Hydrological fluxes of a crest laurel subtropical forest in the Garajonay National Park

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Introduction

- The presence of the evergreen laurel forests of the Canary Islands contrasts sharply with the aridity (< 600 mm year⁻¹) of the lower zones of the islands. Thus in addition to conventional precipitation, wind-driven fogs may be considered as an additional source of water for the laurisilva ecosystem.

- Traditionally it is assumed that the existence of such laurel forests in the Garajonay National Park (La Gomera) is related to fog precipitation phenomena, but without taking into account the complexity of the fog interception process and its relationship to other hydrological variables.

Based on a two-year measurement campaign in a selected 43.7 ha watershed (N28°07'42", W17°51'34") within the Garajonay National Park, we quantify and evaluate the role of forest evapotranspiration, fog and conventional precipitation, by a combination of different physically-based models and monitored meteorological data.

Materials and methods

Instrumentation

- Vegetation in a selected plot within the watershed was mapped in detailed and a scaffolding tower equipped with micrometeorological instruments. Climatic data was collected from February 2003-January 2005 at 3 min. intervals.

- Gas exchange characteristics of representative laurisilva species were measured with a LCpro portable photosynthesis system (ADC Bioscientific Ltd.).

- Fog water was measured with a 0.5x0.5 m standard fog collector (QFC) covered with a Raschel type propylene mesh with 65% shade coefficient installed on top of the scaffolding tower.

- Fog water impaction model

Fog water captured by vegetation is assumed to result from an impaction process of fog droplets onto cylindrical vegetative elements (needle-like leaves of E. arborea trees).

Thus the impaction model assumes that fog water flux is proportional to:
- fog liquid water content
- cross-section of cylindrical elements (needle-like leaves and mesh elements of the QFC)
- capture efficiency of the impaction process
- effective wind velocity

Air liquid water content was computed applying the above model to the artificial fog collector data, taking into account the design characteristics of the QFC (Fig. 4).

Evapotranspiration

Potential evapotranspiration ET₀ (mm) was estimated with Penman-Monteith approach (www.icia.es/gh/software.html) taking into account species-specific derived leaf stomata conductance dependencies on global radiation and temperature.

Additionally, the following considerations take into account the particularities of the laurel forest vegetation:
- LAI was taken as 0.14 close to the value proposed for evergreen subtropical forests.
- The active leaf area index was computed from LID-4.2, reduced by a shelter factor of 1.25.
- The wind speed at the top of the canopy was computed from measurements at the top of the tower and the logarithmic wind-speed profile assumption.

Wet canopy evaporation rate

Wet canopy evaporation rate was computed by setting to zero the surface resistance in the Penman-Monteith equation.

Water intercepted by vegetation

The interception process was described following Rutter et al. (1971), whereby the interception losses are computed from a water balance at the stand and the stem level. This model considers that the amount of fog, F (l m⁻²) and rainfall, P (mm) water stored in the canopy changes with time as a result of evaporation and drainage. When the canopy storage capacity is exceed, water drips to the ground.

Water contribution to the soil

The fog water and precipitation that may reach the soil surface Lₑ (mm) was computed as throughfall (Pₑ) + water dripping from the canopy and stems (Dₑ).

Results

Table 1. Annual totals of the hydrological variables studied.

<table>
<thead>
<tr>
<th></th>
<th>F (mm)</th>
<th>P (mm)</th>
<th>ET₀ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 1</td>
<td>315</td>
<td>542</td>
<td>690</td>
</tr>
<tr>
<td>Period 2</td>
<td>370</td>
<td>565</td>
<td>800</td>
</tr>
<tr>
<td>Period 3</td>
<td>412</td>
<td>510</td>
<td>900</td>
</tr>
</tbody>
</table>

Table 3. Annual totals of water contribution to soil.

<table>
<thead>
<tr>
<th></th>
<th>Nₑ mm</th>
<th>Pₑ mm</th>
<th>Dₑ mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 1</td>
<td>732</td>
<td>60</td>
<td>108</td>
</tr>
<tr>
<td>Period 2</td>
<td>814</td>
<td>76</td>
<td>135</td>
</tr>
<tr>
<td>Period 3</td>
<td>906</td>
<td>84</td>
<td>153</td>
</tr>
</tbody>
</table>

CONCLUSIONS

- Although rainfall is subject to seasonality, rainfall events during the humid season are responsible for most water inputs.
- The fog water collected by the vegetation represents a 20-45% surplus of the conventional precipitation, being mainly significant during summer.
- These conclusions are constrained to well-exposed windward areas of the Garajonay National Park with high density of needle-leaved E. arborea trees (favourable for fog water capture).
- The dependence of stomatal conductance on temperature and global radiation exhibited by the laurel forest vegetation, under the climatic conditions of this area, results in low evapotranspiration rates during the wet season.

Fig. 1. Location of the plot in the selected watershed.

Fig. 2. Micrometeorological instrumentation installed in the scaffolding tower.

Fig. 3. Fog droplets captured by needle-leaved E. arborea trees.

Fig. 4. Schematic of the model developed to compute fog water intercepted by needle-leaved E. arborea trees from the fog collection data obtained with the QFC.

Fig. 5. Monthly hydrological variables during the periods studied.