Improving Water Resource Assessment in Hawaii by Using LiDAR Measurements of Canopy Structure to Estimate Rainfall Interception

Problem and Research Objectives

Water resources in Hawai'i continue to experience increasing demand, putting pressure on existing sources and increasing the need for better estimates of resource capacity (Oki 2002). For groundwater sources, in particular, reliable estimates of sustainable yield limits are critically important. Groundwater recharge estimates, in turn, are needed to determine accurate safe yield limits. Recharge is highly spatially variable in Hawai'i (Giambelluca 1983) because of extreme gradients in precipitation and evapotranspiration (ET). The accuracy of recharge estimates in Hawai'i has been limited by a lack of direct measurements of ET within forested recharge areas.

Recent research has improved our knowledge of stand-level ET in Hawai'i and pointed to the need to better understand interception loss—the amount of rainfall intercepted by leaves and stems and subsequently evaporated (Giambelluca et al. 2009). The amount of interception loss, which can vary from 10% to 50% of incoming precipitation (Roth et al. 2007), is strongly influenced by canopy structure (especially canopy gap fraction); leaf, stem and epiphyte storage capacity; and branch angle (Rutter et al. 1975; Gash 1995), and, hence, is highly variable across the forested landscape.

Alien trees, some of which—such as *Psidium cattleianum* (strawberry guava)—are highly invasive, are markedly different in structure from native trees such as *Metrosideros polymorpha ('ōhi'a).* Very little is known about the rate and spatial variability of interception loss and the effects of alien tree introductions on interception in Hawai'i. Better estimates of interception are needed to improve water-resource assessments. Such improvements would be highly valuable to water-supply purveyors of the various counties and state water planners. The traditional method for measuring interception, based on canopy water balance, is difficult and very limited in spatial coverage. However recent advances in ground-based and airborne Light Detection and Ranging (LiDAR) technology offer the promise of spatially-distributed estimates of interception using a physically-based approach (Roth et al. 2007).

Methodology

We used a ground-based LiDAR system to map the three-dimensional above-ground biomass distribution at two study sites within Hawai'i Volcanoes National Park. The two sites represent an intact native *M. polymorpha* forest and a *P. cattleianum*-dominated invaded forest.

At each site we were already operating a flux tower fully equipped with eddy-covariance, micrometeorological, and canopy-water-balance sensor systems. Using LiDAR we acquired high-resolution scans of each stand (Figure 1) over an area of 0.36 ha surrounding each tower.

In an adaptation of the Gash (1995) revised analytical interception model, these data are used to determine the following canopy structural parameter values: canopy capacity, canopy cover fraction, trunk storage capacity, free throughfall coefficient, and fraction of water diverted to stemflow. We are using the model to estimate throughfall (TF), stemflow (SF), and interception (I), and compare the results against our measurements of TF and SF at each site.

Principal Findings and Significance

This work is still in progress. To date we have completed the LiDAR scans at the two field sites in Hawai‘i Volcanoes National Park (Figure 1). These data are currently being analyzed

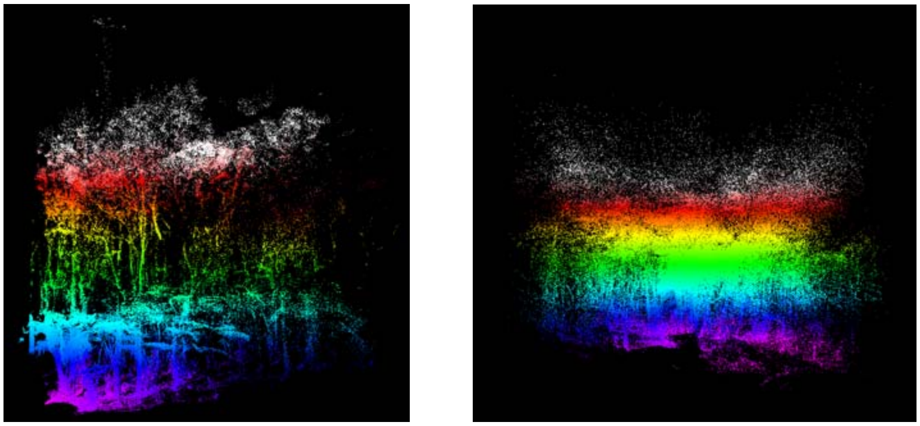

Figure 1. Image derived from high-resolution LiDAR scans done at Thurston Lava Tube (left) and Ōla‘a (right).

and new methods are being developed to extract information relevant to setting parameter values in a canopy rainfall interception model. Based on preliminary analysis, vertical biomass profiles have been derived for the two sites (Figure 2).

