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Interception of water by pastures of *Pennisetum clandestinum* Hochst. ex Chiov. and *Melinis minutiflora* Beauv.

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ABSTRACT

The conversion of montane cloud forests into pastures for grazing cattle is the main cause of important impacts on rivers and streams in most of the Andes. In order to evaluate the effects of vegetation changes we need to understand water fluxes, particularly canopy interception. We measured net precipitation responses by the canopies of *Pennisetum clandestinum* Hochst. ex Chiov. and *Melinis minutiflora* Beauv. under simulated rainfall. The samples were taken from grazed pastures during 1 year, digging out round mats of grass, placing them on wire-mesh devices after eliminating soil and underground biomass, and irrigating with different water amounts. The resulting data allow us to present a validated model for each species that predicts percentage of interception at different precipitation intensities taking into account previous canopy wetness within determined biomass ranges. We use these models to estimate 2 years of interception values for pastures of both species in the upper watershed of El Cañadón, Capaz River, Venezuelan Andes. Mean annual precipitation of El Cañadón is 1244 mm and the estimate of pasture interception was 36.5% and 31.8% for *P. clandestinum* and *M. minutiflora*, respectively. Interception models, such as the ones derived in this study, provide a basis for quantifying interception rates as a function of previous wetness of canopies and grass species.

1. Introduction

Andean cloud forests play an important role in watershed hydrology. The conversion of montane cloud forests into pastures or into various types of crops is the main cause of important impacts on rivers and streams (Bruijnzeel, 1990, 2001). One of the most significant effects of the changes in the vegetation due to human activities is the alteration of the water dynamics in the systems (Bruijnzeel, 1990; Bruijnzeel and Proctor, 1995; Cavelier and Vargas, 2002; Ataroff and Rada, 2000). In most of the Northern Andes, cloud forests have been replaced by pastures for grazing cattle, mainly by two African grasses *Pennisetum clandestinum* Hochst. ex Chiov. and *Melinis minutiflora* Beauv. (Ataroff, 2001, Cavelier et al., 2001). Understanding the water balance and main fluxes in ecosystems and agroecosystems is necessary in order to evaluate the effects of vegetation changes on catchments runoff. Canopy interception (the proportion of rain water retained and evaporated by vegetation) is one of these important fluxes as it determines the proportion of water reaching the soil.

Interception depends on the characteristics of precipitation and vegetation canopies. Pasture and prairie canopies have a particular structure and foliage mass that differs from other better studied canopies, such as forest canopies, and consequently need different methodological approaches (Clark, 1940; Seastedt, 1985; Acevedo and Sarmiento, 1990; Ataroff and Sanchez, 2000; Brye et al., 2000; Rincón et al., 2005).

Interception estimates based on net precipitation (throughfall plus stemflow) are relatively easy to study in forests. However, in pastures with mat-forming grasses (lawn hyphen like grasses), interception is hard to measure, in most cases as a consequence of the complicated aerial architecture of those systems. The use of mini-gutters (or similar devices) placed on the soil surface and under the grass canopy may lead to erroneous estimates of net precipitation. Rincón et al. (2005) using this method, found lower net precipitation values compared to soil water content. The main purpose of the present study was to model the interception of *P. clandestinum* Hochst. ex Chiov. and *M. minutiflora* Beauv., two mat-forming grass species commonly cultivated in deforested areas of cloud forests in the Venezuelan Andes. The model was based on experimental data using simulated rains under laboratory conditions and taking into account previous canopy wetness within determined biomass ranges. We used the resulting models to

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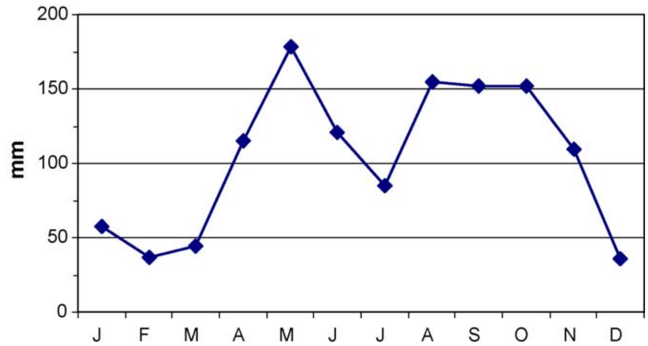

Fig. 1. Annual precipitation for the study area (mean of 2005–2006).

estimate the interception of two pastures of the cited grasses in El Cañadón, Mérida State, in the Venezuelan Andes.

