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Full Length Research Paper

Throughfall and Interception Loss in Relation to Different Canopy Levels of Coffee Agroforestry Systems

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Abstract

The partitioning of gross rainfall into throughfall and canopy interception loss was studied in two different shade levels of coffee agroforests in the Pachat village of Kodagu. Data on meteorological characters was collected using automatic weather station on a half-hourly basis during study. Throughfall and interception loss in each system were checked for correlations with gross rainfall characteristics. Rainfall was mainly distributed between July and October i.e., the monsoon period. Throughfall ranged from 84 - 91% and interception loss ranged from 8.9 - 15.7% of gross rainfall in the high and low shade levels of coffee agroforestry systems studied and varied with gross rainfall in both systems. The throughfall was significantly higher and interception loss was significantly lower in high shade level system compared to low shade level system. The stand structures of the agroforestry vary considerably and influenced the rainfall partitioning, hence may be the differences.

Keywords: *Coffee agroforestry system; Throughfall; Interception loss; Stand structure; Meteorological characters*

Introduction

Coffee is the second largest traded commodity in the world after petroleum. India is the world's sixth largest coffee producer country with production area concentrated in the Western Ghats, one of the world's hot spot of biodiversity. Kodagu is one of the smallest district in the state of Karnataka and the entire district is part of the Western Ghats. The district has 81.40 per cent of its landscape under tree cover, and is one of the densely forested districts in India. The most important climate characteristic of this region is the South-West monsoon with nearly all the annual rainfall occurring within 6 months (June to September). Even during post monsoon months of October and December study area receives significant amount of rainfall. Over the last 30 years, coffee cultivation has been expanding tremendously in the region (from 15% to 32% of the total area in Kodagu) to the detriment of forest. Still, both Robusta (80%) and Arabica (20%) are grown under the shade of multi-strata agroforestry systems (AFS) and hence play a major role in biodiversity conservation and provision of goods and services for the local and global communities. One major service relates to water provision, which is important since the main rivers providing water for urban centers and agriculture in Southern India all originate from these coffee areas of the Western Ghats. The tree composition of this region has been profoundly affected by important changes in management practices such as introduction of fast growing tree species (mainly *Grevillea robusta*) for timber production and stand for pepper. Current research concentrates on how the change in tree cover affecting the water fluxes in the coffee agroforestry systems in the Cauvery watershed of Kodagu district. Nevertheless, it is often argued that additional work is needed to explain and improve model predictions for impacts of deforestation. Evidently, this local study would provide base level information on different shade level conditions that might allow for an evaluation of the presumed influence of deforestation on regional climate.

Materials and Methods

The study area is in Pachat village of Kodagu district in Southern India, (Latitude: 12" 17' 58.17 N Longitude: 75" 49' 15.94 E Elevation 897 m). The areas for the present study were selected based on the different shade levels namely high shade level system (HSLS) and low shade level system (LSLS) i.e., with shade tree's mean crown area of 10.40 m^2 and 4.76 m^2 respectively in the Pachat. To measure throughfall and gross rainfall above the canopy two plots were selected with different shade levels. Approximately 300 m from the plots, in an open area, an automatic weather station (AWS) was installed to measure gross rainfall and temperature. Parameters were measured and recorded for every 30 minutes using a datalogger. Rainfall in the open area was also measured by a manual rain gauge providing information on total rainfall. Gross rainfall in each plot was measured in two ways: (1) automatic measurements with one automatic weather station; (2) manual measurements with five rain gauges. Throughfall was measured under ten coffee plants in the each plot of 50 m X 20 m (1000 m^2) using 8 small and one large collectors placed under quarter of canopy of each coffee plant, systematically located. To allow for direct correlation of gross rainfall above the canopy and throughfall, manual rain gauges and small collectors had an orifice of 71.6 cm^2, the AWS and large collectors had an orifice of 500 cm^2 respectively. Throughfall and rainfall collectors were calibrated against standard AWS in the open. Because of the large variability in throughfall due to the coffee agroforestry structure many readings are needed to study interception. However, when using average values, moving the collectors has a positive effect by reducing the standard error of estimations. Therefore, for each throughfall collector three positions were fixed, (after every measurement) collectors were systematically relocated within the three positions.

