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Rainfall partitioning in a tropical forest of Manipur, North East India

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Precipitation follows several pathways before arriving at the forest floor in a forested ecosystem (Rutter & Morton 1977). Incident rain passing through the forest canopy can be divided into three fluxes. One flux freely falling through the canopy and dripping down the leaves is called throughfall, whereas the other flux runs down the branches and trunks and is called stemflow. However, a part of precipitation never reaches the soil but is evaporated from the forest canopy and is known as interception. Numerous investigators have measured rainfall both in the open and beneath forest canopies (Joroen *et al.* 2008; Keim 2004; Link *et al.* 2004; Price *et al.* 2003; Pypker *et al.* 2005; Staelens *et al.* 2006). Since the data available from tropical regions are limited, the present paper aims to quantify the various pathways of rainwater reaching the soil in two stands of tropical forest from Manipur, northeast India.

The forest stands presently studied happen to be sacred groves. Sacred groves are the forest patches protected by the local community for their beliefs and traditions. The study was conducted at Nambol (24.72°N latitude and 93.837° E longitude) and Wangoi (24.673°N latitude and 93.899°E longitude) sacred groves protected by the Meitei community. Nambol sacred grove is drained by Nambol river and the dominant species of the site is a deciduous tree *Ficus glomerata*. Wangoi sacred grove is drained by Imphal river and the site is dominated by evergreen species like *Celtis australis*, *Eugenia praecox*, *Michelia champaca*. The area is characterized by sub-tropical climate. The average temperature ranges from 0°C to 32°C, mean relative humidity from 57.18% to 83.98%. The average annual rainfall was recorded as 1635.5 mm. The characteristics of the two sites are given in Table 1, following Usharani (2004).

Throughfall and stemflow were measured following Opakunle (1989). Three plots, each 20 m x 20 m in size, were selected for the hydrological study in each grove. Enumeration of all the trees was made in each grove. A total of 29 trees which were sampled for the hydrological studies from both the groves were selected. For measurement of throughfall 10 funnels, each of 100 mm diameter, in each plot, were used. The rainfall was measured by placing three such collecting funnels in an open area near the experimental sites. Net precipitation is the amount of rainfall which reaches the soil after penetrating the canopy and litter layer and was calculated by adding throughfall and stemflow. Gross precipitation in the studied plot was obtained by multiplying mm of rainfall by plot size.

A total of 201 rainfall events in the hydrological year (1999-2000) were considered for calculating throughfall, stemflow, net precipitation and interception loss. The maximum number of rainfall events was 120 in shower class 0-10 mm which constitutes 59.70% of total events. The number of rainfall events was 28 under shower class 10-20 mm that accounted for 13.9% of the total events. Thirteen rainfall events were recorded under shower class 20-30 mm and between 30-50 mm shower class, nine events were recorded. There were only three rainfall events

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Table 1. Characteristics of studied sites.

Site Characteristics	Scared Grove Nambol	Sacred Grove Wangoi
Trees ha^{-1} (>31.5 cm gbh)	1960	2500
Basal area m^2 ha^{-1} (>10.5cm gbh)	7.63	9.87
Diversity index (H')	2.58	3.07
Soil texture	Sandy loam	Loam
Soil nutrient (N,P,K,Ca,Mg and Na) storage upto 100 m depth (kg ha^{-1} for 1999-2000).	18939.08	33546.16
Litterfall (ton ha^{-1}) for 1999-2000	6.61	6.34
Nutrient(N,P,K,Ca,Mg and Na) return through litter (kg ha^{-1}) for 1999-2000	492.77	446.6

Table 2. Distribution of gross precipitation as throughfall and stemflow in the two sacred groves in dry and wet months. Values in parentheses are percentage of gross rainfall.

	Drier months (mm)	Wet months (mm)
Nambol		
Throughfall	22.9 (39.3%)	841.0 (53.3%)
Stemflow	1.1 (1.8%)	49.9 (3.1%)
Net precipitation	24.0	890.9
Interception loss	34.2	686.4
Wangoi		
Throughfall	14.4 (24.8%)	972.1 (61.3%)
Stemflow	1.6 (2.7%)	75.3 (4.7%)
Net precipitation	16.0	1047.4
Interception loss	42.2	529.9

recorded that were greater than 50 mm size and no event was noted for shower size class more than 100 mm.

