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SESSION II: AGRICULTURAL POLICY AND SUSTAINABLE DEVELOPMENT - I

PAPER 5: FOG: A WATER RESOURCE FOR THE DEVELOPMENT OF ARID REGIONS

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FOG : A WATER RESOURCE FOR THE DEVELOPMENT OF ARID REGIONS

Roberto Semenzato *

Abstract

The Pacific coastline from Peru to Northern Chile is one of the most arid regions in the world, with little rainfall, but considerable amounts of fog produced by the advection of marine clouds towards the continent. This paper describes a project, recently funded by the European Commission, whose objective is to set up a basic plan of sustainable use for the natural resources of the Peruvian coastal desert using collected fog as the only water resource. This plan will be based on the results of a pilot experiment, which is being carried out on the coastal hills of Southern Peru, aimed at verifying the following assumptions : the effectiveness of artificially collected fog water in the restoration of the vegetation in an environment which is undergoing a process of rapid desertification; the ability of the plants to sustain themselves by means of the water supply derived from the fog they collect, and with no more need for man made collectors; the possibility that the surplus of water obtained by means of artificial collectors can be used for subsistence agriculture and for pasture growth.

1. INTRODUCTION

Speaking of fog as a "water resource" one has to keep two basic things in mind. The first, and most obvious one, is that fog is indeed water made of very tiny droplets suspended in the air. The second one is that fog has not to be regarded on the same ground as major water resources such as rain, or surface and subterranean water. In order to better understand this issue, a parallel can be made with the so called and well known "alternative energy supplies" and one can speak of "alternative water resources". The expression "alternative energy supplies" denotes all those types of energy supplies, such as solar, eolic, geothermic, etc. - distinct from main energy sources such as fossil fuel or hydroelectric energy - which are mostly used for small scale applications, like providing warm water for a building (solar panels) or driving force for a water pump (windmills). On

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the same ground, fog, viewed as an "alternative water resource", is not suitable for large scale irrigation or for providing drinkable water for a big city. However, pushing further the parallel, in the same way as "alternative energy supplies" - and research being carried out on them - are considered of the outmost importance in a world where the demand for energy is getting bigger and bigger, it is also important that we are able of devising "alternative water resources" - and carry out research on them - in a world where the demand of clean drinkable water is also getting larger and larger.

The most ancient historical record of fog used as a water supply, as far as we know, is contained in George Glas' - a British historian of the XVIII century - "History of the Canary Islands", published in 1764 (Kerfoot, 1968; Gioda et al., 1995), which reports of a tree used to provide water to the inhabitants of the island of Hierro, in the Canary archipelago. Despite the inhabitants of Hierro considered this phenomenon as a sort of miracle - Garoé, as the tree was named, was considered as a sort of totem - its explanation was clear also to George Glas, who reports in his book : *"Every morning, near this part of the island, a cloud or mist arises from the sea, which the south and easterly winds force against the fore- mentioned steep cliff so that the cloud ... advances slowly ... and then rests upon the thick leaves and wide-spreading branches of the tree from whence it distils in drops ... this tree yields most water in those years when the Levant or easterly winds have prevailed for a continuance, for by these winds only the clouds or mists are drawn thither by the sea"* (Kerfoot, 1968). Despite the use of a scientifically incorrect term - "distil" - to denote the water "production" by the tree, the British historian shows to have correctly understood thee basic mechanism of the phenomenon, which is due to the screening action of the tree on whose trunk and foliage the tiny fog droplets collect.

The most impressive application of fog collection has been the project in Northern Chile, result of a joint Chilean-Canadian collaboration, which has led to the construction of the first "fog water supply system" in the world. Thanks to this newly built system, since May 1992, the 330 inhabitants of Chungungo, a small fisherman village in Northern Chile, have been receiving their entire water supply from 75 large mesh fog collectors which provide a total of 11000 liters of water a day, doubling their per capita supply at one quarter of the cost of trucked water (Cereceda, Schemenauer and Suit 1992; Schemenauer and Cereceda, 1992). This highly successful project is a typical example of the use that can be made of fog as an "alternative water resource".

