

# FOG INTERCEPTION AND WATER BUDGET OF *CAESALPINEA SPINOSA* TREES IN THE LOMAS ECOSYSTEMS OF MEJIA (AREQUIPA, PERÙ)

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**Abstract:** In xerophytic environment, wherever fog constitutes the main moisture resource, fog intercepted by leaves and branches can contribute up to the 80% of the transpirative balance of trees. The present paper deals with the analysis of the relationships, at individual level, between crown characteristics and fog water collection as resulting by measured throughfall and stemflow of native adult relict trees of *Caesalpinea spinosa* in *Tree lomas* coastal ecosystems, Mejia, South Perú. At this aim, 10 trees were selected at altitudes ranging from 450 to 750 m a.s.l. Crown global shape and size was measured as a whole both in vertical and horizontal position. In parallel, branch volume and branching pattern was performed. Throughfall pattern and distribution was investigated by placing rain gauges according to a square grid referred to the crown projection. One or more (in the case of polycormic individuals) ribbon belts were placed around the trunks to measure the stemflow performance. A neoprene cover film was placed on-ground under the crown projection of control trees to monitor the total throughfall. Results show high fog capturing capacity related to the tested crown parameters and to wind flow direction. Crown volume appears the best synthetic parameter to estimate water-capturing capacity. Stemflow does not contribute significantly to the water budget.

## 1. INTRODUCTION

The subdesertic coast of Southern Peru and Northern Chile presents, during the austral winter, stratified clouds originated over the Pacific Ocean colliding with the coastal hills. Produced advective and orographic fog, is the main water resource to maintain vegetation, low density forest formations (tree "lomas", sensu Pefaur et al. 1996, Ferreira, 1961) included. Even when no moisture is caught by rain gauges in open sites, fog is collected and condensed by tree crowns and dripped and/or flown to the ground in appreciable quantities. In xerophytic environments, where fog constitutes the main moisture resource, such water-collecting system can contribute up to the 80% of the need of transpirative balance of trees (Whittaker & Woodwell, 1967; Xiwei & Arp, 1994). The interface system fog/plant works at different levels depending by: **a.** atmospheric factors, in term of fog presence and characteristics (i.e. altitude, moisture rate, wind velocity and direction, radiation and temperature, droplets size); **b.** individual trees and population features (shape and architecture of the crowns, canopy complexity, relative topographic position of trees).

In the hills of Mejia, Department of Arequipa, Peru, the relicts indigenous tree communities are dominated by *Caesalpinea spinosa*. Such formations are extremely degraded because of the

overgrazing and the decreasing of the total amount of precipitations in the last decades.

In the frame of the STD3 EC funded Research Project "Fog-Arequipa", some of the relicts nearby the experimental test-site of *Las Cuchillas* were studied in order to highlight the historical land use, and analyse the present structure of populations and individual trees and their interactions with environmental factors (Angeletti, 1997). With respect to adaptive strategies of plants, it was observed that trees are prevailing located in fog-colliding slopes, at altitude ranging from 400 to 700 m a.s.l. The present paper represents a second phase of surveying relicts structure and functioning mainly deals with the understanding, at individual level, of the relationships between crown characteristics and fog water collection as resulting by the throughfall and the stemflow measured under native adult relict trees of *Caesalpinea spinosa*.

### 1.1 Materials and method

15 trees living in two *quebradas* (valleys) nearby the experimental test site of *Las Cuchillas* were selected. The trees are part of two *Caesalpinea spinosa* population relicts. Trees were selected at altitudes ranging from 460 to 750 m a.s.l. Trees main parameters (i.e. number of stems, height, diameter, crown intersection) were measured.

Crowns attributes were detailed surveyed via 8 vertical sections. Branch volumes (up to 3<sup>rd</sup> order branches) were calculated, leaf area sampled, and total leaf biomass estimated.

