

# Influence of Relief on the Origin and Behaviour of Fog at Tarapaca, Chile(\*)

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**Abstract:** A number of authors have investigated the uptake of water by the tree species *Prosopis tamarugo* in the Pampa del Tamarugal. The general conclusion is that the water source for the trees is groundwater, brought to the near surface area by a deep tap root. Dew is considered to be unimportant where discussed and fog has not been investigated or discussed as a water source. This paper looks at pathways for advective fog and humid air into the Pampa del Tamarugal. Field investigations related to the flow of humid air into the pampa are presented, and observations of the formation of dew and fog are discussed. It appears that these sources of water are available to the different tree species of the pampa; however the amounts remain to be quantified.

## 1. INTRODUCTION

Fog is being studied as a new water resource in different places of the world. Even though almost all fogs constitute a potential for water collection, there are differences in their origin and behaviour that may determine their use and application.

Water from fog is being studied or used in several countries and the fog types vary from one place to another. Coastal fogs are the most investigated, such as in Peru, Chile and Oman; inland fogs have also been studied in Canada, South Africa, Namibia and Ecuador; of special interest are the islands that are frequently covered by fog, e.g. the Canary Islands, Cape Verde, Galapagos, Robinson Crusoe, and many other archipelagos of the world (Cereceda and Schemenauer, 1996). Understanding the origin and behaviour of fog may give a clue for the selection of sites with good water production potential, especially in arid and semiarid environments.

Fog is present in various environments of northern Chile, its origin and behaviour is diverse. Advective and orographic fog is often present in the coastal zone, and radiation fog may be formed in the interior of the continent. Local meteorological conditions define its presence, liquid water content, and its potential for water collection. These local conditions are determined by the relief, in its large and small scale, either because it influences its formation, or because it determines the wind that results in a flux of water that can be collected by trees or artificial fog collectors.

This paper will give the first results of a survey done in the far North of Chile, that has as a general objective to understand the origin and behaviour of both coastal and inland fog, and their relationship to the potential of fog as water resource. It is necessary to understand the distribution of orographic and advective fogs as well as their capacity for penetrating inland (50 to 90 km). The formation of radiation fog may also play a role in certain locations.

## 2. Study Area and Methodology

The study area is located in the Region of Tarapaca, from Pisagua to the Loa river (20°05'S-21°00'S - 70°40'W-70°50'W). The extension of the coastal line is approximately 100 km, and the width, toward the interior, an average of 70 km. The total area is 8.400 km<sup>2</sup>.

From west to east, the relief is formed by a narrow litoral plain (average 5 km); a cliff of 400 to 1000 meters; a mountain range, Cordillera de la Costa, with peaks that can have altitudes of 1500-2000 m (width of 50 to 100 km); a tectonic basin 100 km wide, Pampa del Tamarugal. The study area reaches the glacis of the first mountains of the Andes.

The first step of the methodology was a study of the cartography scale 1:250.000 and 50.000 and a GIS study was done for this purpose; with that information, a systematic survey in the field was done during one week on special features of the relief, such as high

cliffs, corridors between high mountains, local basins and salt flats.

The methodology for the study of presence and potential of fog is based in surveys of 21 days in winter and 21 days in summer in different locations and features of the relief. Measurements are done with standard fog collectors (SFC), wind vane and anemometers according the methodology of Schemenauer and Cereceda (1994); meteorological records of temperature and humidity are done systematically during the survey. The literature on the origin and behaviour of underground water in the Pampa del Tamarugal and tree's physiology related to its source of water show the importance of underground in the area, neither fog nor dew have been quantified in the area (Sudzuki, 1985; Aravena and Acevedo, 1985; Acevedo et al, 1985). A small study of the scarce vegetation in some spots was done as an indicator of the possible presence of fog (Cereceda et. al, 1997 a) and b)). Ancient human stablishments associated to the hunting of the guanacos and their trails, were also studied.

### 3. Results

#### 3.1 The coastal mountain range and the cliff

From the map study and background on vegetation and human establishments, four locations were chosen in the coastal mountain range near the summit of the cliff (Junin, Alto Hospicio, Patache and Chipana). All of them were located above 750 m, and have archeological testimonies, and vegetation such as annual herbs. Alto Hospicio has tillandsia vegetation (*Browmelia* that lives on air humidity and/or fog); Patache has bushes and cacti, and Chipana, mainly cacti. The area that has the most abundant vegetation and archeological existence is Patache. It is important to mention that in the rest of the study area, the desert was absolute; this does not mean that there is no fog, but it means that fog is more frequent or fog deposition more productive at the sites mentioned above.