Results

Stands structure of coffee agro-forestry system

Average values of measured variables of stand structure of coffee agroforestry system are presented in Table 1. The density of trees in high HSLS is 390/ha compared to LSLS 230/ha, the mean tree crown area was higher in HSLS (10.4 m^2) compared to LSLS (4.76 m^2) indicating higher canopy cover. Mean basal area of trees was also higher in HSLS (0.07 m^2) compared to LSLS (0.04 m^2) indicating HSLS trees had higher trunk area in addition to crown area. The density of coffee plants was higher in LSLS (816/ha) compared to HSLS (625/ha) and but the coffee plants in HSLS are older compared to coffee plants in low shade level and also it is recently intercropped with Arabica coffee hence mean basal area of coffee plants in LSLS was lower (0.0033 m^2) compared to HSLS (0.014 m^2). The mean crown area of coffee plants were also low in LSLS (3.15 m^2) compared to HSLS (6.39m^2).

The results indicate that coffee plants were spaced much closer contributing to higher plant density in low shade level than high shade level, but since the coffee plants and trees were older in high shade level the crown area and basal area were higher.

Table 1. Stand Structural characteristics of coffee agroforestry systems.

Parameter	LSLS		HSLS	
	Tree	Coffee	Tree	Coffee
Density (per ha)	230	816	390	625
Crown area (Mean ± SD) (m^2)	4.76 ± 2.91	3.15 ± 1.47	10.40 ± 3.10	6.39 ± 1.68
Basal area (Mean ± SD) (m^2)	0.04± 0.39	0.003±0.003	0.07± 0.48	0.014±0.01

Rainfall and Temperature

The climatic characters at study sites are described as follows. Gross rainfall distribution during the year 2010 in Pachat site is presented in Figure 1. The total gross rainfall at Pachat was 1296.73 mm and total measured rainfall during the study period (July to October 2010) was 874.96 mm (67.47per cent of gross rainfall) that was distributed in 70 rainfall events. Interception loss was monitored between July and October during the monsoon period. Only some rain events like before experimental setup, after the un-mounting of the experimental setup and few large intensity rain events could not be measured since there was overflow in the collectors.

The average temperature during study period was 21.66 ^{0}C. Maximum temperature of the area recorded was 36.40 ^{0}C (April) and minimum temperature was 8.30 ^{0}C (February).

Throughfall

Throughfall was calculated as a percentage of gross rainfall for four different rainfall sizes, from the total of the measured daily gross rainfall and throughfall during the study period. Throughfall ranged from zero, with event below 2 mm, to 94% in storms larger than 55 mm, but mean throughfall varied from 74% to 93% depending on gross rainfall amounts and the different shade level systems (Table 2). The calculated value of total throughfall relative to total gross rainfall ranged from 84% to 91% in the two shade level systems.

The linear functions produce better fits for correlation between throughfall and gross rainfall (Figure. 2), in both shade level systems. The student t-test showed that the regression slope is significantly ($p < 0.05$) higher in LSLS than HSLS of coffee agroforestry in this study (Table 3).

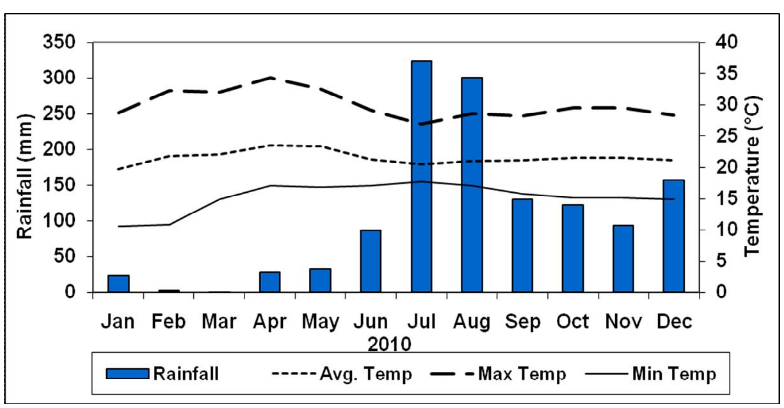

Figure 1. Rainfall and temperature at coffee agroforestry systems of Kodagu.

