THE MISSING LINK IN A PRODUCTION CHAIN

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CON LOS ATENTOS SALUDOS

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SUMMARY

While the author was looking in vain for good quality ground water in the north of Chile under an almost permanent cloud cover near the coast, called Camanchaca, he started to realize that maybe the solution should be sought above the earth surface. He became acquainted with the device to intercept droplets of the fog: fogtraps, introduced in the Sixties by Carlos Espinosa and other investigators of the Universidad del Norte.

The lonely cypress planted in 1962 on top of the coastal range of the Andes above Antofagasta and living exclusively on intercepted fog water, opened his eyes. The productive chain: fog, vertical obstacle, excessive dripwater, other plants that take their share with the evaporation and finally the remaining part that could feed the underground water and the springs, was broken by eliminating the vegetation, and with the vegetation the vertical obstacles.

This manuscript is a geographical and intellectual narrative of the joints effort made by a small group of investigators supported by UNESCO to prove the idea of the disrupted chain and to solve the water supply of a fishing village.

Outsiders take it as a fairy tale and do not believe it as long they have not seen the process in action.

Meteorologists, believing that this is their problem, get hold of it, and analyze the atmospheric parameters that cause the fog, but the fishermen still do not have their water (*). More than meteorology is needed to solve the problem. It is a question of mentality and may also serve as a warning for other chains that are in the process of being broken and which will not produce any more.

(*) At present not only well elaborated plans (existing in more preliminary form since end 1984) but also funds are available for the execution of the final phase of the first fog water supply system. According to the responsible authorities the plant should become operational before the end of 1991.

CONTENTS

INTRODUCTION

1

Any visitor travelling along the South American Pacific coast between 5° and 32° Latitude South will be impressed by the imposing and desolate landscape of the often narrow stretch of piedmont slopes or wider coastal terraces that link the Pacific Ocean with the barren uplifts of the Cordillera de los Andes. Although this coast corresponds geographically to the subtropics and tropics it is always cool arid, extremely desertic, and frequently covered with a low cloud layer of strato-cumuli, called in Quechua **Camanchaca**, coastal fog, or **garúa** (in Spanish), depending on the cloud level with respect to the observer.

When the sun shines the greyish beeches due to the dark andesitic material of the volcanic hinterland, forming part of the Circum-Pacific Fire Belt, contrast with the greenish blue of the ocean. Close observation of the coast line reveals a teeming sea and bird life of the ocean as opposed to the sterile land surface.

When in September 1799 Alexander von Humboldt reached the Pacific Ocean from Cajamarca at about 8° Lat. S, he encountered for the first time this cloud-covered coastal desert. He wrote that to his great surprise the sea temperature, which elsewhere is 27°-28°C at similar latitudes, was only 16°C near Trujillo, and at the beginning of November 15.5° C in Callao, while the air temperature in the former period was 17.8°C, and in the latter case 22.7°C, or 7 degrees warmer than the sea (Fig.1, Fig. 9). So the air could not have cooled off the water. The opposite must be the case.

Since Fernando Magallanes rounded Cape Horn, sailors knew that a current of cold polar waters wedges northward between the South American coast and the warmer waters of the South Pacific Ocean. Recent studies disclose that the southern tradewinds push the ocean waters towards the Asiatic coasts and consequently sea levels over there are normally 30 to 40 cm higher than on the Chilean-Peruvian side. To compensate this pressure difference upwelling of cold Antarctic waters along the steep South American coast maintains the low temperatures of the Humboldt current. According to Vegas (65), (66) this Humboldt current can be characterized as an upspiralling mass of oxygen-rich nutritive water reaching the South American coast from about 40° to 5° Lat. S, and from there diverting again towards the Galapagos Isles, making it the coldest archipelago of the Equatorial region. On its way to these islands, the current regularly hits the most western point of Ecuador, the peninsula of Santa Elena, west of Guayaquil. Wyrtky (1968) notes that the current transports 6 million m^3/sec and has temperatures from 14° C in winter (June to September when Lima is permanently covered by a cloud deck) to 21° C in summer when cloudiness tends to be reduced to the Chilean coast.

The current varies in width during the year; narrower in summer and wider in winter up to 100 miles, predominantly depending on the force of the mid-ocean tradewinds (Fig.1). Of course at low levels these eastern tradewinds are not felt at the western leeside of the Andes range. The latter forms a real climatic barrier with its north-south orientation and average altitudes of 4000 to 5000 m a.s.l. Moreover, since 90% of the water moisture transport takes place at levels below 5000 meters a.s.l., it is obvious that the humidity of the Amazon basin can hardly reach the Pacific coast. This situation creates the exceptional climatic condition in the northern Chilean and Peruvian coastal area. Here throughout the year the climate is generally dominated by the interaction of the following factors:

1. the subtropical Southeast Pacific High Pressure Centre, characterized by subsiding dry air masses,

2. the cold waters of the Humboldt current from below, cooling the subtropical maritime air masses till below their saturation point.

The result is an extraordinary stable temperature inversion with a frequent cloud deck, **Camanchaca,** as basis. The Camanchacas are blown inland from the ocean by western breezes at 30° Latitude S. in Chile, gradually turning south up to 5° Latitude S, induced by the position of the high pressure centre or anticyclone, and evaporate above the dry coastal zone on their way to the interior.

The objective of this document is to explain the efforts made by Chilean and Peruvian professionals coordinated till 1987 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) through its Regional Office for Science and Technology for Latin America and the Caribbean (ROSTLAC), to use these Camanchacas as a non conventional renewable water resource along the arid coasts of Chile, Peru and Ecuador. Since 1987 the International Development Research Centre (IDRC) took over in one specific area in Chile with a new approach, to which reference is made in the last chapter.

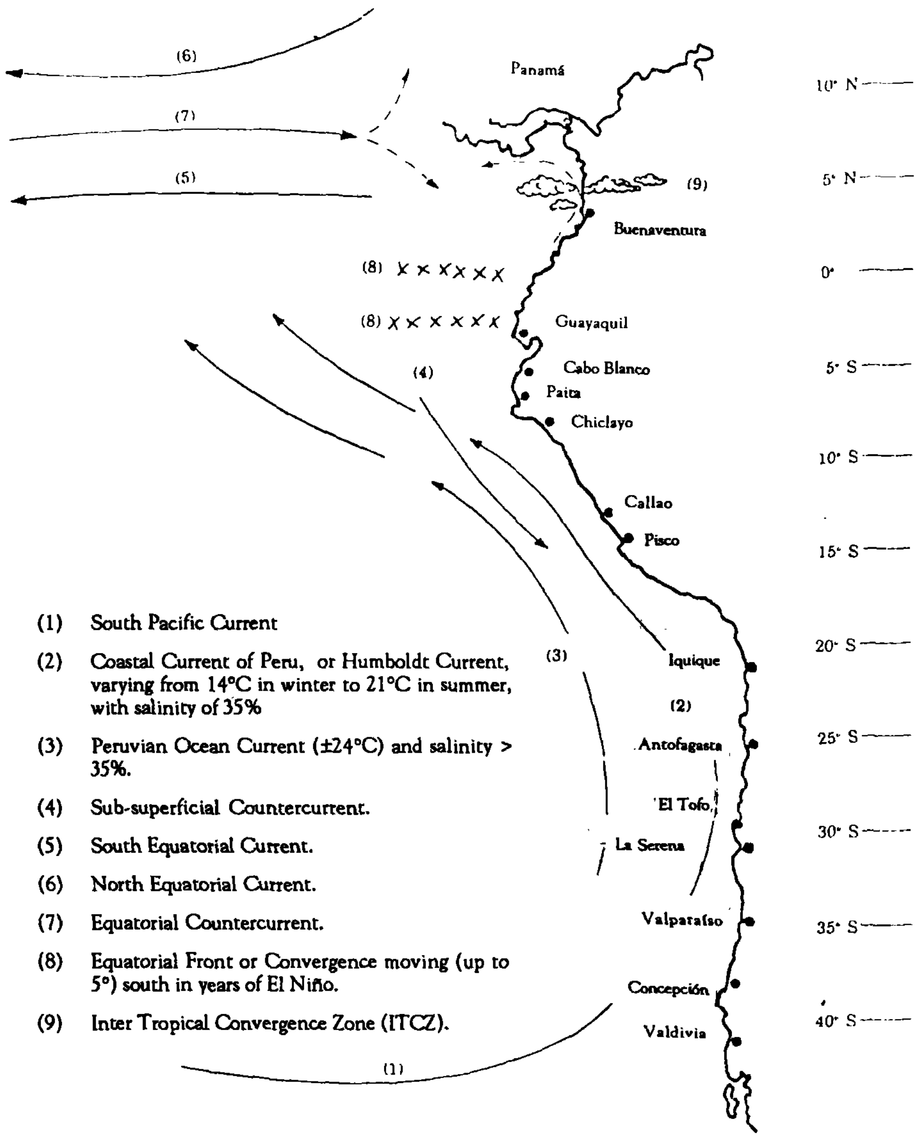


Fig. 1 - Schematic representation of the system of eastern Pacific Ocean currents (After M. Vegas Vélez, 1983).

2

START AT UNIVERSIDAD DEL NORTE (61)

The first studies on water harvesting of the Camanchacas practically coincide with the foundation in 1957 of the "Universidad del Norte" in Antofagasta.

Antofagasta being the driest town of Chile and maybe of the whole world, with a main annual precipitation of 5 mm, receives its water supply from high altitude (3350 m), via a pipeline of about 400 km length. Rationing of municipal water is the normal procedure to combat the eternal shortage of water. Therefore, for the people in this city and surroundings, water represents a permanent matter of life and death (Photo 1).

In the beginning, the first investigators Rev P. German Saa, M. Valdez, Carlos Espinosa, Ricardo Muñoz, with the Israeli scientist Dr. Samuel Duvdevani, also interested in the collection of dew, realized that capturing Camanchaca water was much more promising, and so dew research was abandoned.

The experiments consisted in placing vertical obstacles on strategic locations, where the clouds use to pass on their way from the ocean, via mountain tops, slopes and passes towards the interior, where they dissipate again due to the drier and hotter environment. Periodically the volume of water collected by the intercepting obstacle was measured. These obstacles called "atrapanieblas" or fogtraps, consisted of polyester netting or vertical nylon wiring, sustained by two- or three-dimensional frames of different shapes, positioned perpendicularly to the ruling wind direction. The intercepted water was conducted into containers. The investigators experimented each with their self-made fogtraps not yet ready for standardization of their equipment, with the result that the possibility of quantitative comparison between the measurements was poor. In fact, the objective of these experiments was to find out how the interceptable water content of the clouds varied with the seasons and the geographic location of the fogtraps, like altitude, distance from the coast, influences of local topography, etc. In order to correlate the results, the researchers adopted the norm to relate the values of water collected to the unit of area of 1 m^2 of the fog intercepting surface of the vertical obstacle. This area was defined as the projection of the surface in the dominating wind direction, whatever the shape of the apparatus. Of course this was a very rough approximation, as some fogtraps were more effective than others due to shape, kind of wiring or netting, altitude above ground level, etc.

