DEVELOPMENT OF NEW EQUIPMENT FOR MEASUREMENT OF RAINFALL INTERCEPTION IN EUCALYPTUS PLANTED FORESTS

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ABSTRACT

Uruguay has stimulated the development of its forest sector generating the need of studies about the impact of the production. One of the afforestation effects is the change in the rainfall; this transformation is known as redistribution and the main part is the rainfall interception caused by the canopy. One of the important things to model this phenomenon is perform continuous monitoring programs that allow taking long-term studies. Although there are different strategies require extensive maintenance and are complex to implement. The purpose of this development was the upgrading of equipment used for measurement and quantification of the interception of rainfall minimizing possible sources of measurement error, maintenance and getting more information for further studies. In five months of work the new prototype was successfully built following the upgrading design criteria, increasing the autonomy and improvement the gauge system for the measured. The equipment has had a good performance and it is anticipated further improve according to the needs of data and applications for watershed studies.

Keywords: water balance; eucalyptus; rainfall interception.

1. INTRODUCTION

Uruguay has stimulated the development of its forest sector since the promulgation of Forest Law Nº 15939 in December of 1987. Nevertheless, the substitution of natural grasslands with forest plantations for industrial use has raised concerns regarding hydrological processes of groundwater recharge and water consumption involving evapotranspiration. From the University some years ago has started to study the effect on the change in land use for afforestation (Silveira and Alonso, 2009; Silveira et al., 2011). One of the afforestation effects is the change in the rainfall; this transformation is known as redistribution (Rutter et al., 1971; Huber and Iroumé, 2001). A fraction of rainfall through the canopy, through the space between trees or drip, and reaches the ground constituting throughfall precipitation, while another runs off the leaves and branches to reach the main trunk, and then trickles down his surface to reach the ground, constituting stemflow. This process of redistribution of rainfalls and therefore the amount of water actually reaching the soil surface depends mainly on the type and density of the canopy in addition to climatic factors (evaporation rate and intensity of rainfalls). Some studies in others regions have found trends emphasizing the importance of rainfall interception in the water balance for a watershed with afforestation (Valente et al., 1997;Iroumé and Huber, 2000). Similar patrons are found in Uruguay but need more study of this process (Silveira and Alonso, 2009; Silveira et al., 2011). One of the important things to model this phenomenon is perform continuous monitoring programs that allow taking long-term studies by reducing the sources of error and minimizing the need for maintenance on the equipment used for measurement. The purpose of this development was the upgrading of equipment used for measurement and quantification of the interception of rainfall minimizing possible sources of measurement error and getting more information for further studies.

2. DEVELOPMENT OF THE MEASURING EQUIPMENT

2.1 Fundaments

For the water budget equation in an afforested watershed interception loss from the tree canopy is defined as in the Eq.[1].

$$I = P - (Pd + Pf) \qquad [1]$$

Rain falling over forest cover is redistributed into three components according to equation Eq.[1]. P is the incident rainfall, Pd is the throughfall and Pf is the stemflow. Interception losses (I) are computed as the difference between incident rainfall and the sum of throughfall and stemflow. P is well known and is measured by a conventional rain gauge. For the measure of Pd and Pf there are a variety of strategies as they are more complex variables to register (Iroumé and Huber, 2000; Reid and Lewis, 2009; Mair and Fares, 2010). For this development of the equipment was used a combination of this strategies.

2.2 Previous prototypes

In previous studies the interception losses was measured using the methodology applied by Iroumé and Huber (2000). According to the methodology throughfall was recorded using a galvanized steel gutter with a triangular cross section of 0.15 m in width and 35 m in length (a catchment area of 5.25 m^2). It was installed in the direction of the catchment's natural slope and positioned diagonally between two rows of trees to take into account natural variations in the canopy. The collected throughfall was channelled into a 600-litretank in which water level variations were recorded by a standard logger. The tank was emptied through a small drain pump that was automatically operated by a level sensor and that was powered by a 12-volt battery. For the steamflow measure ten trees positioned close to the galvanized steel gutter were selected and rubber collars were sealed around the trees. These collars were connected to a 50 mm-diameter PVC pipe that channelled the stemflow to a main pipe below the gutter, which was connected to a second 600-litre tank with the same recorder method. Two loggers were needed; one per tank, and the measured recorder was the level of water in the tank.

2.3 New equipment

The main criteria for the development was continue using a redistribution plot with a galvanized steel gutter with a triangular cross section for the throughfall and rubber collars around the trees for the steamflow applied by Iroumé and Huber (2000). But, one of the big problems in this system was the pump for the emptying of tanks, this process had great energy consumption and the two 12-volt batteries used lasted only a month. Another thing to change was the system of measurement, recording pulses corresponding to known volumes (buckets) and no levels of accumulated water inside the tank. If the water is not accumulated measurements obtained have higher resolution throughout the duration of the event rainfall. The solution was change the recorder system and use bucket mechanism, similar to Mair and Fares (2010), but applying the system in the two case, steamflow and throughfall (Liu et al. 2013) with a unique logger system which processes all the data. The dimension of the bucket was estimated used historical database of rainfall in the area where it would be installed. With extreme conditions and avoid the loss of water in the measure was established de size of the bucket in 0.250l per tip. Others criteria were related to the way in which the data were stored. One datalogger was necessary for all the system with long life battery and big capacity in the memory for storage the data.

