A NEW RAINFALL INTERCEPTION MEASURING SYSTEM

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INTRODUCTION

Almost every aspect of an ecosystem can be related to hydrology, such as storm runoff, soil erosion, and pollutant load (Sanders, 1986; American Forests, 1996). Understanding canopy rainfall interception is not only important to hydrology as a science, but also helps us better understand our own ecosystem and provide useful information for landscape management (Xiao et al., submitted). The net precipitation method has been used in most interception studies to describe interception based on gross precipitation, throughfall, and stem flow. Interception measurements have been conducted in both the field and laboratory (Aston, 1979; Lloyd, 1988; Li, 1997) but results have been limited by inadequate measurement techniques. Two common methods have been used in field measurements. Point measurements are accomplished by using funnels or rain gauges directly beneath the canopy. This method is easy to perform, but has large measurement errors (Kimmins, 1973). Area measurements using plastic sheets or troughs associated with tipping bucket or weighing type gages yield spatially correct averages, but adhesion of rainwater to the sheeting or other losses (such as splashing), combined with possible blockage of the collection gutter during large storms (Teklehaimanot et al., 1991) may induce large measurement errors. Some of these experiments have low temporal resolution (weekly or by bi-monthly events). More recently, the loadcell method (Lunderg, 1997) has the advantages of both point (easy to perform) and area measurement methods (spatially correct averages). The loadcell method measured interception well for natural forest conditions except during high winds. However, trees in urban settings are generally isolated with large spaces between them. Due to interarctions among factors influencing interception by open-groen trees (i.e. wind, rainfall, crown architecture) sampling is problematic. In this study, we developed and applied a rainfall interception measuring system that does not rely on spatial sampling under the tree crown and is suitable for use with individual trees that provides desired accuracy or temporal resolution.

OBJECTIVES

- Build a rainfall interception measurement system that provides highly accurate data at high temporal resolution.
- Demonstrate measurement of rainfall interception for two types of large, open grown urban forest trees.

THEORY

Canopy rainfall interception is the difference between gross precipitation (above canopy) and net precipitation (below canopy). Gross precipitation is commonly partitioned into throughfall, stem flow, and interception (Horton, 1919; Rutter et al., 1971; Liu, 1997). Some authors further partition throughfall into free throughfall and canopy drip, and interception into canopy storage and evaporation. These components can be measured directly (stem flow, throughfall, net precipitation, and canopy drip) or indirectly (canopy storage and evaporation). The accuracy of this partitioning is largely determined by measurement accuracy. Direct measurement accuracy depends on the sampling design and the measuring devices. In general, evaporation is estimated using the Penman method.

EXPERIMENTS

Measurement system. Throughfall, stem flow, net precipitation, and micro-meteorological data required for estimating evaporation were measured (Figure 1). The catchment, built under each tree, is larger than the tree crown projection area as to collect all rainfall and throughfall for wind speed less then 15 km/hr. The catchment consists of two sloping sides linked together by a plastic rain gutter. The catchment base was built with 2x4-inch lumber to make the system stable. Sheets of plywood were laid on the top of the 2x4 frame and four mil plastic sheeting was put the top of the plywood. The 25^{o} inclination angle of the plywood and smooth plastic sheeting surface minimized water travel time to the collection system. This design limited catchment surface detention to 0.045 mm based on field measurement. The tree is located in the center of the catchment. Based on a mass balance, water collected from the whole catchment was separated into rainfall and throughfall. Stem flow was directly collected from the tree trunk using a channel fabricated from one inch (25.4 mm) soft Tygon tubing that was spiraled around the tree trunk. Gaps between tubing and tree trunk were sealed with clear 100% silicone sealant. Gross precipitation was measured with a 6-inch (152.4 mm) diameter glass funnel linked to a precipitation container set at the upwind corner of the catchment. Rainfall interception data were collected at 30-second time steps using pressure transducers monitoring water depth in collection containers coupled to CR10 dataloggers. The pressure transducers were tested indoors before being used in the field. A final calibration was conducted in the field. The system correctly measures water depth until the container is full. Measurement accuracy depends on the pressure transducer used and the ratio of water collection area to the container area. The pressure transducer used in this study (Honeywell) has an error less than 2% over it's span. This yields a 0.01% maximum measurement error. Gross precipitation was measured with a Campbell Scientific Inc. TE525 tipping bucket rain gauge (0.25mm resolution). Tree crown dimensions were directly measured for each tree after the experiment.