The scientific staff was responsible for the accomplishment of an intensive general teaching programme, and had little time and means to execute practical field investigations, moreover the investigation sites were of difficult access. Readings could not be made in a systematic way. It happened that captured waters, accumulated in tanks of various sizes, spilled over before the next reading was made. Because of the frequent long intervals between observations, the volumes obtained per fogtrap were converted into units of m^3/m^2/year, which gives little idea about the distribution of interception with time.

Carlos Espinosa and R. Muñoz continued their research with much perseverance. The former worked on the seasonal distribution of the Camanchaca with his iron framed cylindrical apparatus of 0.7 m cross-section and 2 meters altitude, consisting of 1300 vertical perlon filaments of 0.5 mm diameter each, and mutual distance of 1.5 cm, mounted on a 200 l. barrel (surface area vertical object: svo = 1.4 m^2). He patented this equipment in 1963 as "fogtrap Nº 611115" with Chilean invention Nº 18.424 . His measurements were carried out from 14 December 1961 to 29 December 1963 at the Andromeda station in the Miramar mountains, approximately 1000 m. a.s.l., immediately east of Antofagasta. He obtained as an average over the entire period 4.0 liters /day with seasonal distributions as given in Table 1.

Table 1 - Seasonal distribution of water intercepted by fogtrap 611115.

	Spring	Summer	Autumn	Winter	Mean value
liters/day	5.0	1.4	3.3	6.3	4.0
m^3/year	1.83	0.51	1.20	2.30	1.46
SVO	1.4	1.4	1.4	1.4	1.4
m^3/m^2 year	1.30	0.37	0.86	1.64	1.04

R. Muñoz used a pluviograph connected with a fogtrap of a two-dimensional "harp" type, consisting of an iron frame 34 cm wide and 62 cm high, with 130 nylon filaments of 1 mm diameter. With this device he investigated the daily fluctuations of the fog occurrences in the Miramar mountains between 2 September 1963 and 31 December 1964, reaching the following results that were more specified in the period from 1965 to 1968.

- The maximum amount of water was obtained in spring (October-November-December), the minimum in summer.
- During autumn and winter the monthly average of water collected is slightly decreasing.
- The most frequent overcast is produced between 1 and 7 a.m. with a maximum between 3 and 7 a.m. and a secondary maximum between 6 and 10 p.m.
- Between 11 and 15 h capturing was practically zero.

In 1962 a cypress was planted near the observation spot. It was supplied with water by a fogtrap during 2 years, and after that the solitary tree captured its own water directly from the clouds. The cypress, being the only living protrusion in the wide surrounding, became a symbol of the productivity of Camanchaca and the site is called ever since "Loma del Ciprés" (Photo 2).

By 1968 the publications of the various authors, especially Espinosa and Muñoz, had attracted sufficient attention to justify the launching of the "Proyecto Camanchaca" supported financially by the Corporación de Fomento del Norte (CORFO del Norte) and the National Commission for Science and Technology (CONICYT). The objective of this project was to measure the potentialities of the Camanchaca in 38 selected locations along the coastal area of the Atacama desert over an extension of 700 km, from Iquique in the north to Taltal in the south (Photo 3).

In order to make the results comparable, an uniform measuring device was designed called "Atrapaniebla Típico", with the following specifications: a rectangular prism with height of 150 cm and square basis with sides of 39 cm, covered laterally with a polymer netting denominated SARAN, resistant against ultraviolet radiation. This apparatus was mounted on a 200 liter barrel partially dug into the ground to function as a funnel, accumulation reservoir, measuring device, and firm anchorage to resist gusts of wind. The anisotropic geometry provided an intercepting area of the vertical obstacle of either 0.8 m^2 with the wind direction parallel to the diagonal, or 0.6 m^2 with the wind direction parallel to the sides of the base. For the conversion of the measurements in volume/m^2, the mean intercepting area of 0.7/m^2 was used (Fig. 2).

The measurements took place from September 1968 to August 1972 and led to the following conclusions:

- The most favourable altitudes for capturing cloud water are between 800 and 1200 m above sea level.
- The period of optimum capturing covers the months of August, September, October, November, except for the measuring station on the Morro Moreno, the protruding mountain on the peninsula of Mejillones in front of Antofagasta.

Among a wide variety of values obtained, there are sites where the interception was neglectable, while others showed peak values of 60 liter per week, 4.46 m^3/m^2 year. The selection of the measuring site was conclusive in this connection. Of course it happened that promising sites were discarded due to difficulty of access. In other cases in order to select a site of high prognostics but difficult access, the logistic problems were such that the sites could not be visited with the desired frequency. These reasons explain why a lot of values delivered by the project were defective and incomplete.

In many occasions, due to excessive time lapses between successive readings, the volumes collected had exceeded the capacity of the barrels and had spilled over. Also many droplets had been blown off the netting beyond reach of the water collectors. In any case, readings provided reliable minimum values.

However, four observation points were well controlled and showed an outstanding persistence and regularity in their water production, fluctuating between 6 and 30 liters/week with an average of 15 liters/week or 1.11 m^3/m^2/year (see Table 2).

Table 2

Site		Range of interception		Average
		Lts / week	m^3/m^2.year	m^3/m^2 year
1.	Michilla (mina)	6 - 10	0.45 - 0.74	0.51
2.	Mirador	10 - 15	0.74 - 1.11	0.83
3.	Los Morros(Miramar)	15 - 20	1.11 - 1.49	1.21
4.	Morro Moreno	23 - 30	1.70 - 2.22	1.90
Weighted average		15	1.11	1.11

The Morro Moreno site, deviating from the other sites due to its protruding position into the Pacific west of Antofagasta, needs a special comment (Photo 4). For every inhabitant in Antofagasta, used to observe the daily spectacle of this mount with its almost continuous garland of clouds, the excellent yields obtained at this station were not surprising. Water obtained on Morro Moreno is at least 1.7 times more than the average yields obtained along the rest of the coast. This figure was even considered too low, since in the majority of cases the observers, after a tough 90 minutes climb, starting from the fishing village of Juan López, 25 km from Antofagasta, encountered the water containers filled up to the rim. Moreover the wind force is so strong that apart from blowing a great part of the harvested droplets off the screens, the fogtraps themselves were frequently destroyed.

In order to clear up this question, Ricardo Zuleta, who joined the scientific staff at the Universidad del Norte in the Sixties, launched independently from the previous surveys, an observation campaign in the period of 19th August 1970 to 10th February 1971. The observations took place simultaneously at the Andromeda, Miramar and Morro Moreno stations with a specially designed 2-dimensional fogtrap, with the surface area of exactly 1 m^2 of mosquito netting type. As a result, Zuleta found a factor of 3.9, instead of the above mentioned 1.7 (See Table 3).

Table 3 - Measurements made by Zuleta

Site	Specific yield	Relative interception	Standard deviation
Andromeda	0.09 m^3/m^2.year	0.1	2.2
Miramar	2.00 m^3/m^2.year	1.8	25.8
Morro Moreno	4.36 m^3/m^2.year	3.9	46.9

The discrepancy of these results on such a promising site was the motivation to study the case more thoroughly by installing a meteorological station consisting of a standardized WMO fogmeter (Grunow type), which allows the correlation of the different atrapanieblas, a Fuess pluviometer, maximum and minimum thermometer, Lambrechts anemograph, a Robitzsch bi-metallic actinograph, thermographs, hydrographs, etc. Also the chemical and bacteriological analyses of the captured water were made as well as the qualitative behaviour of certain crops raised with these waters. This study was carried out from 1st September 1970 to 31st May 1972. The results obtained in 1971 only, appear in Table 4.

Table 4 - Experimental results obtained on Morro Moreno with Grunow fogmeter

Mean annual values of 1971

Mean annual values

Variable	**Symbol**	**Equation**	**Value**	**Unit**
Total period (1 year)	T		365	days
Total time with Camanchacas	Tc		105.28	days
Number of days with Camanchacas	cT		319	days
Number of camanchacas	Nc		568	
Duration of camanchacas	t c	Tc/Nc	4.45	hours
Index of persistence of Camanchacas	f	cT/T	0.87	
Index of annual concentration	Ic	Nc/cT	1.78	
Yearly fraction of Camanchaca occurrence	†	4.45/24	0.18	
Volume of total interception (during 1 year)	V		0.066	m^3
Specific interception (during 1 year)	qe	V/SVO	3.3	m^3/m^2
Surface of vertical obstacle	SVO		0.02	m^2
Average wind velocity	W		4.7	m/sec
Max velocity of wind	W max.		16.7	m/sec
Min.velocity of wind	W min.		0.6	m/sec
Average air temperature	temp		9.7	°C
Average annual global radiation	R		172	$watt/m^2$

It is interesting to note that on Morro Moreno the phenomenon is persistent although there were 46 days without Camanchaca in 1971, which is more than the average of 10 days mentioned by Espinosa. However, the phenomenon occurs much more than once a day. Zuleta calculates 1.78 Camanchacas/day, and an average duration of 4.45 hours. Measurements like the average temperature of 9.7°C must be characteristic for periods with Camanchaca.

Espinosa mentions wind velocities from 2.16 km/hr to 60 km/hr with an average of 17 km/hr. The author supposes that the stronger winds were blowing outside the time that Camanchaca occurred.

So far the various measurements showed relative values comparing the water potential of the clouds at different sites related to the surface of the vertical obstacle (SVO). But also equal surface areas of vertical obstacles may capture a different percentage of the liquid water content of the cloud depending on the wind force and the internal structure of the fogtrap.

Zuleta made an effort to calculate the fraction of the total liquid water content of a cloud which can be captured. This fraction demonstrates to what extent the water production can be optimized.

A major problem with the interception was always the loss of large droplets blown off the intercepting surface (netting or filaments) outside the water accumulation device in which the water volume can be measured. Of course, with increasing wind velocity more water is lost although production tends to increase.