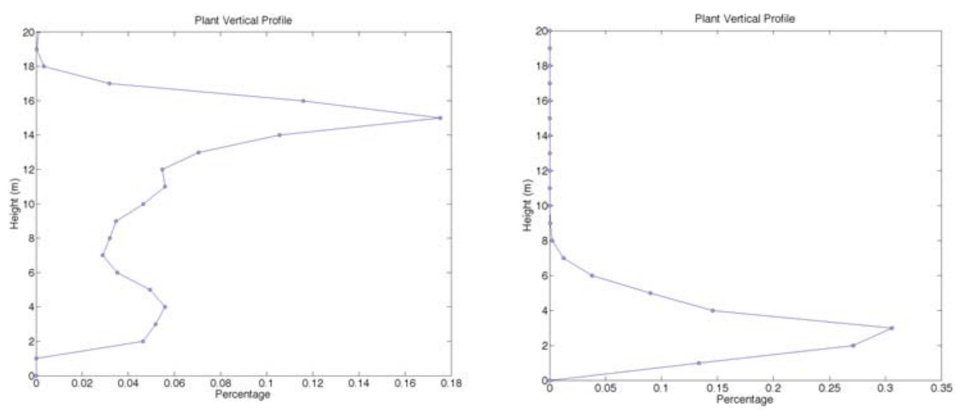

Figure 2. Vertical biomass profiles derived from high-resolution LiDAR scans done at Thurston Lava Tube (left) and Ōla‘a (right).

We are also developing and testing a new interception model to take advantage of the vertical detail in canopy-structure information we expect to be able to obtain from the LiDAR data. The new model divides the vegetation into three layers to represent the crown, subcrown, and fern layers of the canopy. In addition, epiphytes will be represented separately in each layer.

The model differs from other interception models by explicitly accounting for water storage and movement at different levels in the canopy. Utilizing LiDAR-derived information on the vertical distribution of leaf, branch, and stem mass, vertical variations in both water storage and evaporative demand are represented in the model. This allows for more realistic simulation of the wetting, drainage, and drying process. Figure 3 shows a preliminary model simulation of throughfall and stemflow at the Ōla‘a site for a storm in June 2007.

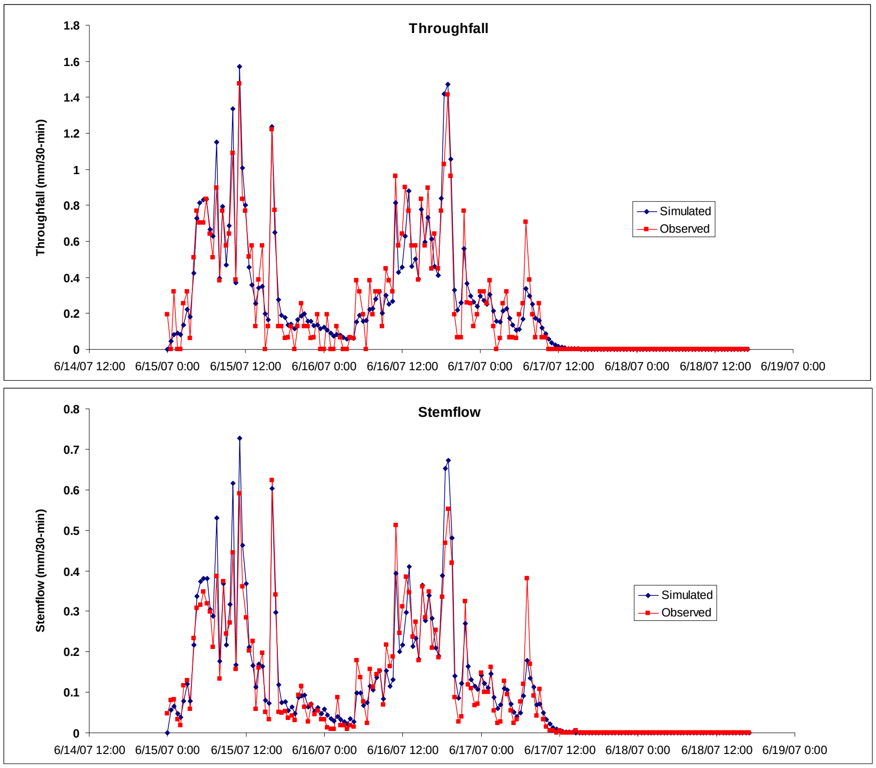

Figure 3. Simulated and observed throughfall (top panel) and stemflow (bottom panel) for a sample period in June 2007 at the Ōla‘a study site.

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