Table 2. Rainfall characteristics and its distribution into throughfall in coffee agroforestry system.

Rainfall ranges	No. of rainfall events	Rainfall (mm)	Throughfall	
			low shade level	high shade level
< 5	20	49.20	41.04 (83.42)	36.30 (73.77)
5-10	19	134.631	120.354 (89.40)	105.31 (78.22)
10-20	20	263.531	237.254 (90.03)	222.30 (84.36)
20-65	11	427.595	398.727 (93.25)	373.72 (87.40)
Total	70	874.96	797.34 (91.13)	737.62 (84.30)

Note: Values in the parenthesis are percentage values of gross rainfall.

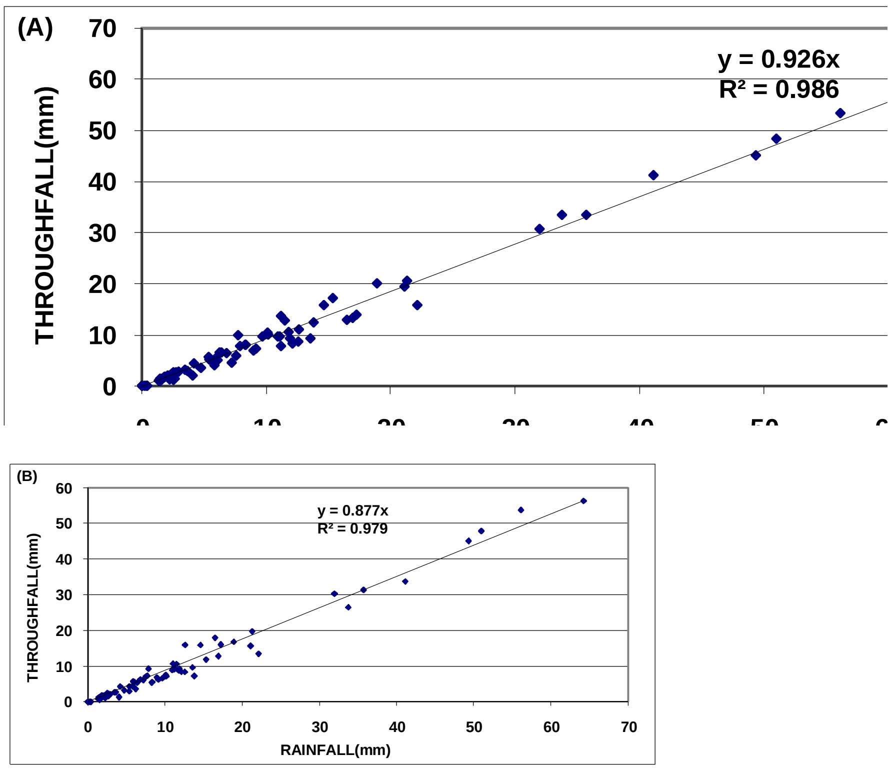

Figure 2. Throughfall versus gross rainfall during 2010, in (A) LSLS and (B) HSLS of coffee agroforestry in the Pachat site.

Table 3. Throughfall and interception from low shade and high shade level sites of coffee agroforestry system with the gross rainfall of 874.96 mm (July to October 2010).

	Throughfall (mm)	Mean ± SD	Interception (mm)	Mean ± SD
LSLS	797.38 (91.13)	11.39± 11.22	77.58 (8.87)	1.11 ± 1.10
HSLS	737.63 (84.30)	10.53±10.42	137.33 (15.70)	1.91±1.92
p<0.05	0.032		0.044	

Note: Values in the parenthesis are percentage values of gross rainfall.