In 1965 Ricardo Zuleta, experimenting with mosquito netting, observed that the intercepted mini-droplets due to surface tension between the droplets gradually form a continuous flat liquid film if the mazes of the netting are not too wide. With increasing wind this film becomes concave until at a critical velocity for a certain maze dimension the film breaks and large droplets blow off the intercepting system. Because of their large size these droplets have a strong vertical component of movement and fall not far behind the intercepting screen on the ground.

Zuleta collected these large blown-off droplets and found out that he could obtain another 6 % of the total volume of water collected on the screen.

These experiments led to the design and construction of his so-called battery. This device consisted of a parallel set of 10 netting screens, each one of 0.10 m^2, oriented perpendicular to the wind direction and mutual separation of 6 cm.

Through a special systems of gutters he could measure independently the production of each of these 10 screens. He closed the sides of the first battery and left open the sides of a second one. Of 80 probes executed between 1967 and 1969 at the Miramar station, he analyzed only the 26 most reliable ones (see Table 5).

Experimental results of fog interception in batteries composed of parallel sets of screens, according to R. Zuleta (Table 5).

Table 5 - Proportional interceptance in batteries of netting screens

Successive screen number	**Open battery** % captured	% accumulated	**Laterally closed battery** % captured	% accumulated
1	43	43	34	34
2	23	66	22	56
3	10	76	12	68
4	6	82	8	76
5	5	87	6	82
6	4	91	6	88
7	2	93	5	93
8	2	95	3	96
9	2	97	2	98
10	1	98	1	99
11*	1	99	1	100
12*	1	100	0	

(*) Values obtained by graphic extrapolation (Fig. 3)

Higher values observed in the first screens of the open battery are probably due to turbulence of the fog mass provoked by the presence of the battery itself. According to this effect the values obtained in the laterally closed battery may be more representative.

Zuleta supposes that of the 22 % captured on the second screen of the laterally closed battery, 6% corresponds to the large droplets blown off the first screen as was concluded before. If one uses this 6% for the watering of plants behind the fogtrap, **one may assume that 40% of the liquid water content transported by the cloud is interceptable.** According to the experiences accumulated over time by the investigators in the Antofagasta region, this fraction is in agreement with later findings.

From this real interception Zuleta calculated the theoretic maximum interception (qt)

For instance: Real average interception along the North Coast according to Table 2:

$$q\,NC = 1.11\ m^3/m^2\ year$$
$$qt\,NC = 1.11/0.4 = 2.77\ m^3/m^2\ year$$

Real average interception at Morro Moreno (q MM) according to Table 3:

q MM = 4.36 m^3/m^2 year;
qt MM = 4.36/0.4 = 10.9 m^3/m^2 year

Another important consequence of the battery experiment was that on the basis of the result the average liquid water content could be estimated.

Applying the mean values of Table 4 and the specific productivity or interception (qe), the average liquid water content (lwc) of the Camanchacas along the north coast can be calculated as follows:

lwc NC = qt NC / w * f * tc * 31.5 = 2.77/ 4.1 * 0.25 * 0.17 * 31.5 = 0.5 gr./m^3,

and the same at Morro Moreno:

lwc MM = qt MM / w * f * tc * 31.5 = 10.9 / 4.7 * 0.87 * 0.18 * 31.5 = 0.47 gr./m^3

In any case this was the ingenuous way the first observers of the Universidad del Norte tried to solve the difficult questions with which they were confronted with the minimum of instrumental means and research funds.

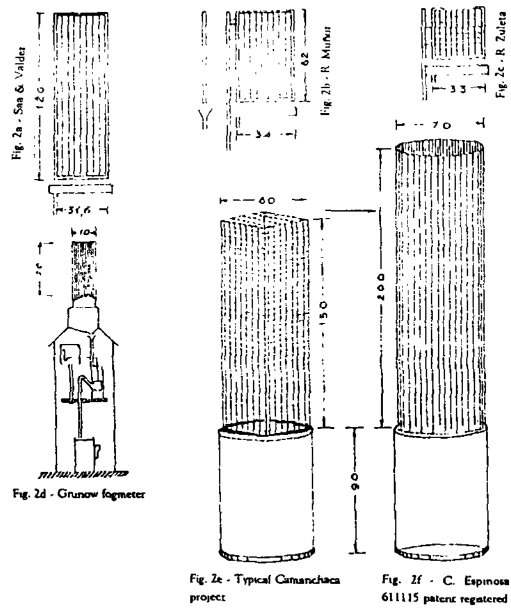


Fig. 2 - Various types of fogtraps used by the investigators of the Universidad del Norte, Antofagasta.

Fig. 3a

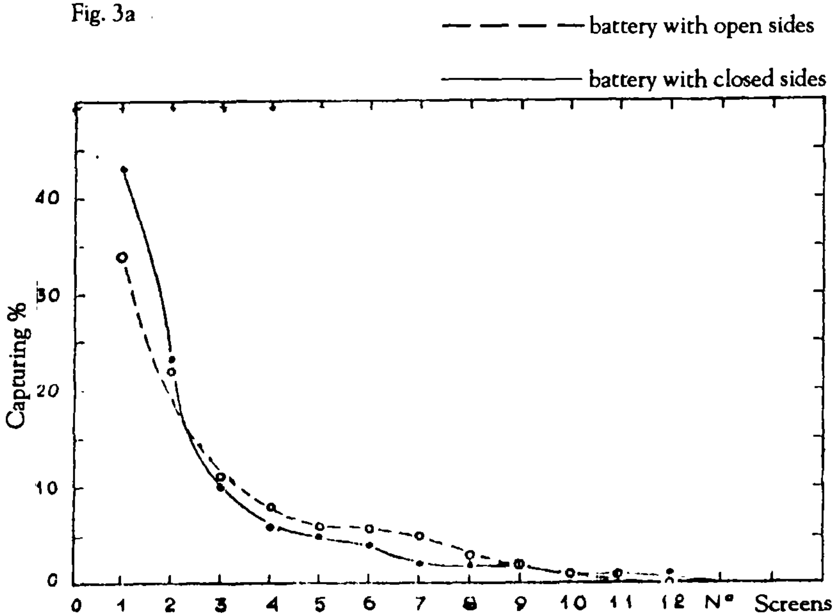


Fig. 3b - Andrómeda Station

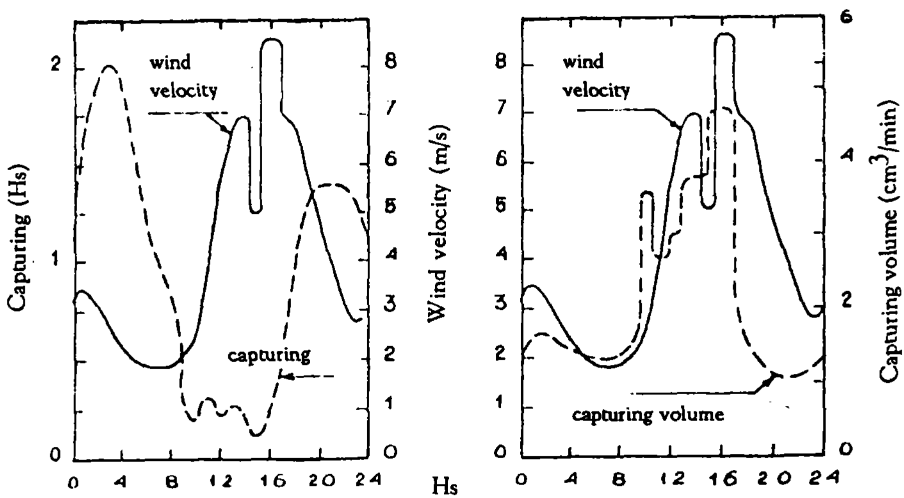


Fig. 3 - Capturing on successive screens of batteries made by Zuleta (61)

(According to R. Zuleta (1967-1969)

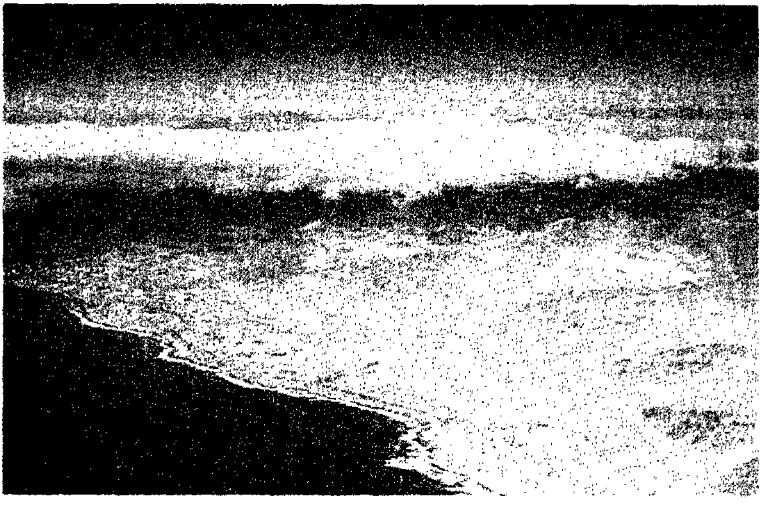


Photo 1 - The city of Antofagasta under the Camanchaca clouds, situated on a narrow piedmont between the coastal Andes range and the Pacific

Photo 2 - The cypress above Antofagasta with Ricardo Zuleta at the right side and Carlos Espinosa behind the tree. This is the only tree in a wide surrounding. Its branches grew perpendicular to the wind to intercept the maximum of water. But also the wind force on this protruding mountain top limits its growth in altitude. The dripwater generates in its turn secondary vegetation underneath

Photo 3 - Carlos Espinosa next to one of his old fogtraps from the 1968/1969 campaign

Photo 4 - Morro Moreno seen from Antofagasta with top in Camanchaca

3

THE MESSAGE OF THE CYPRESS

At the beginning of 1971 the author appeared on the scene as the *senior hydrogeologist* and later interim project manager of the UN/UNDP project "*Water Resources Development in the Norte Grande (CHI-35)*" Due to experiences in the Middle East and Sahel area of Africa he was acquainted with "*Groundwater Exploration and Evaluation in Semi Arid and Arid Regions*" as was requested. He applied for the post attracted by the Background Information included in the Job Description of August 1969:

Lack of water has long been the prime factor in the limited development of the Norte Grande, a vast area of over 180,000 km² comprising roughly the northern quarter of Chile. The area has been called the driest desert in the world, and in the western part of the region, even a sprinkle of rain is very rare.

Precipitation does increase, however, toward the Cordillera de los Andes, where it varies from about 300 to 500 mm annually. Water for coastal cities, including Antofagasta, has long been imported from the Cordillera by pipelines, some as long as 365 km.

