Evaluation of the Use of Fog Water for Regeneration of Arid Ecosystems(*)

P. Cereceda*, L. Villegas ** P.Osses* R.S. Schemenauer***

* Pontificia Universidad Católica de Chile ** Universidad Nacional San Agustín, Perú
*** Environment Canada. (*)European Union STD3

Abstract: The potential of fog as a water resource has been evaluated since 1995, and presently is being used in an experimental forestry plantation in the degraded ecosystems of the lomas of Perú. A survey carried out for one year was done in the coastal mountains of the province of Arequipa. The results show that a yield of 6 L/m^2/day can be obtained in selected areas. The best potential for fog water collection was found at an altitude of 850 m. The main factors that rule fog behaviour are the relief and its connection to the stratocumulus clouds coming from the sea. Twenty big fog collectors are collecting more than 2.000 m^3 of good quality water each year.

1. INTRODUCTION

In the last decade, fog has been studied as a new water resource for several purposes and is being used intensively in some places of South America; in Ecuador and Chile for domestic consumption, and in Peru for agriculture, forestry and regeneration of ecosystems. Several other places have been investigated, and the results are promising (Cereceda and Schemenauer, 1996). This paper describes the survey done to evaluate the potential of fog as a water resource for artificial regeneration of arid ecosystems in the Chilean and Peruvian deserts. The core of the project is a two hectare plantation of native and exotic trees and bushes. The irrigation is done solely by fog water using a reservoir and drip irrigation system designed for the project. To understand the possibilities of regeneration, a complete survey of the ecological system (flora and fauna) of lomas has been done, as well as the response of the vegetation to dry and humid years.

This project has been funded by the European Union, and the following universities participate in it: University of Padova and University of Firenze of Italy; University Paul Savatier of France; Universidad Nacional de San Agustín of Perú and Pontificia Universidad Catolica of Chile. Environment Canada has had an active participation in the development of the project.

The general objective of the project is to study fog as a resource for sustainable development in the arid regions of Peru and Chile. The main goals of the geographical research on fog were to study the behaviour of fog and its temporal and spatial variation, and to select the place to establish the experimental station for a forestry plantation.

2. The Study Area and Methodology

The study area is located on the coast of the Province of Arequipa, specifically in Mejia (17°00'00"S-17°00'45"S--71°59'50"W-71°59'30"W).To achieve the objective it was necessary to do a survey for one year, and measure the potential of fog water collection in several zones of the study area.

The indicators used to choose the sites for the measurement of the fog potential were the following: altitude, relief and topography, orientation of the valleys and slopes, distance to the sea, and space for collectors (Schemenauer and Cereceda, 1994). Once the area with fog was stablished, the main indicators were related to the needs of the forestry experiment: soils, slope, space, access, native vegetation, human activities, ownership of the property, amongst others.

Four mountain ranges were chosen: Mejia, Taro, Majuelo and Cuchillas. In each one, a set of collectors was installed and measured systematicaly for one year. After that period, the site was chosen and the survey continued only in selected areas and for scientific purposes.

The methodology used has being described in Schemenauer and Cereceda (1994) and is based on the use of a standard fog collector (SFC) of 1 m^2 of

polypropylene mesh, equipped with an anemometer and wind vane, with data recorded on a Dachris data logger. Daily measurements of temperature and other meteorological data were done manually at the sites and the fog behaviour was studied systematically in the mountain ranges.

3. Results

3.1 Spatial Variation

Twelve sites were equipped with SFCs for the first 8 months; they were located in areas from 350 m to 850 m, distributed in different features of the relief and with different orientations to the predominant winds. The results of the survey showed that the fog was insignificant at levels inferior to 650 m. From 650 to 750 m, the potential for fog water collection was important but far below the yields produced at levels over 800 m. The fog season begins in July which is a month representative of the low collection period. This month and September, the month with the best record in 1995, have been chosen to show the spatial and seasonal variation of the fog in the area (Table # 1):

It is interesting to note the differences that can be seen in the three locations at 750 and 760 m. The reason can be found in the fact that they are located in different mountain ranges and the local topography is also very different. Taro 1 is in a narrow summit, Majo 2 is in a narrow plain directly facing the predominant winds from the sea, and Prueba 1 is at the beginning of a ridgeline that divides two small valleys that channel the fog upward.

3.2   Temporal Variation

To show the annual and monthly variation two sites at similar altitude have been chosen (Table # 2).