A total 1635.5 mm of gross precipitation was recorded in the hydrological year May 1999 - April 2000. Throughfall, stemflow and interception loss for dry and wet periods for the hydrological year are given in Table 2 for the studied sites.

In Nambol sacred grove, the quantity of stemflow (51 mm, constituting 3.1% of gross rainfall) was much lower than that of throughfall (863.9 mm, constituting 52.8% of gross rainfall) for the study period. The interception loss was computed as 720.5 mm (44% of gross rainfall). In the wet period (March to October) the maximum interception of rainfall was 43.6% of gross precipitation whereas the net precipitation was 56.1%. In the dry period (November to February), the interception loss was 58.1% and net precipitation as 41.2% of gross precipitation. In this forest, out of 654160 litres of gross precipitation on the floor of each plot, 345560 litres of throughfall and 20400 litres of stemflow were computed corresponding to a net precipitation of 365960 litres per plot under forest canopy. The interception loss was 288240 litres per plot.

In the sacred grove at Wangoi, for the study period, the amount of throughfall was 986.6 mm (60.3% of gross rainfall) compared to 76.9 mm (4.7% of gross rainfall) stemflow. The interception loss was 572 mm (34.9% of gross rainfall). In the wet period the amount of water conducted through net precipitation was 65.9% of gross rainfall and the interception loss was 33.3% of gross rainfall. In the dry period, 27.2% of gross rainfall was conducted through net precipitation, whereas the interception loss was 71.7%. 654160 litres of precipitation, 394644 litres of throughfall and 30760 litres of stemflow were computed for each plot corresponding to a net precipitation of 452404 litres under forest canopy. The interception loss was computed as 228796 litres per plot.

Our results for throughfall compare with 54.6% in Sal forest (Dabral & Subba Rao 1969), 51-77% in *P. roxburghii* (Pathak *et al.* 1983), 50-60% in Hard beech forest (Millar 1963) and 58% in *Quercus suber* (Xiao 2000), whereas our values for stemflow were comparable with that of 3.4% in Chir pine forest (Dabral & Subba Rao 1968), 1.5-8% in Sitka spruce forest (Johnson 1990), < 3% in *Eucalyptus* (Prebble & Strike 1980).

Table 3 shows the relationships of throughfall, stemflow and interception loss with gross rainfall. All these relationships with rainfall are significant.

Table 3. Regression parameters describing the relationships of throughfall, stemflow and interception loss with gross precipitation, according to y = a + bx, where, x = gross precipitation (mm).

y variable (mm)	Nambol			Wangoi		
	a	b	c	a	b	c
Throughfall	-4.67	0.56	0.99	-13.44	0.70	0.98
Stemflow	-0.43	0.03	0.98	-0.74	0.05	0.99
Interception loss	5.10	0.40	0.98	14.14	0.25	0.87

It was found that sacred grove at Nambol intercepts more rain than the sacred grove at Wangoi. In the wet period, deciduous species intercept more water (44.6% of gross rainfall) whereas evergreen species conduct more water (66% of gross rainfall) through net precipitation. In the dry period deciduous species conduct more water through net precipitation whereas evergreen dominated canopy intercepts more water (72% of gross rainfall).

The mean of interception loss at Nambol was found to be greater than the mean at Wangoi ($t=2.901$, $df=11$ and $p < 0.05$). The mean value of throughfall and net precipitation at Wangoi were higher than those at Nambol sacred grove ($t=3.509$, $df=11$, $p < 0.01$ and $t=2.8$, $df=11$, $p < 0.05$, respectively). The significant differences in the precipitation components of the two sacred groves reflect the variation in biological characteristics at the two sites.

Nature of foliage and bark of branches and trunk are some of the important factors which influence throughfall, stemflow and interception. *Ficus* dominated canopy in the studied plots of sacred grove Nambol with rough bark conducts less water through net precipitation than *Eugenia praecox* and *Michelia* canopy of sacred grove at Wangoi which are smooth barked evergreen species conducting more water through throughfall and stemflow resulting in more net precipitation. Evergreen dominated canopy in sacred grove at Wangoi intercepts less water than deciduous dominated canopy in sacred grove at Nambol.

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