Development of groundwater resources, however, has been much more limited. Saline groundwater is encountered in some localities, but in others such as the Pampa the Tamarugal (near Iquique) supplies of good quality groundwater have been found to be available.

The predominantly urban population of the region was estimated at 350,000 in 1965. The economic contribution of the region, especially in export earnings, is out of proportion to its share of less than 5% of the total population. About 40% of the exports of the country come from the Norte Grande through copper, nitrates and other minerals, and fishmeal.

The Government of Chile is keenly aware of the water problems of the Norte Grande, and the consequent limitation to development. Consequently, a comprehensive investigation and evolution of both physical and economic factors of water development is essential.

Evidently coming fresh and unprepared from the Old World, far away from any fire belt, the scenery of the Norte Grande produced the kind of shock which Alexander von Humboldt had experienced over a century before: first the exaggerated land - sea contrast and secondly the strange task of looking in vain for good quality groundwater with a cloud cover above. As a hydrogeologist it made him feel somehow disoriented and rather helpless.

Obviously he was totally unfamiliar with ongoing activities of the Universidad del Norte, which were only known to an inner circle, because fear of scientific competition brought a tendency for secrecy, as is often usual among university researchers.

Every groundwater man who has visited the impressive snow-covered water divide between the Pacific and Atlantic at only 100 to 200 km from the coast, cannot resist the idea that, in spite of the deserts in between, at least a small fraction of the melting waters may reach the Pacific by seeping through underground joints and fractures. Does not the Cordillera de los Andes with its vulcanism and earthquakes find itself in plain status nacendi ! Had not this idea also occurred to Charles Darwin during his passage in this part of the world, as can be read in his book "Journey with the Beagle"? These arguments motivated to undertake a survey consisting of the collection of ground-, river-, snow- and rain-water samples from the central Andes range to the coast. The objective was to find through the stable isotope content of Oxygen-18 (O-18) and Deuterium (H-2) of the water samples the origin (in the Andes fairly well-defined by the altitude level of infiltration) of these waters and the extent to which they had been exposed to evaporation, as these parameters would answer crucial questions about surface-water ground-water relations of the region with only one overland drain represented by the tiny river Loa, discharging into the Pacific, in a wide stretch of more than 1000 km coastline (Fig.4).

A difficulty was that no rainwater sample could be obtained from the coastal area. This created at last the contact with Carlos Espinosa, professor in physics at the Universidad del Norte. With his help a sample of Camanchaca station Nº 71040212 (70°18' Long W 23°30' Lat S) was obtained.

Without any doubt the results were contradicting the supposed coastal resurgences of seepages originating from the central Andes chain. To the contrary the few existing coastal springs are fed by infiltrations from about 1000 m a.s.l. and certainly not from 3000 m to 4000 m or more. This altitude corresponds to the level of the regular overcast touching the coastal range at about 800 to 1200 m, and needed now to be observed with more attention. Further investigation demonstrated that this zone was characterized by a marked cactaceous vegetation, watered by Camanchaca.

The isotope investigation was executed in collaboration with Claudio Silva H., scientific representative of the Chilean Commission of Nuclear Energy. It consisted of 61 Oxygen-18 determinations, all analyzed free of charge by Dr.W.G.Mook of the Physics Laboratory, University of Groningen, the Netherlands, and Dr. Eneas Salati of the Isotope Laboratory in Piracicaba, near Sao Paulo, Brazil. Unfortunately the Deuterium content was not examined.

UNOTC (now TCDC), as the executing agency of the CHI-35 project, was not interested in the isotope survey.

Since the project suffered a lot of administrative difficulties the author did not renew his contract but requested instead an inter-agency transfer, which resulted in June 1972 in his posting to UNESCO as Regional Hydrologist at the Regional Office for Science and Technology for the Arab States (ROSTAS), at that time established in Cairo, Egypt.

Although there was only one Camanchaca sample in the stable isotope survey showing isotopically the same characteristics as the coastal spring waters, this was enough to become intrigued by the occult precipitation caused by the Camanchaca. This in combination with the existence of the cypress (Photo 2) led to the following conclusion:

A tree captures water from fog not as a function of its water needs but as a function of its capacity to intercept the tiny droplets which move horizontally in the cloud. The capacity of interception is related to its surface area perpendicular to the ruling wind direction. The instantaneous yield intercepted does not only allow the tree to survive, but also provides dripwater to a secondary vegetation generated at the foot of the tree. Moreover the dripwater that is neither absorbed by vegetation nor evaporated, will feed the groundwater, finally supplying water to the springs. So in order to activate this chain reaction, interception capacity has to be created by establishing artificial trees or vertical obstacles that allow natural trees to grow until they are self-sufficient.

It would still take a long time before the value of this conclusion was recognized even by the scientific community.

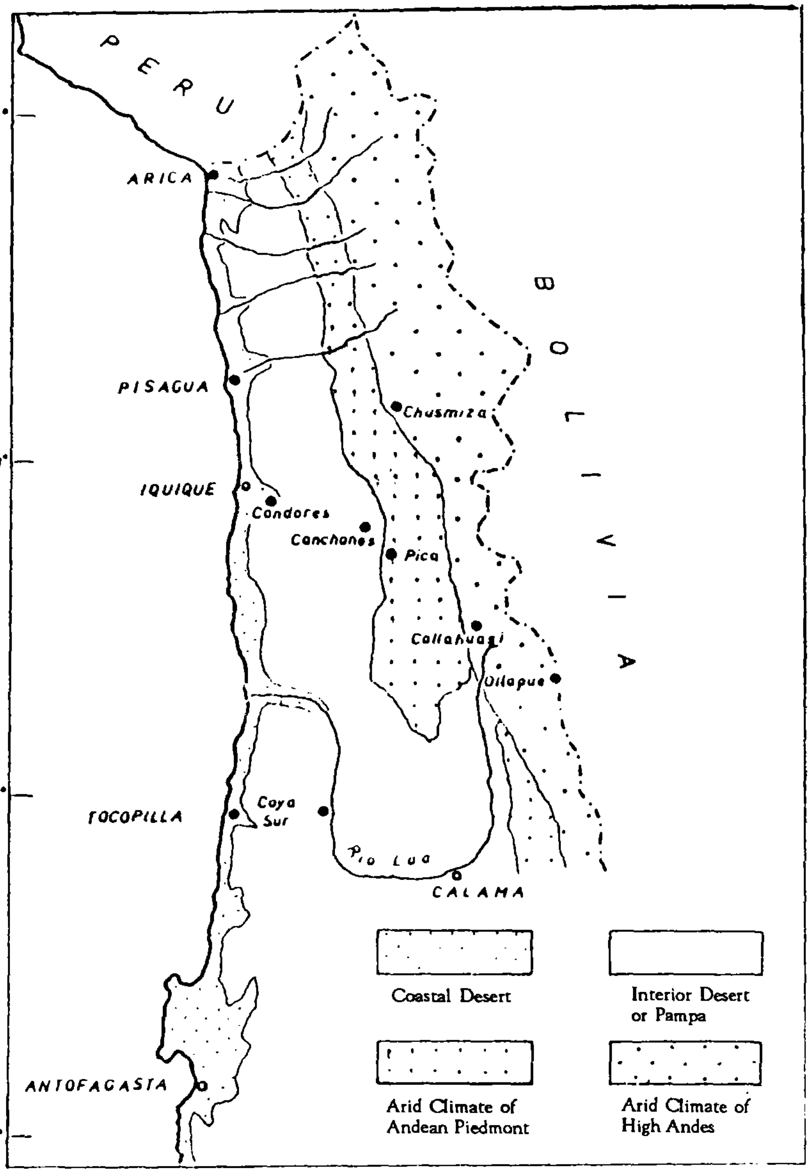

PERU
BOLIVIA
ARICA
PISAGUA
IQUIQUE
Condores
Conchones
Chusmiza
Pica
Collahuasi
Ollapue
TOCOPILLA
Coya Sur
Rio Loa
CALAMA
ANTOFAGASTA
18°
20°
22°
24°
Coastal Desert
Interior Desert or Pampa
Arid Climate of Andean Piedmont
Arid Climate of High Andes

Figure 4

4

TOWARDS REGIONAL COLLABORATION

During the UN Conference on Desertification held in Nairobi, Kenya, in September 1977, there were, as usual, private conversations, this time among the arid zone specialists, which were most enjoyable.

Dr. H.F.Lamprey, project manager of the UNEP/MAB Integrated Project on Arid Lands (probably one of the first practical efforts ever made of this type) raised the subject of the rehabilitation of the vegetation and the restoration of productivity of the arid lands of the Kulal area, south east of lake Rudolf in Kenya. Lamprey explained some unusual hydrological problems which could be related.

The Mount Kulal region was selected for the project as it includes an exceptional range of eco-climatic zones within a relatively small area, from a dense forest zone on Mount Kulal to the Karoli desert 30 km away, with a mean annual rainfall of 100 mm.

Mount Kulal, a volcanic mountain range 25 km long and 8 km wide, rises to 2,300 m above sea level and supports a 35 km^2 montane forest. It is questioned to what extent this forest that captures moist from the clouds may be of importance for supplying water to springs as far as 70 km away, in the case of the springs of North Korr.

If this relationship could be proved, it would be possible to create new springs, or to increase the yield of existing springs by afforestation on appropriate fog swept (cloudy) mountain slopes at high levels.

Mohammed Altai, director of research of the Ministry of Agriculture, Fisheries Petroleum and Minerals and Ralph Daly, the government adviser for the Preservation and Development of the Environment, were both from the Sultanate of Oman. They mentioned in this context the peculiar case of Dhofar, the southern coast of Oman, neighbouring with Democratic Yemen. The relatively rich vegetation of this area could develop thanks to the formation of the moisture laden clouds supplied by the south west monsoon, occurring normally from the end of May to September.

According to Anthony G. Miller, this air current, while crossing the Indian Ocean assimilates humidity before hitting the south east coast of the Arabian Peninsula. The friction of these winds drag the ocean surface and create a current from Africa towards the coast of India. This movement of surface waters allows upwelling of deep cold waters particularly off the coasts of Somalia and Dhofar. The result is that the monsoon air current cools off to dew point and forms clouds and fogs that build up against the Dhofar escarpment, parallel to the coast, and spills over where this escarpment is sufficiently low. Like the Camanchaca, the cloud deck is limited in altitude due to a temperature inversion at about 1500 meters, caused by dry hot air coming from the Arabian desert under summer conditions. Rainfall in the coastal plain is about 100 mm increasing to 200 - 500 mm at the escarpment, but the occult precipitation in the form of drip from trees increases the normal precipitation many times (Figs. 5a and 5b).

