Introduction and Objective

Few studies have examined the rates of stemflow generation in montane tropical forests because stemflow is considered a miniscule part of the water budget as it comprises only about 5 to 10% of incident precipitation [1]. The purpose of this study was to quantify and characterize stemflow generated during rain events in a pre-montane transitional forest in Costa Rica. The stemflow was then compared to the intensity, quantity, and duration of throughfall occurring nearby. Also, various rain characteristics were selected to observe the effect they have, if any, on stemflow generation. These characteristics include rain depth, intensity, duration, and antecedent dry period.

Methods and Materials

The study site was located within a 30-meter diameter stand in a pre-montane transitional forest within San Juan de Peñas Blancas, Costa Rica near the Soltis Center for Research and Education. The study was conducted during the month of July, one of the wettest months of the year in Costa Rica. A total of six Davis tipping-bucket rain gages were available for use on site. Three of these rain gages were attached to stemflow collectors, and the other three were used to collect throughfall adjacent to stemflow trees. The stemflow collectors were made of 3-centimeter diameter tubing cut lengthwise and nailed to the tree in a downward spiraling formation.

In this way, a drainage system was formed that caught water flowing down the trunk of the tree and routed it to a tipping-bucket rain gage. After attaching the stemflow tubes to the rain gages, the openings of the rain gages were covered with painter’s plastic to prevent any water that was not stemflow from entering. The rain gages were then connected to a datalogger to record the depth of water collected within 10-minute intervals.

Data Analysis

The analysis for this study focused on a number of different parameters corresponding to rain events over the course of a month. Rain events were defined as a minimum of 0.5 mm of rain falling within a 30-minute time interval and separated by two hours without rain. For each rain event the rain depth, duration, and antecedent dry period were calculated as well as the stemflow and throughfall depths and durations. The following equation [1] was used to convert the stemflow depth as measured by the rain gage to a depth that could be compared to throughfall and rain depths.

\[ S = \frac{(Sc \times Ac)}{B} \]

where:
- \( S \) = stemflow depth in equivalent units (mm)
- \( S_c \) = stemflow depth as measured by the rain gage (mm)
- \( A_c \) = area of the rain gage collector (cm²)
- \( B \) = basal area of tree (cm²) as idealized by a circle with diameter equal to the tree diameter at breast height (DBH)

In addition, a funneling ratio was found for each tree for each rain event. The equation [1] used to calculate the funneling ratio is as follows:

\[ F = \frac{S}{R} \]

where:
- \( F \) = funneling ratio
- \( S \) = the stemflow depth in equivalent units (mm)
- \( R \) = rainfall depth in equivalent units (mm)

Results and Discussion

Figure 2 demonstrates the relationship between rainfall depth and funneling ratio, or the depth of stemflow per millimeter of rain. The graph suggests that as rainfall depth increases the tree acts more like a funnel, channeling rainwater to the trunk.

Figure 3 displays a time series of the average rainfall, throughfall, and stemflow over 4 days during the study period. The inset graph shows the time lag and relatively long time duration characteristic of stemflow.

The boxplot in Figure 4 showing the flow durations (minutes) for the three throughfall gages, the three stemflow collectors, and the rainfall gage, demonstrates the high degree of variability in duration times for each stemflow collector. This is likely due to the varying parameters that affect stemflow duration including bark roughness, moisture condition, rain angle, intensity, and depth.

Another important observation of stemflow is the extent to which it is influenced by moisture conditions preceding a rain event. Figure 5 suggests that long antecedent dry periods result in decreased stemflow generation whereas short antecedent dry periods often correspond to large stemflow depths.

Figure 1 – Stemflow collector and receiving rain gage

Figure 2 – Funneling ratio per rainfall depth class for the three trees

Figure 3 – Rainfall, throughfall, and stemflow depth as a function of time

Figure 4 – Box and whisker plot of rainfall, throughfall, and stemflow durations for 37 rain events

Figure 5 – Average stemflow depth per antecedent dry period class

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