Throughfall and stem flow was measured on 10 of the selected 15 trees. The throughfall pattern was investigated by rain gauges settled under the crown projection according to a 1,75m square grid. Funnel-shaped gauges (17 cm of diameter) were placed above the plastic water-collector. Outer the crown projection a control rain-gauge was placed.

Stem-flow water was collected by using a neoprene ribbon per stem (in the case of polycormic individuals) placed at 1m height. Stem-flow water was stored in a container.

A sub-sample of 3 plants was selected in order to

monitor the total amount of throughfall by placing a continuous plastic film under the rain gauges. A control plastic film was placed out the crowns to check the self-collection effect. Data were gathered the second day since June 30, 1997 until August the 4<sup>th</sup>. 12 relevant events were processed, caused by the occurrence of *El Niño* phenomenon.

On-ground throughfall pattern was mapped for each event per plant. Water volumes were calculated by using a isohyet system.

1.2 Results

1.2.1 Crown characteristics

| Tree n. | altitude<br>m a.s.l. | D.B.H.<br>Cm | Height<br>m | Crown<br>projection<br>m <sup>2</sup> | Crown<br>Volume (C.P.)*<br>m <sup>3</sup> | Branch<br>Volume<br>M <sup>3</sup> | Leaf area<br>m <sup>2</sup> | Throughfall<br>l |
|---------|----------------------|--------------|-------------|---------------------------------------|---|------------------------------------|-----------------------------|------------------|
| 2       | 610                  | 25           | 6.6         | 38,3                                  | 72,0                                      | 0,39                               | 25,3                        | 1614             |
| 4       | 570                  | 18           | 4.7         | 29,7                                  | 36,1                                      | 0,27                               | 10,6                        | 900              |
| 6       | 470                  | 17,5         | 5.4         | 45,4                                  | 47,1                                      | 0,32                               | 5,6                         | 1061             |
| 7       | 460                  | 20           | 5.0         | 31,5                                  | 25,7                                      | 0,16                               | 2,7                         | 997              |
| 8       | 460                  | 6            | 2.5         | 4,0                                   | 4,0                                       | 0,01                               | 1,8                         | 130              |
| 10      | 700                  | 40           | 8           | 62,5                                  | 194,9                                     | 0,99                               | 10,7                        | 3143             |
| 12      | 745                  | 40           | 6.5         | 55,2                                  | 134,3                                     | 0,56                               | 23,9                        | 1924             |
| 13      | 670                  | 30           | 7.5         | 53,0                                  | 150,9                                     | 0,33                               | 9,7                         | 1701             |
| 14      | 640                  | 40           | 6.3         | 58,3                                  | 104,1                                     | 0,85                               | 18,4                        | 1517             |
| 15      | 620                  | 35           | 8.5         | 65,6                                  | 177,5                                     | 0,80                               | 28,7                        | 1955             |