Unfortunately due to political instability with Democratic Republic of Yemen at that moment it was not recommended to visit the area.

The Chairman of the Soil and Water Task Force of the UNEP Division of Water Resources, Letitia Obeng, was looking for a new type of potential renewable water resource. If such a resource existed, she wanted to find a country or region which was willing to host a study to examine the potentialities of the resource in more detail. UNEP, in that case, would offer financial support. The UNESCO regional hydrologist proposed **fog moisture harvesting.** After consultation with the Peruvian and Chilean delegates present in the Desertification Conference the following translated text was produced by the Chilean delegation in Nairobi.

Exploitation of the coastal fog

1. *In our country from the north down to the IV Region (including the entire Norte Grande), during the morning abundant fog is produced in the neighbourhood of the sea, covering an extension of approximately 1000 km length.*
2. *Different types of fog traps of varying efficiency have been developed*
3. *Systematic measurements at different locations in the indicated area have been executed by means of standard fog traps.*
4 *The area is characterized by lack of water resources.*

Proposal

To establish different pilot centres which demonstrate the application and use of the moist collectors for forestry and agricultural purposes.

a. *To select the most suitable (geo)morphological conditions for the collector system.*

b. *To evaluate the efficiency of the different types of collectors.*

c. *To select the most suitable vegetation for the exploitation of the fog.*

d. *Socio economical evaluation of the used types.*

Available Resources

The country disposes of studies that cover the following aspects:

Capturing of the fog, capturing and distribution of water, use of tree and shrub species, irrigated agriculture, plastic-covered agriculture.

This work has been developed among others by the following national institutions: Universidad del Norte, Faculty of Forestry of the University of Chile, Corporación Nacional Forestal (CONAF), Instituto Nacional de Investigaciones Agrícolas (INIA), etc.

Needs

Implementation of the pilot project needs the following elements:

1. *Professional and technical personnel: national experts under direct contract, international experts, technical personnel and labourers.*
2. *Transport : 6 vehicles*
3. *Equipment: meteorological equipment, hydrological equipment, fog traps (moist urecollectors), tools and implements.*
4. *Budget for operation: salaries and per diem, fuel, nurseries.*

The Peruvian delegation, although interested in the subject, preferred to consult the authorities at home first .

Letitia Obeng, happy with the suggestion, requested urgently an English document that would describe and explain some characteristics of the resource and could serve as a justification for the financial support.

Some documentation existed, but none made any speculations going beyond mentioning volumes of water that fogtraps could intercept, to develop the cloud water into a practical economic resource.

Although the water sampling data of the stable isotope survey in the Antofagasta region had been discussed with people of the Chilean Commission for Nuclear Energy and the results had been handed over in November 1974, a comprehensive report was never produced on the subject. This was due to the author's transfer to a new post in Cairo and the fact that nobody had ever asked for a report.

With the material which the author had at his disposal in Egypt a document was written in November 1977, called: "*Camanchaca as a potential renewable water resource for vegetation and coastal springs along the Pacific in South America*" (27). It was sent to UNESCO Paris, UNEP and via the Chilean and Peruvian Embassies in Cairo to the appropriate government institutions in Chile and Peru, like CONICYT

For the time being this was the end of the affair except for Letitia Obeng asking for further reactions from Chile or Peru, as her allocation, reserved for a pilot project, might be claimed by other groups for the implementation of the resolutions of the Desertification Conference.

In September 1978 the UNESCO Regional Hydrologist was transferred from Cairo to Montevideo, Uruguay, to the Regional Office for Science and Technology for Latin America and the Caribbean (UNESCO/ROSTLAC). Having the Pacific coast within his area of action, a more thorough effort could be made to promote at least the recognition of the Camanchaca as a potential economic water resource.

At the turn of the year the first contacts in Chile were made with the National Commission for Science and Technology (CONICYT). Morris Assael of CONICYT, remembered the report about Camanchaca and referred to the Institute of Natural Resources (IREN) where UNESCO should get in touch with Mr. Francisco Díaz. The latter also formed part of the Chilean delegation in Nairobi and moreover was secretary of the National Chilean Committee for the International Hydrological Programme (IHP). Díaz would be the Chilean contact.

The Peruvian contact was at the beginning the National Meteorology and Hydrology Service (SENAMHI). This service was headed by Air Force General Oscar Piccone Ocampo, who also was the president of the Peruvian IHP Committee. However, he left the scientific and daily IHP questions to his Director General, engineer Luis Vega Cedano, also secretary of the two-man Peruvian IHP Committee. General Piccone, as an elder airman, felt immediate sympathy for the subject and moreover it appealed to his once-pioneering mentality. He was soon convinced that the first step to be taken would be a preparatory meeting with a small group of Chilean and Peruvian specialists, familiar with the Camanchaca phenomenon, to formulate some basic points which could justify collaboration and to set some rules and conditions for a future more authoritative meeting.

Piccone explained the hydrological situation of the Peruvian coastal area as follows:

The area consists of a coastal plain 2,500 km long and as an average 40 - 70 km wide, which broadens to the north, opening into a vast coastal desert. Mean annual precipitation from the coast to the level of 2000 - 2500 m (except in the lomas) is estimated to be about 30 mm, from a minimum of 4 mm on the coast to a maximum of 100 mm in the eastern highlands. This coastal desert is intersected by 53 or so torrential rivers grading from perennial to intermittent dependent on the rate of penetration into the snow-capped central Andes or slightly lower areas that receive seasonal precipitation. These rivers allow irrigated cultivation in less than 10% of the coastal area. The remaining parts, also intersected by gorges and ravines that reach only the lower less distant pre-cordilleras, are dry, the so-called dry **intercuencas or interbasins** discharging waters only once or twice in 10 years when the **El Niño phenomenon** occurs. Here the only reliable although occult water resource is the Camanchaca occurring from May to October, producing with high frequency the famous **garúa** and often hampering air traffic (Figs. 6 & 7).

After long negotiations and many changes of place and date, General Piccone finally fixed the inauguration day of the meeting for the third Thursday of August in Tacna, capital of Peru's southernmost department neighbouring with Chile. However, on the day before, it was suddenly realized that this Thursday coincided with the 16th of August 1979, initiation of the "centennial" celebrations of the Chilean-Peruvian Pacific War with the military parades and ceremonies that go with such events. The air force General, being highly committed to the memorial, phoned Carlos Espinosa at the last minute to cancel his journey, as the meeting could by no means take place.

Espinosa had already left and was travelling to Arica to cross the frontier in the evening. Muñoz could not come as he had left his post at the Universidad del Norte. Vega Cedano and Dr. Jorge Valdivia Ponce, respectively director general and director of meteorology of SENAMHI could also not go to Tacna. The latter, with his lengthy involvement in the subject matter, could luckily pass his valuable information and documentation to the UNESCO Regional Hydrologist, who had to take the next flight to Tacna. Evidently UNESCO was responsible for the well-being of the officially invited Chilean specialists arriving without visa and financial means. Defeated by the pressure of inevitable circumstances, Piccone could not cancel the gathering in Tacna with the local authorities of SENAMHI and the Ministry of Agriculture, although it would be strictly informal.

Professor Espinosa explained the substantial progress made during the last years by the Department of Physical Sciences of the Universidad del Norte. Recently the attention was concentrated on the cloud banks which are lingering around the top of Morro Moreno, the dark coloured mountain of 1200 m altitude. As mentioned before, this spectacle dominates the panorama from Antofagasta in western direction (Photo 4). According to Espinosa (20), many years of accurate observation revealed that this cloud is absent only 10 non-consecutive days per year as an average. The cloud consists of small droplets proceeding from the south west with a velocity of 5 - 15 m/sec. and temperatures always exceeding 0° C. During the southern position of the sun, the cloud is more variable and has the appearance more of a cumulus cloud of about 500 m thickness. During the northern position, the cloud is a more static phenomenon, presenting itself as a stratus of 200 m thickness. The cloud varies between 500 m (lower limit) and 1000 m (upper limit) above sea level, and normally the top of the mountain sticks out above the cloud. One has here to do with a large-scale process of natural solar distillation of oceanic water created by the peninsular position of the Morro Moreno on the Tropic of Capricorn, with relative low albedo (40%). Consequently it has a high absorptive capacity for the daily solar radiation, which it reflects gradually. In this way it causes the rise of the humid air masses arriving from the southwest by continuous convection. In reality the visible cloud represents only a transitional phase of the movement of vapour masses which change continuously into the liquid phase to be dissolved again into the vapour phase in landward direction outside the convection column. Always according to Espinosa, this exceptional situation gives the liquid water content of the cloud a maximum value compared with the other less permanent Camanchaca clouds covering large stretches of the Pacific coast north of 32° Lat S, but nevertheless with considerable liquid water content. The small suspended drops need only a vertical obstacle to make them precipitate. This might be a cactus or any type of vegetation which reaches sufficient height (Photo 5), a telegraph pole, an accumulation of stones or any other kind of object that sticks out vertically. In order to estimate the volume of water which could be captured from the cloud around Morro Moreno it should be realized that this can only be done while being in the transitional phase of temporarily condensed suspended droplets moving through the cloud.

Using the figures of Zuleta shown in Table 4, the volumetric yield passing the atmospheric storage reservoir with a speed of 5 to 15 m/sec. can be calculated as follows: The front surface of the cloud proceeding with the wind velocity of 8 m./sec as an average, 1,000 m. wide and 300 m. thick is: 1000 x 300 = 300,000 m^2. This movement lasts about 4.45 hours per day while the cloud is visible during a period of 319 days per year. Assuming the liquid water content is 0.5 gram/m^3 or □*10-6 of the cloud volume, the water volume passing by is:

300,000 m^2 X 8 m/sec X 4.45 hr/day X 319 days/year X 3600 sec X □10-===6,132456 m^3 or 6 million m^3 year (equal to 40 % of the yearly water consumption of Antofagasta in 1979).

