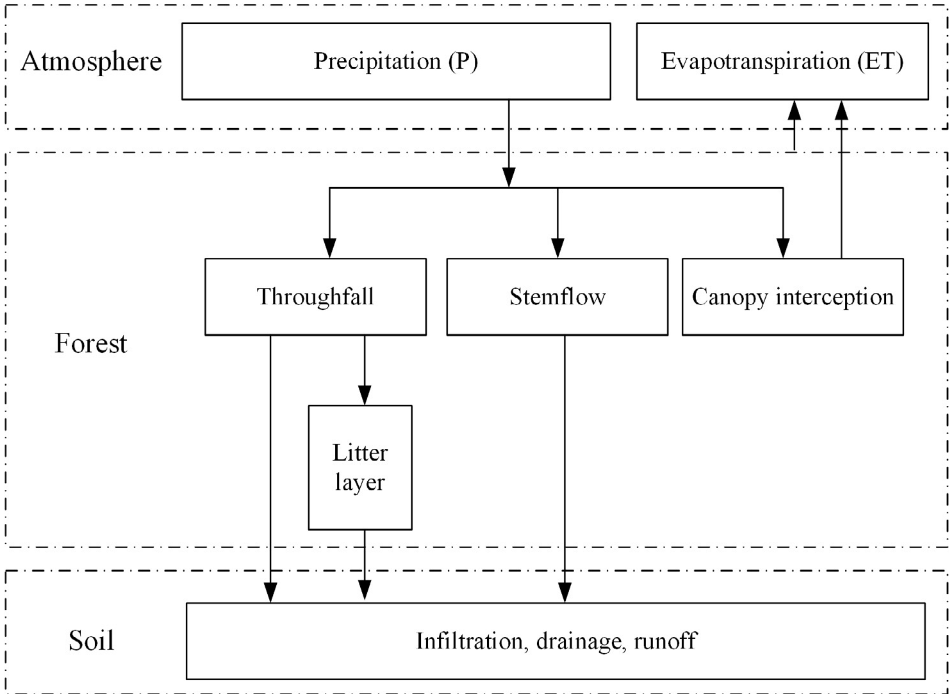

Fig. 1. Rainwater input and output schematic pathways in forests.

Table 1
Previous results of throughfall, stemflow, and interception percentiles from different stand types (Mean annual temperature (MAT), mean annual precipitation (MAP)).

Reference/author (name, year)	MAP (mm)	MAT (°C)	Land use	Interception (%)	Stemflow (%)	Throughfall (%)
Raz-Yaseef et al. (2012)	285	17.5	*Pinus halepensis*	10.88		
Xiao and McPherson (2011)	582.7	15.1	*Ginkgo biloba*	27	1	
	582.7	15.1	*Liquidambar styraciflua*	25.2	4.1	
	582.7	15.1	*Citrus limon*	14.3	2.1	
Brauman et al. (2010)	1500	12.1	*Meterosideros polymorpha*	12		64
	1500	12.1	*Cibotium glaucum*	9		62
Siles et al. (2010)	2300	21	*Inga densiflora*	11.4	10.6 ± 1.1	76.8 ± 2.0
	2300	21	*Coffea arabica*	9.6	7.2 + 0.6	83.2 ± 1.9
Krämer and Hölscher (2009)	600	7.5	*F. sylvatica*	30.8	2.6	67.5
Staelens et al. (2008)	755	10.2	*Fagus sylvatica*	21	7.9	71
Zhou (2003)	450–550	−5.4	*Larix gmelinii*	17.5	3.3	
Yan et al. (2003)	1990	21	Mixed broadleaf	31.8	8.3	
	1990	21	Mixed pine broadleaf	25.2	6.5	
	1990	21	*Pinus*	14.7	1.9	
Liu et al. (2001)	1023	12	*Abies fabri*	24	-	
Crockford and Richardson (2000)	800	8.6	*Pinus pinaster*	17.1		
	800	8.6	*Eucalyptus globulus*	10.8		
Marin et al. (2000)	3100	27.5	Rain forests		1.1	85.39
Zhou et al. (1994)	650	0.2	*Pinus koraiensis*	25.3	3.8	
Lei et al. (1994)	700–1000	3	*Pinus tabulaeformis*	20	2.6	
	700–1001	3	*Pinus arandi*	19	5	
	700–1002	3	*Quercus mongolica*	17.9	2.3	
Tian et al. (1994)	1550	15.4	*Cunninghamia lanceolata*	25.8	0.2	
Zeng (1994)	1650–2650	19.7–24.5	Mixed broadleaf	29.1	3	
Domingo et al. (1994)	395	12	*Pinus pinaster*	15	8.5	76.5
Wei and Zhou (1991)	676	0	*Quercus mongolica*	20	15.3	
	676	0	*Betula platyphylla*	25.9	4.6	
Crockford and Richardson (1990)	900	9.5	*Pinus*		4.8	

evaporate back to atmosphere in several hours after precipitation event (Klaassen et al., 1998; Carlyle-Moses, 2004), while the left (0–12% of gross precipitation) flow to ground via trunks or stems which is called stemflow (Dunkerley, 2000). Previous researches were done to record rainfall partitioning (Table 1), it differed from forest type and structure. Generally, interception was not considered as a necessary process for flood process, but interception influenced antecedent soil moisture condition which was important for the flood generation (Tsiko et al., 2012). Stemflow was important resource of ground water, stemflow also contributed to soil chemistry (Johnson and Lehmann, 2006). Horizontal precipitation was also one of the most important hydrological inputs (Ingraham and Matthews, 1988), it was reported as one factor in determining *Sequoia sempervirens* distribution (Cooper, 1917). Horizontal precipitation like fog was crucial forest characteristic factor in mountains (Ingraham and Matthews, 1988). 0–17% of precipitation input was from horizontal precipitation (Dawson, 1998). Forests re-