Tab. 1 Main characteristics of investigated *Caesalpinia spinosa* trees

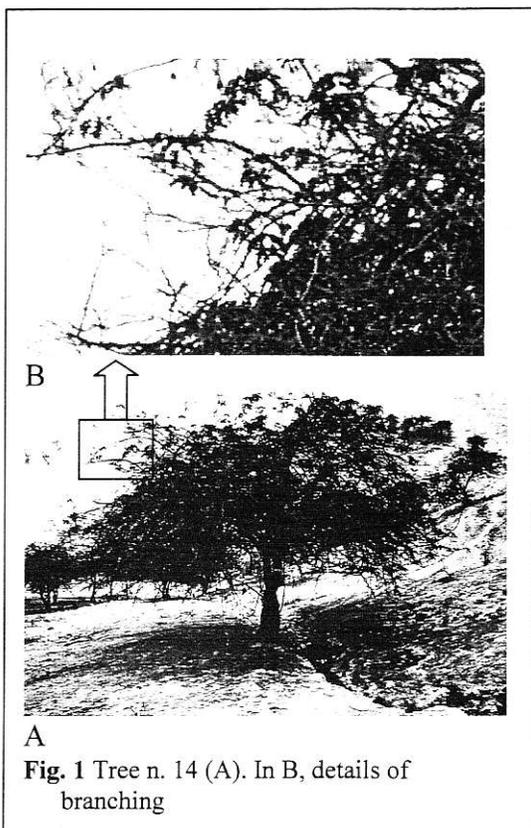


Fig. 1 Tree n. 14 (A). In B, details of branching

Main characteristics of 10 on 15 investigated trees, i.e. the ones under where throughfall was monitored, are given in Tab. 1. In Fig. 1A an example of tree structure is given. Trees 2 to 8 and 10 to 15 are placed in two separate quebradas, SW and NE relatively with regard to Las Cuchillas test site. Trees DBH ranges from 6 to 25 cm in the first site, while in the second site are higher than 30 cm. As far as concern heights, differences are relatively lower. Crown projection ranges from 4 to 60 m<sup>2</sup> and correlates significantly to DBH (R<sup>2</sup> 0,82), while no evidence of significance were found out with respect to slope. In front of high values of crown projection and crown volume, branch volume values are rather low, according to the branching pattern maximising third or upper order of branches, as shown in Fig. 1B. Nevertheless, branch volume is significantly correlated to all the other parameters, as shown in Tab. 2, as well as strong relationships exist with DBH (R<sup>2</sup> 0,79). Height is significantly correlated both with crown projection and crown volume. A lower level of significance is shown by height/branch volume relationships, very likely due to the type of branching pattern, as above discussed. Significance of correlation between Leaf area and all the other parameters are lower (Tab. 2). This result can be explained by a. the reduction in the total

amount of leaves during the dry season and **b.** the influence of air pollution causing partial drying up of crowns in wind-exposed sides.

|     | ALTI | CPR<br>O | CVO          | BVO          | TFA          | LEA   |
|-----|------|----------|--------------|--------------|--------------|-------|
| ALT | 1    | 0,725    | <b>0,832</b> | 0,712        | 0,791        | 0,652 |
| PRO | **   | 1        | <b>0,882</b> | <b>0,87</b>  | <b>0,843</b> | 0,602 |
| CVO | ***  | ***      | 1            | <b>0,837</b> | <b>0,907</b> | 0,56  |
| BVO | **   | ***      | ***          | 1            | <b>0,858</b> | 0,584 |
| TFA | **   | ***      | ***          | **           | 1            | 0,484 |
| LEA | **   | **       | **           | **           | *            | 1     |

**Tab. 2** correlation matrix (R-values)

*Legenda:* Spearman ranking significance,  $\alpha(2)$ : \*0.10; \*\*0.05; \*\*\*0.005.

**ALT:** altitude; **PRO:** Crown projection;  
**CVO:** Crown volume (of crown projection);  
**BVO:** branch volume; **TFA:** throughfall;  
**LEA:** leaf area

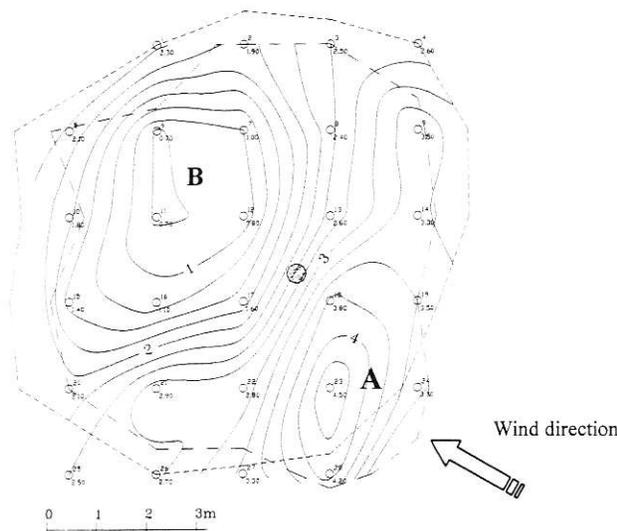
Stemflow is not reported, as far as its contribute is on average lower than 1% of total throughfall amount. Throughfall values correlates significantly with all considered crown parameters, leaf area excepted (Tab. 2). Highest R value is shown by the correlation Throughfall/Crown Volume. Branch volume efficiency in term of captured water is also high: the relationship between the two parameters ( $R^2$  0,74) is direct proportional, indicating a homogeneous behavioural trend of branching in comparison with captured fog water. Average daily throughfall is 42,6 l, ranging between 4 to 89 l/tree/day. Total throughfall per volume unit ranges from 11 to 38 l/m<sup>3</sup> trees having larger diameter show the lowest values.