Anybody acquainted with the lengthy and tedious projects and discussions of the last decades on the improvement of the Antofagasta water supply, realizes that here is a most fascinating alternative which merits attention. Without reaching a solution the following options have been considered: new pipelines of minimum 200 km tapping water from the central cordillera, desalination of seawater or transportation of icebergs from the far south or big polyethylene bags to be filled with freshwater from the nearest river about 1,000 km to the south. Of course of this estimated yield of 6 million m^3 per year, only a fraction could be captured on the Morro Moreno with limited irregular surface area for the construction of fogtraps. With an output of fogtraps of ±40% certainly a few 100.000 m^3/year could be obtained

Espinosa mentioned the progress the Department of Physical Sciences of the Universidad del Norte has made with respect to research of fogtraps. The first fogtraps located in the wide surroundings of Antofagasta at altitudes of around 1000 meters a.s.l. were suffering a lot of changing weather conditions, like sudden strong winds, changing humidity and the high ultraviolet component of solar radiation. From these experiences it was learned that to be functional on sites of difficult access, fogtraps should satisfy the following requirements in order to be used for reliable water exploitation:

1. optimal rigidity of structure;
2. easy mounting and dismounting by unskilled labour at inhospitable locations with difficult access;
3. voluminous;
4. of minimum weight;
5. consisting of easy to manufacture elements;
6. adaptable in shape and size, to fit the irregular topographic conditions to be expected in the rocky Camanchaca sites near Antofagasta;
7. if possible, aesthetically agreeable;
8. of a geometrical shape easy to describe (Photo 6).

Espinosa succeeded to meet these requirements by introducing a structure of a octahedral geometry composed by simple unit elements under the name of "Macrodiamante". This structure system (like LEGO) can be extended geometrically in three dimensions to accommodate any type of rugged surface area.

The macro-diamond fogtrap No 7800526 covered with netting of a dark colour, consisting of 336 tube bars of 99 cm length, outer diameter 16 mm and thickness of 1 mm, served to collect Camanchaca water on Morro Moreno at a rate of about 1 m^3 per day. The construction could be dismantled into two parcels of less than 0.5 m^3 in total and weighed less than 200 kg so that it could be transported by mule (Fig. 8).

At 18° Lat S. at the Chilean-Peruvian boundary between Arica and Tacna, the Pacific coast of South America makes a 60° angle to the west. Here the coast undergoes a change. The coastal area is formed by large-scale pediment slopes consisting of Quaternary non-consolidated detritus material from the Andes mixed with ditto marine terrace deposits. These slopes have the tendency to rise gradually over a distance of 40 to 70 km to about 1000 m above sea level, where the rocky Andes buttresses form a steep wall of about 4,000 m. height.

In the 1st and 2nd Region of Chile the coast rises steeply within 10 km to the first pre-cordillera range of 1000 to 2000 meters a.s.l. followed by a longitudinal valley system parallel to the coast, often filled up with sediment to above 1000 m. The second pre-cordillera range exceeds 3000 m, and after a wide depression with extensive salt deposits (salares) reaches the central cordilleras 5000 to 6500 m. a.s.l. characterized by a snow-capped row of volcanoes forming the western boundary of the Altiplano of about 4,000 m. a.s.l. also with salares in the south and Lake Titicaca in the north.

This affects the Camanchaca in the following way. Where the SW wind can funnel the clouds through the passes of the coastal range, the cold clouds cascade down into the valley where the ruling desertic climate dissipates the clouds (Photo 7). The wind normally keeps its dynamism as far as the Camanchaca penetrates.

In Peru the perpendicularly oriented steep Andes uplift practically stops the wind. The coastal fogs move slowly uphill to about 800 m, where the temperature inversion determines the top of the cloud deck, leaving behind green traces of short living vegetation on the slopes exposed to the ruling wind direction, called **lomas.** This happens with preference from May to October at levels from 200 to 800 m a.s.l. The vegetation is composed of an association of sparse herbaceous elements: tuberculous and bulbous plants and some graminea which in favourable years provide grazing for livestock descending for this occasion from higher levels.

While visiting the Lomas of Sama near Tacna in the Camanchaca period, unfortunately the vegetation was practically invisible. It was told that in 1974 the Lomas of Sama developed a dense vegetation cover of 50 cm height over an area exceeding 100.000 ha. In 1976 the loma vegetation appeared again and afterwards until 1979 it vanished although a good observer would find the entire area covered with very small plants waiting for more humidity to green the slopes.

The humidity conditions of the coastal fogs are of an extremely critical nature, only giving rise to extensive loma vegetation during certain favourable years. This must be related to the size of the droplets in the fog. It was also mentioned that fluctuations can be related to the incidental occurrence, in the southern hemisphere, of a warm ocean current, the "Niño" phenomenon. This exceptional situation is caused by the approach of warmer equatorial waters to the coasts of Peru and sometimes even to north Chile. This happens when the mid-ocean southeastern tradewinds decrease and therefore the upwelling of cold waters along the South American coast stays out, in that way giving way to warmer waters.

The following lomas exist: Lachay and Turin in the department of Lima; Atiquipa, Chala, Camaná, Mollendo, Tambo, and Jesus in the department of Arequipa; Clemesi and Ilo in the department of Moquegua, and Sama in the department of Tacna.

The Lomas of Lachay 90 km north of Lima provide the best known example of this vegetation, which is apart from ephemeral, also of a perennial nature. Here one has to do with forest relics that in earlier times must have covered larger parts of the lomas. Moreover, new trees as casuarinas eucalyptus, tara and fourcroya have been planted and a modest horticulture has been introduced making use of the favourable moderate and humid microclimate that has developed under the trees.The natural species here have a longer vegetative period than those that live outside these conditions.

Jorge Valdivia Ponce measured here the difference in precipitation in the open field and under casuaris trees (Table 7) (63).

As a conclusion of the preparatory Tacna meeting, it was stated that the Camanchaca in Chile is a phenomenon more equally distributed over the seasons of the year than in Peru, normally associated with stronger winds and the absence of soils. In Peru the winds are weaker and the seasonal Camanchaca is associated with the lomas with soils that could be cultivated if enough water was available. Moreover, the great significance of the atmospheric moisture in Peru is that it reaches a maximum, when due to the lowest stages of the rivers irrigation water availability is minimum. Further, it was recognized that Chile had made more progress in the technique of the physical interception of the fogs, while in spite of Chilean botanical experience in the National Reserve of Fray Jorge (see page 39) in Peru the taxonomy and plant physiology of the loma vegetation is better known. Some of the national authorities in this field are Drs. Carlos López Ocaña and Marc Dourojeanni, both professors at the Agricultural University La Molina in Lima, and forestry engineer Eric Cardich, the latter presently Vice-President for South America of the International Union for the Conservation of Nature (IUCN).

At the end of the meeting it was gratifying to read in the local newspaper, under lengthy turgid articles dedicated to the Chilean-Peruvian Pacific war, a small message mentioning that with UNESCO sponsoring Peruvian and Chilean specialists had discussed the possibility of collaboration on the rational exploitation of Camanchaca.

Table 7 - Precipitation in Lomas de Lachay in mm.(according to Valdivia Ponce)

year	Open field	Under Casuaris trees
1942	219.7	1.022.6
1943	161.7	997.7
1944	113.7	736.0
1945	133.4	261.4
1964	135.4	407.3
1947	174.5	495.7
1948	243.2	829.2
1949	202.9	684.9
1950	149.0	366.1
1951	153.2	265.5
1952	159.4	449.7
1953	209.4	338.2
1954	120.9	534.8
1956	152.6	561.6
1957	182.3	488.4
1958	138.0	451.6
1959	117.6	556.5
1960	106.4	661.4
1961	91.8	452.3
1962	108.5	475.5
1963	122.4	521.6
1964	87.3	557.1
1965	132.0	666.1
1966	136.6	377.5
Mean value	151.2	545.1

Fig. 5a - View of Dhofar showing main ecological zones

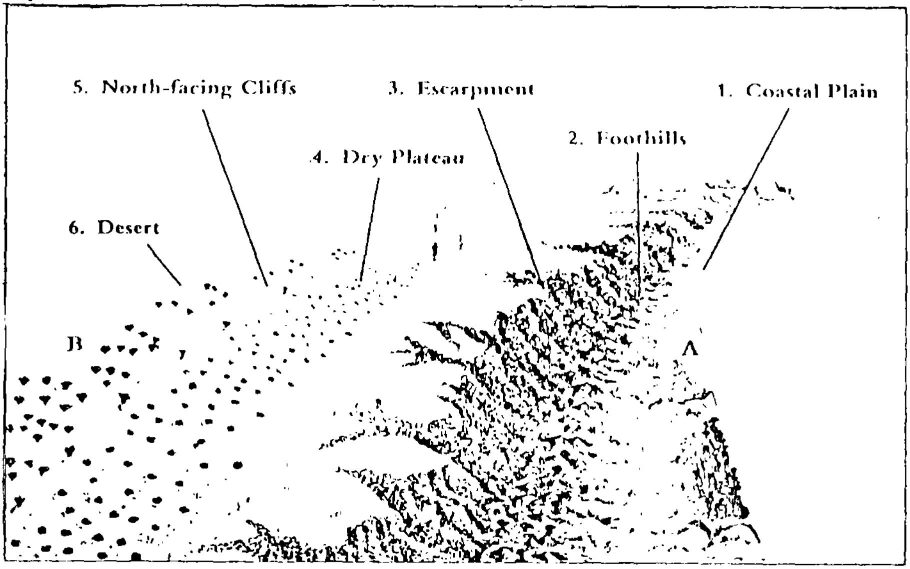
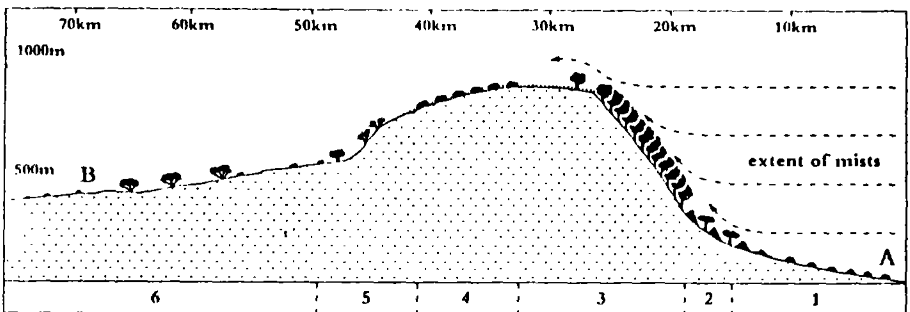


Fig. 5b - Diagrammatic representation of a section through Dhofar (A-B)



1. Coastal Plain – consists of four main features: J.– 'haj' – sand above high tide mark, 'ḥazóg' – areas of soft soil, 'dá'an' – areas of rocky ground, 'ŠŚ šb' – wadis. **2. Foothills**, 'ḥaškík' – belt of termite mounds running along the foot of the mountains dominated by trees of *Boscia arabica*. **3. Escarpment** – consists of two main features: 'flmút' – sheltered seaward slopes of escarpment woodland, 'xótem' - heavily wooded slopes and summit grassland cut by deep wadis. **4. Dry Plateau**, 'kutn' – high, dry plateau dominated by bushes of *Euphorbia balsamifera* and short grassland. **5. North-facing cliffs**, 'moḥúfi' – area in the rain shadow of the mountains generally sparsely vegetated but with *Acacia etbaica* and *Dracaena serrulata* locally dominant. **6. Desert** 'feger', 'negd' – open desert and scattered trees of *Boswellia sacra*.