The project of the European Commission on the coast of Southern Peru is more focussed on research and takes a multidisciplinary approach, resulting from integration of research on fog collection, agroforestry and water resource managenement applied to the recuperation of large areas of the ecosystem of the coastal desert in an environmentaly friendly fashion and to the sustainable use of its natural resources. One of the innovative

points of this project is to set up the appropriate technology to maintain the equilibrium between environment and human activity : technology for the collection of fog water in the appropriate quantities, for its storage with avoidance of evaporation and leaching losses and for establishing high efficiency conveyance and irrigation methods. This project represents the first attempt in the world to generate water from fog in a coastal desert - one of the driest on earth, with only 5 to 10 mm of annual precipitation - for potentially large scale applications in the management development of an ecosystem, in which the water can be used for plant cultivation, for grazing animals and ultimately for domestic use.

In the following I will give a short description of the European Commission (EC) project on the coastal hills of Peru and report the results obtained so far.

2. THE EC PROJECT

2.1 Objectives

This project should represent the first step towards a general and longterm achievement : the sustainable use of the natural resources of the coastal hills of the Peruvian desert by exploiting fog as a water resource. The first step towards this goal consists in a field demonstration of the role fog water can play in producing large quantities of water for retention and reintroduction of vegetation on the hills in the coastal desert of Peru. The field results and the experience gained will then be used to develop a plan for the rational use of the existing natural resources in the coastal desert : the development of subsistence agriculture and the growth of pasture for controlled cattle grazing; the controlled use of the enhanced natural vegetation; the utilization of collected fog water for domestic use in small communities. The idea is to set up a basis for the recuperation of large areas of the coastal hills of Peru, a fragile ecosystem which is at present undergoing a process of rapid degradation and desertification, due mainly to overgrazing. In this general framework, the specific objective of the project is to set up a basic plan of sustainable use for the natural resources of the Peruvian coastal desert using collected fog as the only water resource. This plan will be based on the experimental verification of the following assumptions :

(a) the effectiveness of artificially collected fog water in the restoration of the vegetation;

(b) the ability of the plants to grow by means of the water supply derived from the fog they collect, with no more need for man made collectors;

(c) the possibility that the surplus of water obtained by means of artificial collectors can be used for subsistence agriculture and for pasture growth. This verification will be based on the results of a pilot experiment which has started being carried out in a station installed in the hills of the coast of Southern Peru, near the town of Mollendo. The results of this pilot experiment, together with the results of research

aimed at analysing ecological history, succession and human influence on vegetation dynamics, fragility and vulnerability of the system, causes which led to its deterioration, possibility of recuperation and maintainance of an equilibrium between human intervention and natural development, will form the basis for a plan of sustainable use for the natural resources of the ecosystem.

2.2 Description of the research work

The pilot experiment has been preceded by a preliminary part which consisted in evaluating the fog collection potential of various locations, preselected after a direct inspection on the basis of criteria such as topography, soil characteristics, wind exposure. This part, besides being a research activity in itself which will be shortly described in Section 3, was carried out in order to choose a site suitable for installing the experimental station where the pilot experiment had to be carried out. The experimental station consists of a line of 20 fog collectors of 50 m^2, placed on a hill crest perpendicular to the flux of incoming fog, made of a mesh of polypropylene; a pipe network which carries the water from the fog collectors to a large reservoir downhill; another pipe network which carries the water from the reservoir to the lots where different species of plants are grown. From preliminary measurements taken in the site where the fog collectors have been installed, it results that during the fog season the 20 fog collectors may yield from 10000 to 30000 liters of water per day.

The water obtained from fog collection is being used throughout the year to experiment with the species of plants selected, which are cultivated in lots in the experimental station area. An experiment is being carried out on the basis of the different species, with different densities and different water supply by using the standard techniques of experimental design in order to identify the most suitable species and densities and the minimum duration of the water supply. During the experiment, the evolution of the grass cover will also be analyzed.

The objective of this phase is to evaluate whether a selfsustained reforestation process can be triggered, with the plants acting as natural fog collectors. If the plants provide enough collection surface for fog water to make the plant growth selfsustained, the collectors are going to yield a surplus of water which can be used for irrigation of plants of economical interest for local consumption. In this case research will be carried out in order to explore how water can be saved while being stored, conveyed and distributed. Due to the relative large amounts of water to be stored, natural depressions will be used and techniques of impermeabilization of reservoir walls will be tested (use of clay material, sodic salts, etc.). The water will be transported by a network of plastic pipes and will be distributed by appropriate methods of selfregulating localized irrigation. In order to re-

duce the evaporation in the reservoirs, the water surface will be covered with pollution-free floating materials and using simple technologies.