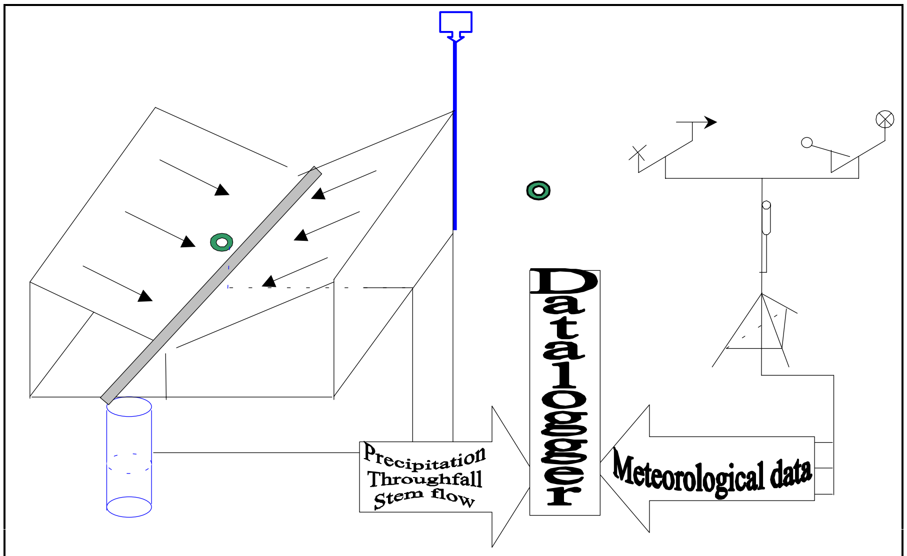


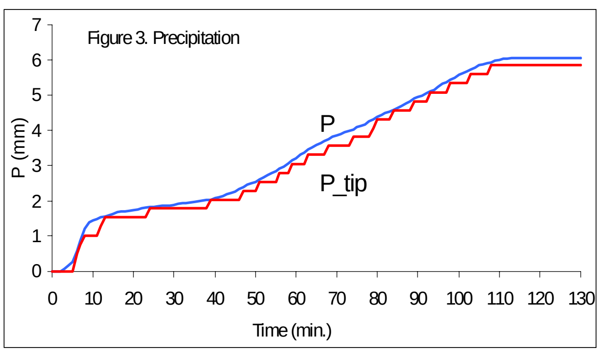
Figure 1. Rainfall interception measuring system

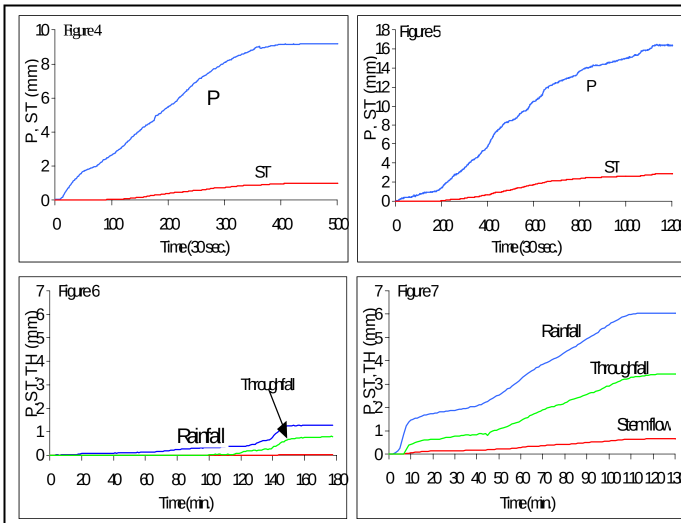
Study sites and materials. The rainfall interception experiment was located at the Department of Environmental Horticulture's field experiment site located in the southeast corner of the University of California, Davis campus (W 121°46'32", and latitude: N 38°32'09"). About 70% of the experimental field was covered by grass and 30% bare soil. A nine-year old broadleaf deciduous pear tree (callery pear) and an eight-year old broadleaf evergreen tree (cork oak) were selected for this study (Figure 2). These two trees are separated by 63 m. The pear tree was about 8.45 m height, 22 cm DBH, and the average crown diameter was 4.8 m. The oak tree was about 5.6 m in height, DBH 8.0 cm, and the average crown diameter was 3.2 m.

Figure 2. Rainfall interception measuring setup for pear tree (left) and for oak tree (right)

RESULTS

During our 1996-1997 field study, the measurement system worked reliably. Figure 3 shows a rainfall hydrograph measured from this system (P in figure 3) and from a tipping bucket rain gauge (P_tip in figure 3). Two data sets compared well except the former data set has higher temporal resolution. Figures 4 and 5 show gross rainfall and stem flow hydrograph for a small and a large rainfall event for the pear tree. Initially precipitation wets the canopy surface. There is a time lag between onset of precipitation and stem flow or throughfall. This is shown in Figures 6 and 7 for a small and a larger rainfall events at the oak tree site. Stem flow was not observed in the small rainfall event (Figure 6), but in the larger event stem flow was more than 10% of gross precipitation (Figure 7). The ratio of stem flow to precipitation at different rainfall rates is listed in the Table 1. The ratio of stem flow to precipitation increased with increasing precipitation and is larger than we found in the literature (Rutter et al., 1977; Jetten, 1996) that has been used for estimation stem flow in their numerical modeling. The ratio of stem flow to gross precipitation is larger for the pear tree compared to the oak tree. Three factors





account for this. During the winter, the pear tree was leafless, resulting in larger stem surface directly exposed to precipitation. The oak tree was in leaf partially sheltering the stem surface from rain drip, thereby reducing direct interception by stem surfaces. Compared with the oak tree, the pear tree has a smoother bark surface that limits interception loss by reducing both surface detention storage and travel time from branch to ground surface. Finally, most branches in the pear tree has angles greater than 0^o (from horizontal toward vertical), which makes the water flow on the branches downward until they converge to the main trunk.

Table 1. Stem flow at different precipitation

Precipitation (mm)	Stem flow / precipitation	
	Oak tree	Pear tree
1	0%	1%
2	1.5%	5%
3	1%	22%
4	8%	20%
5	8%	14%
6	11%	14%

DISCUSSION AND CONCLUSIONS

- High temporal resolution and highly accurate measurements of canopy rainfall interception at individual tree level can be accomplished with our measuring system. The measuring error is on average less than 0.01%. This rainfall interception measuring system is reliable and easy to build. Wind does not affect the measurements.
- The datalogger and the pressure transducers consume power at very low energy (0.5-13 mA and excitation current 2 mA), but pressure transducers measurements are very sensitive to power supply voltage, therefore a constant voltage power supply is needed. Also, the container must be frequently emptied during heavy or long storm events to maintain continuously accurate data collection.
- Falling litter (for long term measurement) did not block the gutter but regular removal is necessary to minimize detention storage.

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