

EUROPEAN COMMISSION

Directorate General XII

**Fog as a new water resource for the sustainable development of
the ecosystem of the Peruvian and Chilean coastal desert**

Contract N° TS3 CT94 0324

FINAL REPORT 1995-1998

Fog Water Collection Evaluation in the coast of Arequipa

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PUBLICATIONS, CONFERENCES, WORKSHOPS AND ANNUAL REPORTS

1. JOURNALS

“Diferencias y similitudes de la niebla de Iquique (Chile) y Mejía (Perú)”
Cereceda P., Schemenauer R.S., Osses P. Larrain H. Y P. Lázaro
Revista Norte Grande
Vol # 25
1998

“La niebla: recurso para el desarrollo sustentable de zonas con déficit hidrológico”
P. Cereceda and R.S. Schemenauer
En Clima y Agua: la gestión de un recurso climático
La Laguna, Canarias, España
1996

“Fog Collection”
Schemenauer R.S. and P. Cereceda
In TIEMPO IIED, London, UK26,17-21
1997

“Agua en el Aire”
Cereceda P. and R.S. Schemenauer
In Revista Universitaria (P.Universidad Católica de Chile) Vol 56: 45-49
1997

Note: the last two papers are for general public, they were done during the project and include the last conclusions of Mejía, Peru.

2. CONFERENCES AND WORKSHOPS

“Evaluation of the potential of the fog for water collection in the coastal area of Arequipa, Perú”

Pablo Osses McIntire

Workshop “Evaluation of fog as a water resource”

September 30 – October 4, 1996

“La niebla, agua para regeneración de ecosistemas desérticos”

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

Seminario Internacional Forestación y Silvicultura en zonas Áridas y Semiáridas INFOR, Instituto Forestal, Chile

October 21-25, 1996

“Evaluation of the use of fog water for regeneration of arid ecosystems”

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

First International Conference on Fog and Fog Water Collection

July 21-25, 1998

Vancouver, Canada

“Fog water collection at El Tofo and other coastal sites in South America and Arabia”

Cereceda P., and R.S. Schemenauer

First International Conference on Fog and Fog Water Collection

July 21-25, 1998

Vancouver, Canada

“Bases metodológicas para la selección de sitios de niebla para experimentación forestal en Mejía, Perú”

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

Congreso Latinoamericano de Ecología

October 1998

Arequipa, Perú

3. REPORTS

First Annual Report

Year 1995

Cereceda P., Schemenauer R.S. and P. Osses

November 1995

Second Annual Report

Year 1996

Cereceda P., Schemenauer R.S. and L. Villegas

November 1996

Third Annual Report

Year 1997

Cereceda P., Schemenauer R.S. and L. Villegas

January 1998

REPORT

INTRODUCTION

The researchers of the Pontifical Catholic University of Chile worked for four years in this project. There was an active interaction between the other participant universities, mainly with Universidad de San Agustín. In addition, the activities were planned also with Padova and Firenze.

All the objectives given in the project proposal were accomplished during the four years of activities. A series of articles were published in journals and annals of conferences and the researchers attended to four conferences and workshops. The main core of the project was done in the first year and in the next period the activity was limited to data collection on Standard Fog Collectors (SFC) and analysis of the information.

The main purpose of the research was to provide information on the presence of fog and its potential to produce water for irrigation of the plantation located in the coast of the province of Arequipa in the area of Mejía, specially in Cerro Cuchillas. These was accomplished after the first year of activities, and the system has been working since then regularly.

1. Objectives

The general objective was to evaluate the potential of the fog as a resource of water and to give the background to locate a fog water collection system.

To accomplish this objective, the following several specific objectives were followed:

- a) to understand the behaviour of fog in the area of Mejía,
- b) to measure the collection of fog water in different areas of Mejía
- c) to understand the relationship between wind direction and wind speed with fog water collection
- d) to understand the behaviour of rain, drizzle and fog

2. Methodology

A methodology was designed in order to understand the behaviour of fog according geographical parameters, based mainly in geomorphology and some meteorological parameters such as wind.