2.3 Relevance for development

The place where the project is being carried out is located in a region with one of the lowest rainfalls in the world. In Peru the ecosystem of the coastal desert is undergoing a process of severe degradation and this project will tackle the recuperation of large areas of this region and the rational management of its natural resources. This means to regenerate the vegetation, to allow the development of subsistence agriculture and controlled cattle grazing, and to collect and store water for domestic use in small communities. If this project is carried out successfully, its results will contribute to develop a methodology of work suitable for applications in other regions of the world with the same climatic characteristics.

2.4 Environmental impact

The presence of fog in the coastal desert of Peru is due to the simultaneous action of the Pacific anticyclone and of the Humboldt current, which are permanent phenomena. Therefore fog water is a resource available in practically unlimited amounts and it would get lost if not utilized naturally by the vegetation, or artificially by man made collectors. Since the vegetation is the most important natural collector of fog water, its restoration will enhance the collection process and this is going to produce a beneficial environmental impact in the region as far as improvement of humidity conditions, availability of underground water, regulation of basins and seasonal coastal streams are concerned.

3. EVALUATION OF FOG WATER COLLECTION POTENTIAL

3.1 Experimental methodology

As explained above, this part of the project was a sort of independent subproject in itself, even if its objective was to use the results obtained to select the best site where to carry out the experimental work during the subsequent years. The specific objectives of this activity, which was carried out during the period May-December of 1995, were the following

- to know the behavior of fog in the area of interest and to measure the fog water collected in several sites inside that area;
- to measure meteorological parameters : wind direction and velocity, and air temperature in all the stations, wind velocity and direction on a continuous basis in at least two stations;

- to measure the precipitations in several sites in the area of interest and distinguish between rain, drizzle and fog.

The study area is located between the coordinates $17^0 00' 00''$ S - $17^0 00' 00''$ S and $71^0 59' 50''$ W - $71^0 59' 30''$ W. It corresponds to a mountainous coastal area, with a little litoral plain at Northeast and with a wide river plain at Southeast. In this area some sites were chosen according to the geographical requisites which determine the fog water collection potential : presence of a hill range; height of the hills; closeness to the coast line; orientation of the hill range; exposition of the hill sides in the range; enough space to build an extended line of fog collectors; slope of the hill sides. In each of the sites chosen, which were initially ten with two additional ones added later on, a Standard Fog Collector (SFC) was installed. An SFC consists in a frame structure of 1.0 × 1.0 m in the interior and with a mesh, with a 35 % shade, which captures the fog droplets. This panel is supported at 2 m above the ground by two vertical posts which on their turn are supported by four cables firmly tied to pegs hammered in the ground. Immediately below the frame there is a half-pipe which collects the water collected by the mesh and takes it to a tank. A detailed description of an SFC is given in the annual activity report given in the Reference list. SFC's are made just for data collection purposes. The actual collection of fog water to be used for applications is performed by large fog collectors of roughly 50 m^2 ("atrapanieblas") which work on the same basic principle. A daily tour of all the fog collecting stations was made, and in most of them data on fog collection, air temperature and wind velocity and direction were taken manually, while two of them had automatic data loggers with four channels which recorded wind speed and direction, and volume of fog and rain every 60 minutes. From the data recorded in all the stations the following information were obtained :

- fog water collection in liters for the whole period of data collection;
- monthly collection rates in liters;
- collection in liters for each day of each month;
- number of days in a month with collection rates over 25 liters;
- maximum number of consecutive days without collection;
- maximum number of consecutive days with collection;
- percentage of days with collection in each month and in the whole period;
- basic statistics : average, median, mode and standard deviations in liters for each month.

In the stations with automatic data loggers, in addition to the above, also the following information were obtained :

- average monthly collection for each hour of the day;

- average monthly collection vs. wind direction;
- average monthly collection vs. wind velocity;
- average duration in hours of each collection event.

The information obtained from the pluviometers were processed similarly to those of the SFC's in the cases when some precipitations were recorded. A sample of the information obtained is presented in Table 1.