3. RESULTS

The development was successful and managed to build new equipment in five months of work. This equipment combined the two model design, the plot and the tipping bucket gauge system. Comprised four stationary collectors with bucket mechanism equipped with actuator, switch output connected to a single event-based data logger. In the plot have for the throughfall measures four collector troughs, two per stationary collector. For the steamflow measures have ten collectors (pipes of 30cm diameter) for the rubber collar of the threes, five trees and pipes per stationary collector (Fig.1). For the data recorder was building a logger used pic microchips microprocessor and programmed four impulse inputs (one per actuator) and drivers for the use of sd card.

Figure1. (a) The equipment comprised four stationary collectors with gauge system, four collectors troughs and ten collectors for the rubber collar of the threes. (b) steamflow gauge system and (c) throughfall gauge system both of them comprised with a tipping bucket mechanism equipped with actuator, switch output.

The area where was tested the equipment is located in western Uruguay in the department of Paysandú. There are experimental watersheds covered with an adult plantation of Eucalyptus *Globulus ssp*.

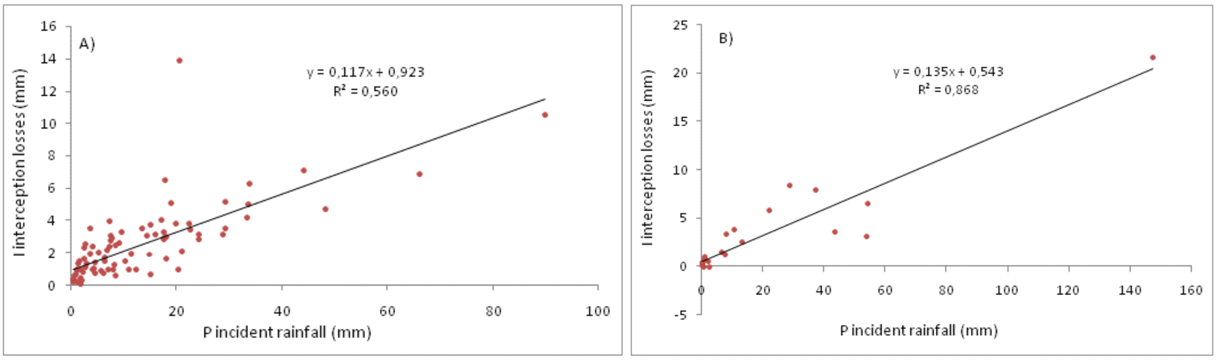

Figure 2. (a) Simple lineal regression for the first two years of data since 2008 to 2009 in a watershed near to watershed in the study with the old prototype. The slope corresponds to the interception coefficient. (b) The same approach for the year 2015 data in the watershed of the study and with the new equipment.

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In one of these watershed was installed the new redistribution plot since January of 2015. The logger recorded successfully the data in the sd card (2 GB), one year of data with a bucket of 0.250 litres per tip, 200Kb in the sd card and the battery life was six moth. The first analysis showed that the calculated interception with the new equipment was similar to that estimated for trees of that age with the previous methodology (Fig.2). Interception was 11.7 % of the incident rainfall for two first years of data (2008-2009 with 98 rainfall events) in other watershed near to the study area and with the same plantation of Eucalytus (Silveira et al., 2011). The coefficient of interception for the study area and one year of data (2015 with 25 rainfall events) was very near, 13.5 % , although they were not equal, not significant for a t test.

4. CONCLUSION

The new prototype was successfully built following the upgrading design criteria, increasing the autonomy and improvement the gauge system for the measured according to the needs of data and applications for watershed studies. Some of the advantages are:

- There is no need to use tanks and pumps for the system, increasing the battery life and reducing the need of maintenance.
- Greater accuracy in the measured of water quantity and times of the events. It possible estimates different interception for different rainfall intensities because the data is not accumulated in time.
- Greater ability to save data with the use of the sd card.
- Greater autonomy of the redistribution plot with six months of battery life.
- A single logger to store all the data, steamflow and throughfall in the same file.
- Two full systems (steamflow and throughfall) in the same plot allowing the possibility of backup in case of damage.
- Similar results have been obtained with the two prototypes (the old prototype and the new) for one year of data.

Interception is a phenomenon that depends on many other variables, making it very difficult comparison in cases where we do not have the same type of conditions (climate, species planted, rainfall) (Valente et al., 1997; Huber and Iroumé, 2001) this causes the values can be highly variable, (Huber and Iroumé, 2001; Liu et al. 2013; Wang et al. 2013). The best way is to compare with data that excite in similar conditions, in the same watershed or near with similar characteristics of the study area. In this sense the comparison with data from similar areas showed similar results between the new methodology and the others (Silveira et al., 2011). The main differences can be the result of the low number of events that have registered with the new equipment (25 rainfall events), reducing the number of observations for characterizer the interception. It is hoped that with the registration of new events, the pattern will reaffirm their similarity.

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