A methodology was designed to locate the site for the installation of 20 large fog collectors. These were based on geographical factors, specially in the requirements of the plantation, such as soils and relief. (See First Annual Report)

For the next three years, only measurements of fog water collection was planned. (See Second Annual Report and Third Annual Report)

The main instrumentation was based on the Standard Fog Collector (SFC) and data collected automatically during the first year with Dachris Data Loggers. (See First Annual Report).

During the first year, Geographer Pablo Osses stayed in the field for six months making measurements in a daily basis in different locations of the study area, and visual observations. In the following years, some data collection on Cerro Cuchillas was continued by the staff of Universidad de San Agustín.

The methodology is explained in the following papers included in this Final Report:

“Bases metodológicas para la selección de sitios de niebla para experimentación forestal en Mejía, Perú”

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

Congreso Latinoamericano de Ecología

October 1998

Arequipa, Perú

“Evaluation of the potential of the fog for water collection in the coastal area of Arequipa, Perú”

Pablo Osses McIntire

Workshop “Evaluation of fog as a water resource”

September 30 – October 4, 1996

3. Conclusions

After four years of project, several conclusions were made, based on data obtained in the field, on geographical observations and in the relationship with other areas were the team of the Catholic University has worked or is working at the present moment. These conclusions have been published in journal papers and given in scientific conferences. Data has been added in the papers, so at this moment, only the last year has not been given to the scientific community. A new paper is being prepared to give a summary of the activities and goals achieved.

The main conclusions are:

a) Fog behaviour:

The fog present in the area is advective. It is generated several hundred kilometers to the west of Mejía, in the sea. Several factors such as the Anticiclón del Pacífico, the trade winds, the sea temperature and the Humboldt Current, are relevant to the

formation of the stratocumulus clouds. The relief plays an important role for the formation of orographic fog. Both types of fog are present in the study area.

Fog behaviour is determined by the inversion layer that fluctuates between 500 and 1.200 m.a.s.l. This was observed by the data collected with SFCs at different altitudes in the Mejía area. The lower areas had less number of days with fog, and less liquid water content, while the upper areas, near 900 m.a.s.l. showed the best potential for fog water collection.

Wind is another parameter that highly influences the behaviour of fog. Places with high winds and oriented to the South were the best places for fog water collection. This is due to the fact that high wind speed means more air mass moving through the interception surface, hence more droplets can be gathered. Winds from the South are the prevailing winds in the area and come directly from the sea, the source of humidity. (See First Annual Report).

The results of this survey are in the following publications:

“Diferencias y similitudes de la niebla de Iquique (Chile) y Mejía (Perú)”
Cereceda P., Schemenauer R.S., Osses P. Larrain H. Y P. Lázaro
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“La niebla: recurso para el desarrollo sustentable de zonas con déficit hidrológico”
P. Cereceda and R.S. Schemenauer
En *Clima y Agua: la gestión de un recurso climático*
La Laguna, Canarias, España
1996

b) Site selection for large fog collectors

More than 10 locations were studied during the first year, these locations were chosen according to the following parameters: altitude, distance to the sea, slope orientation and form of the relief. The data on fog water collected was measured daily. Temperature, wind speed and wind direction also were measured in each site. After six months of data, the area of Cerro Cuchillas showed the best yield. From June 1995 to June 1996, the yield was 5.6 L/m²/day.

Twenty fog collectors were located in the ridgeline of Cerro Cuchillas (850 m). The plantation was located below this area in a terrain that had adequate relief and soils for the forestry experiment (750 and 700 m). In this area the water collection from fog was of 2.4 and 1.7 L/m²/day.

The best place for the plantation would have been the area where the collectors were located, but the soils did not have all the requirements established in the proposal.

The results of this survey are in First Annual Report and Second Annual Report.

Also in:

“La niebla, agua para regeneración de ecosistemas desérticos”
Cereceda P., Schemenauer R.S., Osses P. and L. Villegas
Seminario Internacional Forestación y Silvicultura en zonas Aridas y Semiáridas
INFOR, Instituto Forestal, Chile
October 21-25, 1996

“Fog water collection at El Tofo and other coastal sites in South America and Arabia”
Cereceda P., and R.S. Schemenauer
First International Conference on Fog and Fog Water Collection
July 21-25, 1998
Vancouver, Canada

c) Annual yield and seasonal variation

The area of Mejía has shown in the three and a half years of survey a very good potential for fog water collection. Fog is definitely a water resource that can be used for domestic, agriculture/forestry and ecological purposes.