Fig. 5 - After Anthony G. Miller

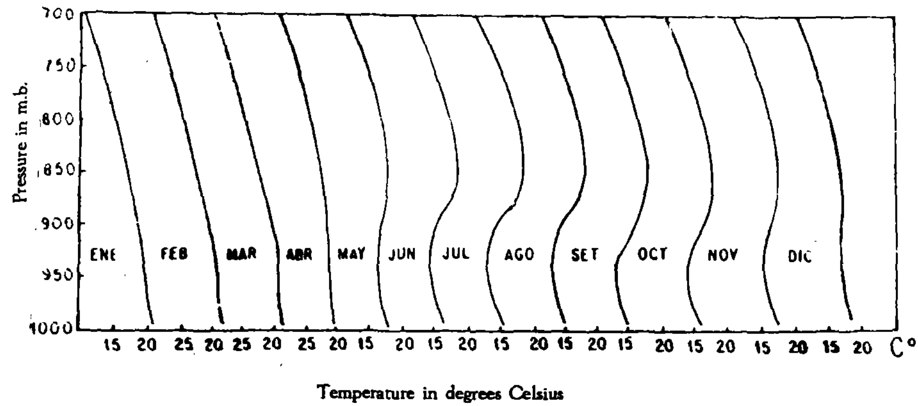


Fig. 6 - Thermal structure of the inversion layer above Lima, an average situation of 20 years observation (40)

Camanchaca occurs when the temperature increases with increasing altitude, that is when the curve has an inverse S shape (40)

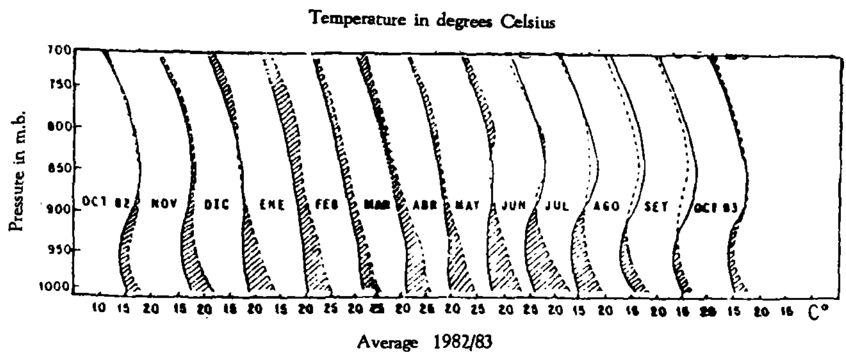


Fig. 7 - Thermal structure of the inversion layer in Lima, during the "El Niño" 1982/1983 (40)

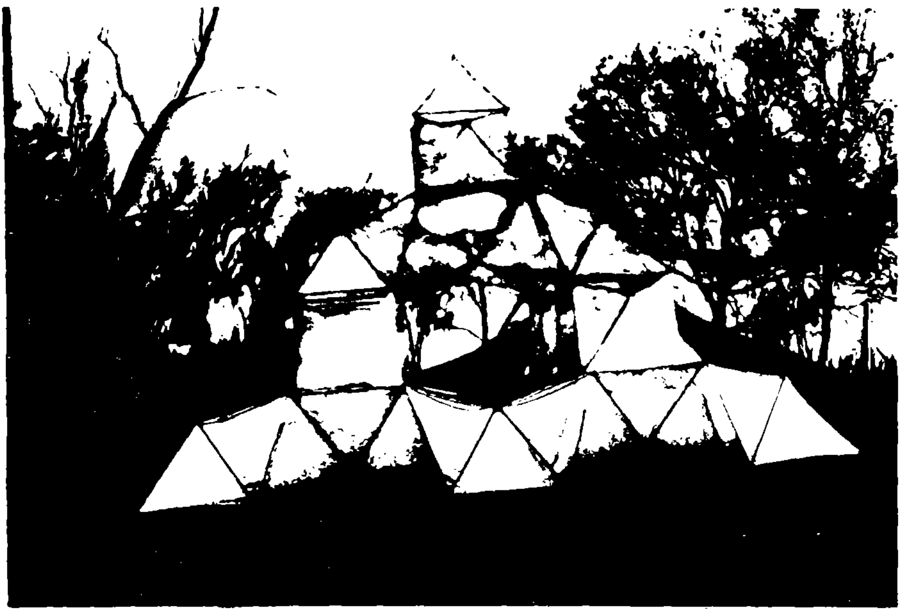


Fig. 8 - Macro-diamond on Morro Moreno

Photo 5 - Tree covered with epiphytes functioning as fogtrap

Photo 6 - From left to right, Carlos Espinosa and Ricardo Zuleta in Camanchaca laboratory

5

BINATIONAL EXPERT MEETING

The report on the meeting in Tacna for the preliminary evaluation of the Camanchaca (coastal fogs) as a renewable non conventional water resource was sent to UNESCO Paris and to the official contacts in Santiago and Lima, this time also to Dr. Carlos López Ocaña, Director of the Peruvian Research Centre for Arid Zones and professor at the National Agrarian University La Molina in Lima.

The results were satisfying. As far as UNESCO was concerned, during the Third Intergovernmental Council of the IHP, held in Paris in November 1979, it was decided to reserve US$ 4,500 to organize a meeting for the definition and formulation of a regional project. In Paris it was agreed upon that eventual Camanchaca matters should be handled within the scope of the IHP, which since 1975 was the continuation of the successful International Hydrological Decade (IHD) launched by UNESCO in 1965.

The national IHP committees formed the institutional infrastructure for futher action. Of course also the Man and Biosphere programme (MAB) in Paris was informed as well as their collaborators in Peru like Mr Lizárraga, former director of ONERN. He had just become UNEP representative for Latin America and the Caribbean.

Certainly the action would also have fitted within the MAB programme, also initiated by UNESCO after the 1972 Stockholm Conference on the Protection of the Natural Environment. However, by pure coincidence, the subject had received more attention from the water people, as the first step to be taken was harvesting the cloudwaters in order to use them for the improvement of the environment in arid zones. This was considered to be more associated with the IHP point of view, looking for direct technical solutions, than the philosophical ethical approach of MAB, at that time steering towards conservation or long-term conceptual objectives. On second thoughts a combined IHP/MAB approach would probably have been the best. Within UNESCO circles integration, even within the science sector, was at that time still wishful thinking. The administrative structure of the UN organizations, copied from the western government models, with all its divisions and subdivisions made real integration impossible like in all the other UN organizations as well as in the national governments. Only at local level, in the regional offices, such an approach was possible although it complicated the internal UNESCO financial administration.

However it can be noted with satisfaction that at present this alarming situation is in the process of being overcome to cope with the crucial environmental questions. Interdisciplinary integration, since long recognized as a basic principle, is now also put into practice although the traditional structure of sectors, divisions and subdivisions, each with their specific responsabilities, will always be a hampering factor.

From the Chilean and Peruvian side it was clear that the report had made the relevant specialists aware of the need of collaborating in the study of this regional phenomenon by spreading the investigation over various pilot projects, in order to accelerate the accumulation of experience under various conditions of topography, latitude, meteorology, etc. To obtain support from UNESCO and extra-budgetary financial assistance from third organizations it was fundamental that also at Chilean and Peruvian government levels Camanchaca be recognized as often the only exploitable water resource in coastal regions for the benefit of both countries, while the green light should be given for further joint action.

Peru was just at the end of its military regime and democratic elections pointed out that architect Belaúnde would become the future president, willing to stimulate applied scientific actions of this type. However his government would be installed only on 29th July 1980. So patience had to be maintained until the time was ripe for the organization of an official meeting. Of course in the meanwhile preparations could be made with interested groups and informal exchange of information initiated.

In Peru the institutional involvement took shape as follows: the meteorological division of SENAMHI of the Ministry of Defense, the General Direction of Forests and Fauna and the General Direction of Water and Soil, both of the Ministry of Agriculture, Oficina Nacional de Evaluación de Recursos Naturales, (ONERN), established with the help of UNEP, and the Universidad Agraria La Molina in Lima with ofshoots like the Peruvian Arid Zone Centre, headed by Carlos López Ocaña

A group of scholars of this last University was just terminating a well documented manuscript on the taxonomy and productivity of the "loma"vegetation (62).

The Chilean planning office ODEPLAN (with ministerial status), approved the action in principle. The Chilean IHP committee would function as national coordinator. The National Forest Corporation CONAF would be the counterpart organization while the Universidad del Norte offered to host an eventual meeting, and intended to become the most involved university. Francisco Díaz, the specific Camanchaca contact in the Chilean IHP committee, was glad with the participation of Carlos López Ocaña on the Peruvian side, as both had been delegates at the Desertification Conference in Nairobi where the binational effort started. An encounter between the two in order to discuss their points of view entirely confirmed the conclusions of the report on the Tacna meeting.

The regional project for the rational expoitation of the Camanchaca, which was the final objective of the future meeting, had to be a long-term project of at least 5 years duration, to give trees the opportunity to grow to be self sufficient natural fogtraps. Four to six pilot areas should be chosen for plantations not bigger than one hectare each, and possibly smaller. Fogtraps had to be exchanged, optimized and standardized. All this with expensive transport to the selected sites would require considerable financial support, which UNESCO would not be able to give. In the best case, UNESCO could provide the international coordination: exchange of information, coordination meetings, regional working groups, and technical visits to representative sites. So other organizations were contacted like UNEP and IDRC of Canada, who had already sent its South American representative stationed in Bogota to UNESCO/ROSTLAC in Montevideo to discuss possible participation in UNESCO projects which fitted their terms of reference. Also the United Nations University in Tokio was informed.

The influence of the "Niño" phenomenon on Camanchaca and precipitation along the coast had obtained the attention of the Executive Secretary of the Intergovernmental Oceanographic Commission (IOC). They were willing to promote the investigation of the accurate correlation of ocean and weather phenomena in the joint IOC/WMO/FAO/ Comisión Permanente del Pacífico Sur (CPPS) working group for the purpose of prognostics.

