Fog Contributions to Pedogenesis and Hydrology in *Pinus muricata* Ecosystems on Santa Cruz Island

Randal Southard* and Julie Baker

**Project Objectives**

1. Characterize isotope signatures of rainfall, fog, soil solution, and pedogenic phyllosilicates;
2. Identify precipitation inputs from rainfall versus fog drip for soils under Bishop pine (*Pinus muricata*) canopy versus grassland;
3. Characterize soil temperature and moisture regimes, determine depth of wetting of rain and fog, and describe soil morphology and genesis on a lithosequence under pine forest;

**Approach and Procedures**

Pairs of artificial rain and fog drip collectors (Fischer and Still 2007), along with throughfall collectors, were installed in pine canopy (north-facing slope) and grass/shrub (south-facing slope) ecosystems on chlorite schist and rhyolitic tuff/breccia parent materials (*table 1*). Soil samples at 5-cm depth increments were collected during rain and fog events, and the soil solution was vacuum extracted and analyzed for stable hydrogen and oxygen isotopic composition, along with water from throughfall collectors. Soil temperature sensors (HOBOs) were installed at a depth of 50 cm at each site. Four soil moisture sensors were installed at each pine site at approximate depths of 5 cm, 10 cm, 15 cm, and 20 cm to measure depth of fog wetting.

Soil profiles were excavated at each site and described. Soils were characterized by morphologic horizon and the <0.2 µm fraction extracted (Jackson 1975; Soil Survey Staff 2004). This fine clay fraction, which most likely represents authigenic minerals, will also be analyzed to determine stable isotope ratios to compare to water values (Clayton and Mayeda 1963; Tabor et al. 2002). Pine and grass litterbags at each site were set out and continue to be harvested, weighed to determine decomposition rate, and analyzed for C and N content.

**Results and Discussion**

Throughfall water isotope δ18O values range from -2.0 to -4.5 for fog and from -4.0 to -6.7 for rain (*figs. 1 and 2*). The δ2H values follow a pattern similar to δ18O (data not shown). These values match well with the range of data points (*fig. 3*) collected by Doug Fischer at UCSB (Fischer and Still 2007). Throughfall collectors were emptied every 2-3 months, and sometimes contained a mix of rain and fog waters. Local meteoric water lines for rain, fog, and mixed waters were calculated from these data (*fig. 4*).

---

*Soils and Biogeochemistry Graduate Group, Land, Air and Water Resources, University of California
Davis, CA 95616

*Principal Investigator
Extracted soil solution isotope values indicate piston flow of water with each precipitation event (fig. 5). For example, the March 2006 rain event brought lighter water into about the top 10 cm of the profile, while heavier water was pushed down deeper into the profile. Similarly, the soil water profile from the May 2006 fog event shows heavier water near the surface of the soil, while lighter water is pushed deeper into the profile. Soil solution in open areas was heavily influenced by evaporation, while soil solution under pine canopy did not show strong evaporation effects. In the grass sites, extracted soil solution shows an enriched isotope signature over fog values, and plots off the meteoric water line, indicating that fractionation during evaporation has occurred.

Soil moisture probes under pine canopy have recorded soil water content at incremental depths (fig. 6, only Sierra Blanca is shown). In general, water content is greater in the profile, although during summer fog events, water content near the surface increases and may sometimes infiltrate deeper. Although fog water does not provide enough moisture deeper in the profile to influence the soil moisture control section, the additional moisture does influence decomposition rates and the pine trees may be able to take advantage of this water, as evidenced by the many very fine and fine roots found to the depth of fog wetting.

Litterbag decomposition rates were highest under pine canopies at both sites for both pine and grass litter (figs. 7 and 8). The extra available moisture from fog drip appears to aid decomposition even though temperatures are higher at the grass sites. In addition, the Weather Station sites (schist) had higher decomposition rates than the Sierra Blanca sites (rhyolitic tuff). This may be explained by a difference in measured precipitation at the two sites, perhaps due to the difference in elevation. Average total precipitation for 2006-2008 was 19.7 cm/year for Weather Station and 13.7 cm/year for Sierra Blanca. Summer (June, July, and August, when most fog events occur) soil temperatures averaged 16 °C at the pine sites and 27 °C at the grass sites, while winter (December, January, February, when most rain events occur) temperatures averaged 12° and 16°C at the pine and grass sites, respectively.

Based on our research to date, fog intercepted by pine vegetation does appear to contribute to the local hydrology of the soils under pine canopy. We have traced fog water into the soil profile using the stable isotope methods, and the microclimates created by the canopy/open distinction affect decomposition. Soils under pine canopy are deeper and more developed (as indicated by clay illuviation) than adjacent soils in open areas. Although it is difficult to separate the effects of climate and vegetation on soil formation, we anticipate that the differences in soil climate and water source will also be apparent in the pedogenic phyllosilicates once the mineralogical work is complete.

References


Jackson, M.L. 1975. Soil chemical analysis—advanced course. 2nd Edition. Published by the author, Madison, WI.


**Table 1. Fog collector locations**

<table>
<thead>
<tr>
<th>Site</th>
<th>Weather Station</th>
<th>Sierra Blanca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent Material</td>
<td>Chlorite schist</td>
<td>Rhyolitic tuff/ breccia</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Grass/ scrub</td>
<td>Bishop pine</td>
</tr>
<tr>
<td></td>
<td>Grass/ scrub</td>
<td>Grass/ scrub</td>
</tr>
<tr>
<td>Elevation (ft)</td>
<td>1400</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td>930</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>50</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>Aspect (°)</td>
<td>150</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>310</td>
<td>336</td>
</tr>
<tr>
<td>Avg. Soil Temp. (°C)</td>
<td>21.6</td>
<td>20.3</td>
</tr>
<tr>
<td></td>
<td>13.9</td>
<td>14.2</td>
</tr>
<tr>
<td>Soil Temp. Regime</td>
<td>thermic</td>
<td>thermic</td>
</tr>
<tr>
<td></td>
<td>mesic</td>
<td>isomesic</td>
</tr>
</tbody>
</table>
Figure 1. Throughfall $^{18}$O composition at Sierra Blanca and Weather Station sites under pine canopy.
Figure 2. Throughfall $^{18}$O isotopic composition for Sierra Blanca and Weather Station sites in open grass/shrub ecosystem.
Figure 3. Isotopic composition of fog and rain water near Sierra Blanca. “Fog” values for rainy months are a mixture of fog and rain water. Dry season fog water is consistently enriched compared to rainy season fog/rain water. From Fischer and Still (2007).
Figure 4. Local meteoric water lines (LMWL) for fog, rain, and mixed waters collected in throughfall collectors at all sites.
Figure 5. Stable $^{18}$O isotopic composition of vacuum extracted soil solution with soil profile depth at all sites.
Figure 6. Soil water content (m$^3$/m$^3$) over time at depths of 8, 15, 20, and 25 cm at the Sierra Blanca site.
Figure 7. Decomposition rate of pine litter at all sites.
Figure 8. Decomposition rate of grass litter at all sites.

This research was funded by the Kearney Foundation of Soil Science: Understanding and Managing Soil-Ecosystem Functions Across Spatial and Temporal Scales, 2006-2011 Mission (http://kearney.ucdavis.edu). The Kearney Foundation is an endowed research program created to encourage and support research in the fields of soil, plant nutrition, and water science within the Division of Agriculture and Natural Resources of the University of California.