3.2 Discussion of results

After an intensive campaign of eight months of continuous recording, some conclusions could be drawn, even if one has to keep in mind that only the data corresponding to one fog season have been taken, and therefore they are purely indicative as far as the fog water collection potential of the area is concerned. Despite this limitation, some general facts have been understood. The first one is the behavior of fog with altitude. It results that fog occurence is very little below 400 m of altitude, and sometimes also above 850 m it occurred that no collection was recorded because the clouds were lower than the station. The best collection rates have been observed at around 700 m of altitude. As far as the occurence of fog during the period of observation is concerned, it was noted that last year it appeared as if there was a shift forward in time of the fog season, which normally one expects to start in May, to peak in July and August, and start declining in September. In 1995, on the contrary, very poor fog collection rates were observed in May and June, and a considerable increase was observed starting in July. September deserves a special mention since during this month fog collection rates have been much better than during the previous months. For instance, in one opportunity, a collection event of $107 l/day/m^2$ - the highest ever recorded in South America - was observed, while the average collection rates were close or higher than $10 l/day/m^2$ for most of the stations.

In general, according to the opinions of the "lomeros" (people who live temporarily in the coastal hills for extended periods of time during the year, mainly for cattle breeding), it seems that during 1995 there was no occurrence of "lomas" (with this name they indicate the occurrence of fog). This means that cattle breeders considered 1995 a dry year which did not generate enough vegetation for cattle breeding, a fact evidenced by the low number of cattle breeders in the area and by the short time they spent there. In the region people say that 1995 was the fourth dry year in a row and this means that we have collected data during a typical year with little fog, so that the collection rates measured can be taken as lower limits. Yet, the total volumes of water which might have been collected on the basis of the fog collection rates observed are still considerable.

CONCLUSIONS

Fog collection research is a relatively new interdisciplinary subject, dealing with the study of fog as an alternative water resource for arid and semi-arid regions, and its applications to environment conservation, microirrigation and domestic use. In a time when the demand of water is steadily increasing, there exist strong practical motivations to look for alternative water resources with respect to the conventional ones - like surface and subterranean water or rain - specially in arid and semi-arid regions, where the difficulty of water supply is often accompanied by precarious life conditions for the local people.

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Table1. Maximum and average monthly collection rates (in liters) for each location. A blank square means that the SFC was not installed in the corresponding month.

	May		June		July		August		September		October		November		December	
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.
Mejia 1	7.85	0.37	1.90	0.13	24.40	1.89	9.00	1.05	61.10	11.81	7.83	1.49	0.40	0.01	2.60	0.12
Mejia 2	6.00	0.25	1.72	0.08	17.20	1.34	4.90	0.48	57.90	9.70	6.02	1.01	0.25	0.01		
Mejia 3	6.75	0.28	1.70	0.08	18.20	1.87	6.20	0.64	56.27	9.44	6.59	1.12	0.24	0.01		
Cuchillas	7.65	0.41	10.00	1.04	73.20	7.59	55.00	11.01	107.35	28.15	37.67	11.11	12.02	1.95	16.00	12.08
Majo 1			5.90	0.30	55.10	6.17	45.00	9.57	68.00	18.15	29.80	8.34	7.00	1.23	18.75	1.42
Majo 2			10.60	0.70	49.80	4.29	33.60	6.20	84.60	20.86	22.49	5.39	4.00	0.48	14.20	0.76
Taro 800	13.70	1.48	11.75	1.17	49.90	4.40	28.75	7.32	85.40	24.28	32.50	3.48	4.83	1.71		
Taro 600	5.60	0.34	0.95	0.16	29.00	1.41	9.50	1.14	55.13	10.90	6.40	1.17	0.38	0.02		
Taro 400	0.30	0.01	0.30	0.01	3.65	0.18	0.10	0.01								
Taro 350	0.10	0.00	0.23	0.00	1.90	0.08	0.05	0.00								
Parcela	0.30	0.01	0.37	0.01	3.40	0.17	0.11	0.01	12.55	2.22	0.36	0.06	0.00	0.00		
C. Laguna	5.75	0.39	7.20	0.40	39.40	1.65	25.65	2.30	96.00	8.87	47.22	15.28	0.45	0.03		
Prueba 1									61.45	13.31	16.75	3.61	2.41	0.31	4.30	0.29
Prueba 2									50.00	9.43	8.74	1.67	1.41	0.10	1.50	0.09