#### 3.2 The corridors cliff to Pampa del Tamarugal

The Cordillera de la Costa in the study area has the appearance more of an altiplano than a massif mountain range with abundant peaks. Associated with the cliff sites, four paths or corridors that connect the coast with the inland area (Pampa del Tamarugal) were found and studied. The paths had directions W-E and SW-NE and were directly correlated with the sites

Chipana had halfway, transversal small mountain ranges with tillandsia vegetation. The most extensive and vigorous field of tillandsia was found in the corridor of Patache. Fog and humid air masses are intercepted by these N-S small mountain ranges that have altitudes above 900 m.

#### 3.3 Local salt flats and the tectonic basin of Pampa del Tamarugal

There is no doubt that the Pampa del Tamarugal is an important feature that plays the role of a low pressure area that sucks the air masses from the coast toward the interior of the continent. But due to its large extent, it is suppose that its effect is equal across the study area. For that reason, local features in the Cordillera de la Costa and in the Pampa itself were investigated. In the first form mentioned, some salt flats (salares) of different dimensions were studied. Associated with the Patache area, the flats of Llamara and Pintados are located in the west end of the Pampa. Associated with Chipana the big salt flat Salar Grande is a feature that definitely determines the airmass flow. However, near the Junin and Alto Hospicio no depressed relief or flats were found. It will be necessary to understand the local relief of the Pampa del Tamarugal to explain the airmass flow. Junin has a very narrow coastal range (less than 50 km) and Alto Hospicio has a wide relief at the end of its path, at the entrance of the Pampa; these topographical characteristics may explain the presence of fog in the Pampa. It is important to consider that it is possible to get heating and inflow to a low pressure area in hilly area as well as in flat terrain, i.e. hillside also heat up and result in rising air currents. The Pampa del Tamarugal has this name because of an ancient forest of huge dimensions (220.000 hectares) that was present until the beginning of this century. It was cut to give wood to the numerous nitrate companies that operated for more than 80 years in the area. Actually, this pampa has been reforested with the same species (*Prosopis tamarugo*) which live from underground water, and perhaps from the fog water collected by their branches and leaves. Associated with them are the "retamillas" (*Retamilla* sp) that have superficial roots and do not get there water from underground aquifers. It is interesting to note that some trees areas are very degraded and some are very vigorous, probably related to the lowering of the water table and the presence or absence of fog. This hypothesis have been questioned, but until now, there is evidence in relation to the source of underground water, but none to support the role of fog in the forest.

#### 4. Conclusions

The coastal and inland fog have different behavior, and not always the same source, when there is great humidity and captation in the coast, is not always happens the same in the pampa.

Air masses loaded with humidity penetrate across the west-east corridors toward the interior of the territory. This water load usually shows as dew in the pampa.

An important part of the humidity from the cloud , condense over the Cordillera de la Costa, and is not able to reach the inland territory.

The fog of the coastal sector constitutes a contribution of water to the environment, and if it is collected, will be profitable for domestic and other uses.

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#### REFERENCES

Acevedo A., Sotomayor D. and V. Zenteno, 1985: Water uptake as affected by the environment in *Prosopis tamarugo* Phil. "In the current state of knowledge on *Prosopis tamarugo*". Universidad de Tarapacá - CONAF. 1985

Aravena R. and E. Acevedo, 1985: The use of environmental isotopes oxigen-18 and deuteriom in the study of water relations of *Prosopis tamarugo* Phil. In "The current state of knowledge in *Prosopis tamarugo*", Universidad de Tarapacá - CONAF. 1985

Cereceda P. and R.S. Schemenauer, 1996: La niebla, un recurso hidrológico para el desarrollo de zonas con déficit hidrológico. "Clima y Agua", 15-33, España

Schemenauer, R.S. and P. Cereceda, 1994: A proposed standard fog collector for use in high elevation regions. "Journal of Applied Meteorology", 33, 1313-1322.

Sudzuki F., 1985: Environmental moisture utilization by *Prosopis tamarugo* Phil. In "The current state of knowledge in *Propopis tamarugo*", Universidad de Tarapacá - CONAF. 1985.