The variation of the presence of fog from year to year has to be taken in account. In projects that use the large fog collectors system, the minimum annual rate observed should be used, so that in “dry years” no shortages of water will be expected. In this project, the yield of 5.8 L/m²/day was used to plan the system, but several activities can be planned for the “humid years” so that the water is used rationally.

The average of the area in the high ridgeline is almost 9 L/m²/day, where the large fog collectors were installed, and in the area of the plantation is between 2.5 and 3.5 L/m²/day. This is considered a good yield for plants to use the fog water once they are sufficiently grown up to collect their own resource.

Year/ L/m²/da y	Cuchillas 3	Prueba 1	Prueba 2
1996	5.8	1.56	1.18
1997	11.76	5.70	3.77
1998	9.32	3.64	2.22
Average	8.96	3.63	2.39

El Niño Year (ENOS)

The climate of Perú is highly affected by the presence of the El Niño and La Niña phenomenon. Year 1997 was considered El Niño and 1998, La Niña. In the case of the presence of fog in the area, it can be seen that there are no significant differences in the yearly average, both were very high. But, if they are compared to 1996, dry periods for the western coast of the Southern part of South America, there are significant differences, almost half of fog water was produced.

It may be possible that the El Niño extended its influence to the months of January and February of 1998, this was also seen in a Chilean project some 500 km South, in Iquique, where the high yields were maintained. This period that corresponds to summer in Peru are known as period free of fog, since its general behaviour is to show only 7 to 8 months of fog and the rest as clear skies. What is difficult to explain are the high average shown in the months of July and August, maybe due to the presence of rain in the area.

In the arid climate of Peru, El Niño must be considered as a regular phenomenon, so it should be taken in account when calculating the annual average of an area. Years 1982-1983, 1987-1988, 1991-1992 were El Niño years, so in considering statistically the yields they will tend to rise the average, which is correct, but in the use of the resource is a main issue.

The seasonal variation is very important to consider in the moment of designing fog water collection projects. In the case of the study area, it is difficult to determine due to the above explanation, but it should be expected that fog will begin to be frequent from July to November, having a diminishing trend in the summer and fall seasons.

The temporal and spatial variation is discussed in the following papers:

“Evaluation of the use of fog water for regeneration of arid ecosystems”

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

First International Conference on Fog and Fog Water Collection

July 21-25, 1998

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“Fog water collection at el tofo and other coastal sites in South America and Arabia

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“Bases metodológicas para la selección de sitios de niebla para experimentación forestal en Mejía, Perú”

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

Congreso Latinoamericano de Ecología

October, 1998

d) Fog water production

In 1996, twenty large fog collectors were constructed, each of them with a surface collection (Raschel mesh) of 48 m², that means that in total there were 960 m² of collecting surface.

With a yield of 8.96 L/m²/day the total production of water was in the period of 8,600 L per day, or 3.140 m³ in the year. The year with the lowest average (1996), the total collection was 2,032 m³, and in the highest, 4,120 m³ (1997).

The requirements for the plantation were determined as 700 m³ per year. It can be seen in the figures shown above that the goal was accomplished and that there is a considerable amount of water that can be used in other forms as agriculture or domestic purposes.

e) First International Conference on Fog and Fog Collection

One of the most important activities done during the project was the organization of the First International Conference on Fog and Fog Collection that took place in Vancouver in July 1998. This conference was prepared by Dr. Robert S. Schemenauer, member of our team, since 1995. Pilar Cereceda was a member of the Scientific Community in representation of South America.

Eight students that worked in the European Union project attended the conference and helped in the organisation and presentation of papers during the sessions. Pablo Osses that worked in 1995 in the project, built a large fog collector in the hotel for the participants to learn about the system.

More than 150 researchers of all over the world attended the conference and more than 200 papers were submitted. A special session was given for the European Project members, who presented their results and had meetings to plan the follow up of the project.