Interception loss in coffee agroforestry system

Interception loss of water by coffee agroforestry canopy is calculated by subtracting the measured daily throughfall and stemflow from gross rainfall. The contribution of stemflow to net rainfall is very low (1%-2%) and generally ignored in the water balance (see Maruti, 2010; Holscher *et al.,* 2004 and Tobon-Marin *et al.,* 1999), so we did not studied stemflow in this study. Furthermore, it is related to gross rainfall characteristics and coffee agroforestry system parameters. Following net throughfall trends, the percentage of interception loss relative to gross rainfall varied from 6 to 100% in both shade levels, depending on rainfall size. There was a significant difference in both shade level systems as indicated by student t-test (Table 3). The student t-test showed that the interception loss is ($p < 0.05$) higher in HSLS than LSLS of coffee agroforestry system.

Total interception loss, expressed as percentage of total gross rainfall, also differed between both the shade levels: 8.87% (±1.22) in the low shade level and 15.70 (±2.09) in the shade level systems. For small storms (less than 2 mm), interception loss values were very close to those of gross rainfall. For heavy showers, however, the relative value of interception loss became smaller.

Though climatic conditions are similar in the both shed levels studied, there is a clear difference in amounts of interception loss when comparing similar rainfall events. This implies that amounts of interception loss from the coffee agroforestry canopy did not only depend upon gross rainfall and climate conditions. Differences in interception loss between these close by coffee agroforestry may be related to differences in their structure.

Discussion

Also, the variability of throughfall in both systems decreased asymptotically with an increase in gross rainfall, as already shown (Gutierrez, 2007) in coffee agroforestry system in Costa Rica. For the rainfall events the spatial differences between systems, there were lower values of throughfall and higher values of interception loss in the HSLS compared to the LSLS during the study. The differences in the throughfall and interception losses between both systems can be explained by the higher density of shade trees and higher mean tree crown area in the HSLS compared to the LSLS (Table 1). Others studies by Gutierrez, 2007 and Huber and Iroume, 2001 have showed that canopy cover influence the canopy storage capacity, and therefore the throughfall. This is most probably also explains why such variability exist in the latter values, i.e. it is probably largely due to differences in rainfall characteristics and agroforestry structure between the type of shade levels studied. Moreover, it is clear from the relation between throughfall and storm size (Table 2) that the high CV of throughfall is the result of the large variability in rainfall classes. Nevertheless, we conclude from our results that when the method of systematic relocation of collectors is used to estimate this throughfall, it has a positive effect by reducing the standard error of estimations (Lloyd and Marques, 1988), which are essential in order to assess the combined effect of site vegetation structure and rainfall characteristics on throughfall.

The values of cumulative throughfall and interception loss which varied between 91.13 - 84.3% and 8.87 – 15.70% of the gross rainfall for both systems are within the ranges reported in the literature for various forest types and climatic zones (from 55 to 90%, according to canopy structure and climatic conditions) (Gutierrez, 2007 and Huber and Iroume, 2001). On the other hand, our data is higher for throughfall (82.12- 78.19%) and less for interception loss (16.99 - 18.25) measured under coffee agroforestry system at Kodagu, India (Maruti, 2010).

Conclusion

These rainfall characteristics largely explain the partitioning of rainfall into throughfall and interception loss in the agroforestry systems studied. The observed differences in throughfall and interception loss can partly be attributed to differences in vegetation structure. Their range is similar to the overall range in these parameters as published in earlier studies from the Amazon basin and Indian agroforestry systems, implying that the latter variability may very well be connected with differences in forest structure.

Results from the coffee agroforestry system studied provide some insight into the rates of interception loss from tropical agroforestry canopy and strengthen the understanding of the contribution of forests to atmospheric moisture. Moreover, this study of throughfall and interception loss in a range of agroforestry system demonstrates the relevance of vegetation structure for the interception of rainfall by the canopy and for the net precipitation reaching the forest floor. The results show that the structural characteristics together with the rainfall amount and rainfall duration are the main parameters determining rainfall partitioning in the coffee agroforestry systems of India.

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