From the above data some conclusions can be derived. The years 1995 and 1996 gave a similar yield of fog collection. Year 1997, shows considerable better production, but it is important to consider that in South America, the presence of El Niño Phenomenon was very intense. There is a consisten difference between the years 1995 and 1996. the total water production for the seven months (June - December) with data in both years, was about 20% higher in 1995 at Majo 1 and about 7% higher in 1995 at Cuchillas. this pattern is not. however, repeated for specific months. For example, at Cuchilla, August gave a better yield in

1996 than in 1995; while in September, 1995 was far more productive than 1996. Often it is possible to use the height of the inversion layer to explain differences between years, but in this case, the altitudes of the sites are equal, so other factors should be examined, such as wind speed and direction. Other meteorological data such as temperature and humidity at the ocean surface, which determine the cloud base height and indirectly the cloud liquid water content, will also play a role.

The main fog season begins in July and ends in October, but the rest of the months still have some days with fog that produce valuable yields. The variability in monthly water production under scores define the need to have suitable reservoirs in place to store water to allow for a uniform delivery thoughout the irrigation season.

Table # 1: Fog water collection by SFCs at different sites in 1995.

Site	Altitude meters	Sept. 95 $L\ m^{-2}\ d^{-1}$	July 95 $L\ m^{-2}\ d^{-1}$
Mejía 1	590	11.8	1.9
Mejía 2	565	9.7	1.3
Mejía 3	575	9.4	1.4
Cuchillas	850	28.1	7.6
Prueba 1	750	13.3	
Prueba 2	700	9.4	
Majo 1	825	18.1	6.2
Majo 2	760	20.7	4.3
Taro 1	760	24.3	4.4
Taro 2	610	10.9	1.4
Taro 3	400		
			0.2
Taro 4	350		0.1
Parcela	410	2.2	0.2

Table # 2:   **Monthly variation of fog water collection by SFCs in 2 sites.**

Month	Majo 1 $L m^{-2} d^{-1}$			Cuchilla $L m^{-2} d^{-1}$		
	1995	1996	1997	1995	1996	1997
January		2.0	0.1		2.5	0.4
February		0.5	1.9		0.8	2.0
March		0.2	1.7		0.4	2.6
April		1.1				1.3
May		0.8				1.3
June	0.3	5.4		1.0		7.6
July	6.2	3.3		7.6		4.5
August	9.6	7.8		11.0		21.2
September	18.1	10.9		28.1		13.1
October	8.6	7.8		11.4		9.7
November	1.2	1.9		1.9		2.2
December	1.4	0.4		2.1		0.5
Average	4.6*	5.0		5.8*		5.4

*Corrected proportionally with 1996 data.

3.3 Projections

After the first year of evaluation, the Cuchillas site was selected for the experimental station and the forestry plantation. A set of 20 large fog collectors were built and the annual production has been approximately 2.000 m^3. Two reservoirs of more than 400 m^3 capacity were constructed and the annual need of 700 m^3 for the plantation were covered. The rest of the water was used in the plant nursery and the station (house for scientists and technicians).

It may be that in the surroundings there are sites with a better potential for fog water collection, but for the scientific purposes of this project, the objective was accomplished. The application of this information to the regeneration of ecosystems on a large scale can also be looked at. A simple calculation shows the possibilities (Table # 3). It is assumed that the large fog collectors each have a surface area of 48 m^2 and that the average annual fog collection rate is 6 $L m^2 d^{-1}$. It is also assumed that each hectare of the plantation has 600 trees.

Table # 3: **Production of water, plantation and costs.**

Collectors	Annual Water prod. (m^3)	Plantation	Cost of Collector (US$)	Cost of System (US$)	Cost of Water (US$) (m^{-3})
100	10,500	15	400	40,000	3.8
200	21,024	30	300	60,000	
250	26,000	38	250	62,500	
300	31,500	45	225	67,500	
400	42,000	60	200	80,000	1.9

As been shown, many hectares can be planted and watered with fog collectors systems until the trees are big enough to collect their own fog water and become self sustainable and begin the regeneration of the ecosystem in a massive way. The array of collectors then can be moved to new sites and extend the area.

4. Acknowledgements

REFERENCES

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.

Schemenauer, R.S. and P. Cereceda 1994: Fog collection's role in water planning for developing countries. *Natural Resources Forum*, 18, 91-100, United Nations, New York.