2. Methods

2.1. Study area

Samples of both grass species used in this study were taken from the farm El Cañadón (x: 239561, y: 962642, Projection UTM, Datum WGS84, Zone 19N), 2200 m asl, in the upper basin of the Capaz river, Mérida State, Venezuelan Andes. The original vegetation of the area corresponded to an upper montane cloud forest with a complex structure, an irregular canopy at 30 m and supporting a high diversity of epiphytes (Ataroff, 2001). The most frequent tree species include: *Retrophylum rospigliosii, Myrcia acuminata*, *Clusia multiflora*, *Alchornea triplinervia, Prunus sphaerocarpus, Guarea kunthiana,* and *Billia columbiana* (Engwald, 1999). Currently, only scattered fragments of the original forest remain since they have been replaced by pastures of *P. clandestinum* (kikuyo pasture) and *M. minutiflora* (capín melao or yaraguá pasture) for cattle raising. The mean annual temperature for the area is 14.5 °C and the annual rainfall for the 2005–2006 period was 1241 mm (Fig. 1) measured every 10 min with a rain gauge (TE525) connected to a datalogger (Campbell CR10X).

P. clandestinum pastures occupied the bottom of the valley in the study area, while *M. minutiflora* was found in top and hillside positions. The animal load for the whole farm corresponded to approximately one cattle head per ha, considered as a semi-extensive grazing system.

2.2. Experimental design

During the year 2005, every 2 months we collected six circular samples of 306 cm^2 for each pasture species and carefully transported them to the laboratory. In the laboratory, the soil and the underground biomass of each sample were eliminated. We then placed the aerial biomass above a wire-mesh screen of the same diameter as the sample which was installed over a funnel supported by a collector container (Fig. 2). The sample was protected by plastic walls. Simulated rain was applied equivalent to 2.5, 5, 10, 20, 50 and 80 mm and 2.5, 5, 10, 20, 50 and 80 mm h^{-1}, distributed in four applications of same volume each separated by 15 min. The nozzle used to generate the simulated rain produced 77% of drops smaller than 4 mm.

We considered net precipitation to be the water that crossed the canopy and reached the collector container. All experiments were conducted in the laboratory less than 24 h after harvesting the samples. Net precipitation was measured every 5 min for 2 h, and in all cases the final drainage was below one drop/min. We repeated the experiment under dry and wet canopies for each sample. The canopy was considered dry when no visible traces of

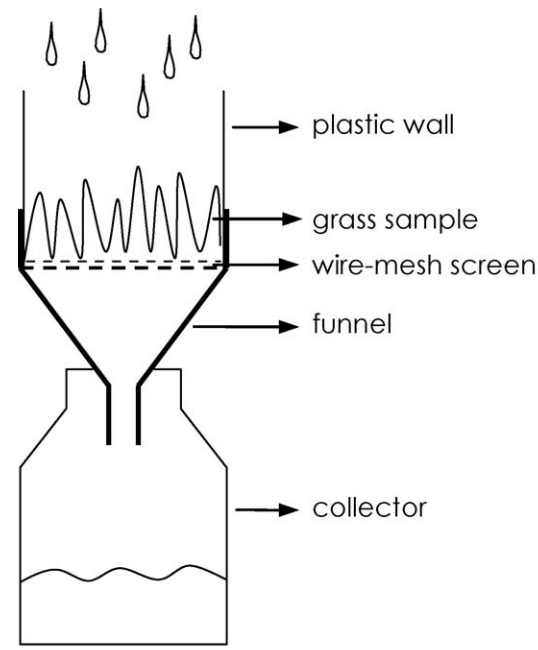

Fig. 2. Schematic design of the device used for experimentally measuring interception by mat-forming grasses.

water were found over the vegetation (leaves and culms) and the canopy had not been exposed to rain for approximately 24 h. The canopy was considered wet when it had received rain between 3 and 14 h before the experiment and showed water droplets on the surface of leaves and culms.

Interception was calculated as the difference between the simulated rain and net precipitation. Additionally, we measured the dry weight of the aerial biomass and necromass for each sample.

As in other studies on pasture ecohydrology (Ataroff and Rada, 2000, Rincón et al., 2005), we assumed that cloud water interception is insignificant, even though it needs to be further studied.

Interception estimates for a 2 year period in El Cañadón were obtained applying the resulting models from this study to every precipitation event during 2005 and 2006, recorded every 10 min, considering the canopy to be dry after 4 daytime hours or 10 nighttime hours with rainfall less than 1 mm.

2.3. Analysis of data

The comparison between the hydrological response of the wet and dry canopies, as well as between species, was carried out with t tests for independent samples (Pardo and Ruiz, 2001). We calculated the partial correlations and one way ANOVA to evaluate the relationship between interception and plant mass (Pardo and Ruiz, 2001).

We present a model of interception as a function of precipitation for each species, considering the previous wetness of the canopy. Since it is necessary to validate each model in order to know its prediction capability on independent data, we used the cross-validation method (CV) for estimating the prediction error. The cross-validation method directly estimates the extra-sample error, which is the generalization error when the prediction model is applied to an independent test sample (Hastie et al., 2001).

3. Results

3.1. Ecohydrology of the mat-forming grass canopies

Laboratory experiments on interception by the canopies of both species showed that drainage (equivalent to the net precipitation)