In Fig. 2 an example of throughfall pattern per event is shown. In relation to wind direction, two peaks occur: the first one (A) is located in fog-wind/crown coping area, while a second one (B) is in the inner part of crown projection coinciding with higher leaf area. Such result highlights the relative importance of branching architecture in term of fog capturing capacity, linked to the above mentioned comments on branch pattern, and moreover verify previous results (Angeletti, 1997) showing the highest leaf are located in crown sectors opposite to main wind direction (Fig. 3)

Evaluation of single events of throughfall show a positive trend according to increasing branch volume, and the water collected per single event is proportionally constant per each individual tree (Fig 4).

**1.3.2 Fog water capturing**

Total amount of throughfall is given in Tab. 1.



**Fig.2** Throughfall distribution under tree n.12 (fog event 2nd august 1997)

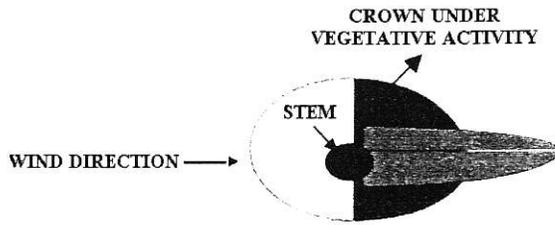


Fig.3 Wind direction and crown vegetation activity model (after Angeletti, 1997)

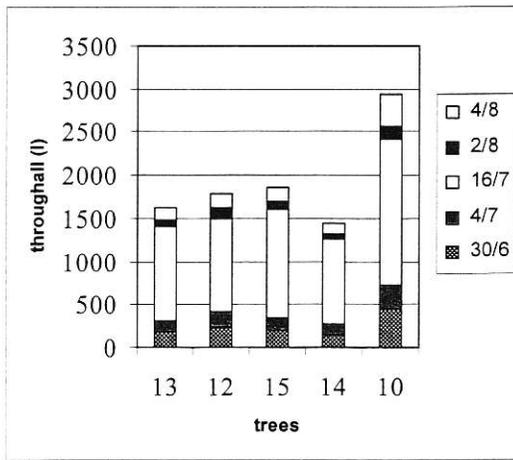


Fig. 4 Throughfall amount per tree and event (dates on right). Trees are arranged on x-axis according to increasing crown volumes from left to right

**1.4 Conclusion and Recommendation**

*Caesalpinia spinosa* trees show a characteristic semi-elliptic crown shape, having a procumbent elongation towards wind direction: such crown form showed a high efficiency in terms of water capturing, especially referred to specific branching pattern.

Throughfall values are significantly correlated to all crown parameters, leaf area excluded. Crown volume appears the best synthetic parameter to estimate water-capturing capacity.

Despite the reduced total leaf area and leaves location opposite to wind direction, high capturing efficiency of branching texture was verified. As the largest part of the crowns is composed by juvenile branches originated by early resprouting after cutting related to grazing activities, the relationship between exposed surface and branch volume is relatively higher as compared to the one expected in undisturbed trees.

Total and daily observed throughfall amount is rather high, especially referring to volume unit of the crowns. Nevertheless, the evaluation of such results in term of available water for trees is rather difficult, as far as has to be taken into

account the infiltration rate and the run-off due to combined effects of slope and soil physical modification (grazing related activities). Furthermore, has to be investigated the effect of human influence on crown dynamics.

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