Archaeologists were contacted as well as the Chilean Commission of Nuclear Energy to help with the detailed understanding of climatic and environmental conditions at present and in the past. It should be reminded that stable isotope measurements of Oxygen 18 had fundamentally contributed to appreciate the potential of Camanchaca.

In September 1980 ROSTLAC addressed letters to the Chilean and Peruvian Ministries of Foreign Affairs to inform that according to UNESCO, the exchange of ideas since the Tacna meeting had progressed to the point that official government support of both countries was considered essential to continue the study of the subject.

In March 1981 the Chilean Ministry of Foreign Affairs answered indicating the convenience of organizing a meeting in Chile to formulate a regional project on the rational utilization of Camanchaca.

One month later a message arrived in Montevideo via the Peruvian Embassy informing that their government also supported the elaboration of a high level technical project on the exploitation of Camanchaca.

After a long and careful preparation of the bi-national meeting finally the green light was given to go ahead. The meeting was financed by UNESCO with funds reserved from the previous year and financial contribution from UNEP to cover the travel costs of the Chilean and Peruvian participants. The interdisciplinary group consisted of hydrologists, hydrogeologist, chemist, physicists, botanists, agronomist, remote sensing and isotope specialists, meteorologists, anthropologist and archaeologist, civil and forestry engineers and economists.

In the period from 1st to 12th June 1981, Camanchaca conditions were first studied in Peru and afterwards in Chile in order to formulate a draft action plan in the closing meeting to be celebrated in Antofagasta.

In Peru Dr. Carlos López Ocaña coordinated the first five days of a programme organized by the following entities:

- — Dirección General Forestal y de Fauna (DGFF) of the Ministry of Agriculture,
- — Servicio Nacional de Meteorología e Hidrología (SENAHMI),
- — Oficina Nacional de Evaluación de Recursos Naturales (ONERN),
- — Universidad Nacional Agraria, La Molina and its Centro de Investigaciones de las Zonas Aridas (CIZA).

After introductory presentations on geography botany and meteorology of the lomas, the sites of Pasamayo and National Reserve of Lachay and the lomas of Pacta were visited.

The Pasamayo site 60 km north of Lima was selected by Dr. Jorge Valdivia Ponce of SENAHMI. The site consists of a narrow passage along the Pacific where the Panamerican highroad divides in two parallel roads, differing a hundred meters or so in altitude, the lower one for heavy traffic and the upper one for private cars, with frequent visibility problems due to Camanchaca. Ponce suggested to improve visibility by intercepting the sea fog, and to use the water for the stabilization of the talud sloping to the lower road by adequate plant fixation. The Ministry of Public Works pays yearly to remove sand and gravel that slides down from the talud on to the lower road and blocks the traffic. On the slopes higher up remains of cultivation can still be observed, although these slopes are presently totally bare (Photo 8).

In Lachay 45 km farther to the north, a considerable volume of water is trucked to the reserve to irrigate the new plantations during the period without "garúa".

The Peruvians indicated how protruding rocks or old trees serve as fogtraps for the young plantations. Seedlings of slow- growing autochthonous tree species were planted also in the drip zone of casuarina trees which grow fast and have an extensive intercepting surface area, to make them overcome the first difficult period in which the root system has to be consolidated. Afterwards the casuarina tree can, if convenient, be taken away.

It was agreed upon to collect and store fogwater for the foresters and to water the plants during dry intervals. Nurseries in the Camanchaca area would increase the amount of surviving seedlings.

Also old deteriorated terraces covered with forest relics were visited (Photos 9 & 10), where apparently in past times crops were grown using dripwater to supplement their water supply.

In Pacta 50 km south of Lima, livestock corrals in the lomas showed how the short living vegetation was used for seasonal grazing of flocks coming from the Peruvian highlands at 4000 m. Twenty to thirty years ago, the shepherds came with their family and often a priest. However, with the disappearance of the forest relics due to firewood collection, the lomas produce less and the flocks are accompanied by one or two llama herds.

As 1981 was a bad Camanchaca year most wells were practically dry (Photo 11).

After having spent four instructive days in Peru, the Chilean visitors, with select Peruvian colleagues, took a regular flight to Santiago, (± 3000 km to the south) from where the group travelled north, 1470 km over land to Antofagasta. Unfortunately the party missed the productive loma area of southern Peru. Travel costs from Lima are too high to be considered practical for systematic studies. However, the transition from the mediterranean environment with ±400 mm precipitation to the Atacama desert with 5 mm precipitation, with all ecological phases in between, could be followed in great detail. A private bus equipped with loudspeaker allowed the Chilean specialists to explain to their previous hosts, the morphological and vegetation particularities of the area crossed while the latter could make comments and compare situations with those in Peru. This, combined with jokes and singing, amalgamated the party after a trip of 3 days to a group of close friends, well introduced to the particular subject of the new water resource with which they would have to deal in the future (Photo 12).

The Chilean coordination was in the hands of civil engineer Francisco Díaz, secretary of the Chilean IHP commission and deputy director of the Instituto de Investigación de Recursos Naturales (IREN). Other organizations involved were:

— Corporación Nacional Forestal (CONAF)
— Universidad Católica, Departamento de Geografía (Santiago)
— Universidad del Norte (Antofagasta)

The first stop was at the mouth of the Río Limari which has cut its bedding through the coastal range called locally the Altos de Talinay. The National Park of Fray Jorge is a nature reserve of about 800 ha, situated on the rounded summits of raised coastal blocks (Altos de Talinay) at a height of 600 to 700 m a.s.l. north of the Río Limari, exposed to the humid southwestern winds and separated from the semiarid open savannah hinterland with annual rainfall of less than 100 mm (Photo 13) by a low dorsal.

Here amazingly dense strips of forest give an idea how some coastal areas could have looked like without human interference (Photos 14 and 15). The vegetation complements its water reserves by capturing over 10 times the amount of rainfall from the Camanchaca clouds, which envelop the reserve with high frequency, and is very similar to vegetation 1,500 km farther south, in the surroundings of Valdivia with annual rainfall of ± 2250 mm. CONAF, in charge of the control of the park, had just erected fogtraps and a device to measure cloudwater interception at various altitudes above groundlevel, also in relation to windspeed (Photo 16).

At the moment of the visit, mist banks entered the territory, visibility decreased, temperature lowered to about 10° C. and after a few minutes the meshes of the fogtrap netting were saturated with water and started to drain along the vertical wiring (Photo 17) towards the gutter at the base of the netting which was evacuating the water into a tank. The interception increases with altitude above groundlevel, due to increasing windspeed and decreasing penetration of heat radiation from the earth surface evaporating the mist at lower levels, until the earth surface has cooled down to air temperature. The waters intercepted by the leaves were dripping by now and caused light drizzle under the trees. The mist bank passed after half an hour, visibility increased, and after a short while the sun was radiating as intensively as before (Photo 18). Solar radiation produced intensive evaporation creating vapour halos surrounding the wet surfaces were the sun could penetrate. All participants felt satisfied to have experienced one complete cycle of Camanchaca occurrence, realizing that quick evacuation of intercepted waters to closed cisterns is as important as the momentaneous interception itself, in order to convert the phenomenon into an usable water resource.

The next stop was at the Caleta Temblador and Caleta Chungungo, where the Catholic University had recently started a preliminary investigation of the Camanchaca. The annual precipitation here is ± 75 mm. Some human settlements surround the coves, Chungungo with 500 inhabitants being the largest (Photo 19). The coastal mountain range of up to 900 m, 6km inland from Chungungo, forms the barrier against which the camanchaca clouds build up to cascade down in the valley behind, via some passes where the clouds dissipate in the desertic environment (Photo 7). Normally up to 450 m above sealevel one can clearly distinguish the intersection between mountain slopes and cloudbase. Below 400 m the sporadic cactaceous vegetation does not even bloom, while at ±700m, a humid environment can even maintain lichens. This zone is also used for grazing by some surviving flocks of guanacos, a close wild family member of the domesticated llama.

Chungungo pays up to the equivalent of US$ 8 per cubic meter of water. The water from a rather dirty well at 60 km distance at the other side of the coastal range is free of charge but the transport by water-lorry is not.

The Compañía Minera del Pacífico (CMP) owned by the Bethlehem Steel Co., exploited until recently the iron deposits in El Tofo, where an unpaved road from Chungungo crosses the crest to join the Panamerican highroad at the other side, which follows the longitudinal valley further inland. The mining company constructed confortable accommodation for its staff on the drier inland slope of El Tofo, just below the crest, with a beautiful view of the snow-capped Central Cordillera. A railway used to transport the ore from the mine to the concentrators on the coast, 2 km south of Chungungo. Finally, a landing-stage allowed direct loading of the concentrate into the ocean ships. CMP, employing most of the adult male population of Chungungo, had water trucked in continuously for the mining staff and the processing of the ore on the coast. With the excess waters gardens were irrigated and eucapyptus trees were grown to provide shade and accommodate the climate in the residential area.

When the mine was closed the Eucalyptus trees kept growing with the Camanchaca, but the transport cost of water became a heavy burden for the population of Chungungo (Photo 19), which had become entirely dependent on local fishing and seafood gathering.

CONAF had asked permission to CMP to use one of the bungalows in El Tofo as a field office and caretaker house from where they could start the investigation of the Camanchaca.

The excursion followed the Panamerican highroad going inland between Chañaral and Antofagasta, following here again the "valley" between the coastal range and the middle range, here called Cordillera Domeyko, this time filled up almost to the rim with detritus material from both parallel mountain chains. This results in a peculiar landscape of sharp-edged bare mountain crests sticking 100 to 300 meters out of the extensive Atacama desert plateau undulating beween 1200 and 2000 meters above sealevel without any intersecting drainage system (Fig.4).

In the area north of Chañaral, unlike other crystalline regions in the world, the dark coloured basaltic dikes and veins intersecting the light coloured crystalline basement, outcropping in the mountain crests, form dark protruding ridges instead of a shallow carved out striation. This means that during long periods, many thousands of years, physical weathering, attacking the coarse-grained granitic rocks, prevails over chemical weathering, activated by aqueous solutions to which basalt is more sensitive. Therefore desertic conditions may have ruled here longer than for instance in the Sahara where grazing of large herds came to an end about 6000 years before the present.

Deflecting 25 km westward of the Panamerican highroad one arrives at Taltal, down the coast. Here was the third site to be visited, ± 50 km north of Taltal in the surroundings of Paposo, with annual precipitation of less than 10 mm. Also here the Camanchaca supports a dense cactaceous vegetation on the steeply rising slopes of the coastal range. The area has a few settlements of which Paposo with ± 100 inhabitants is the largest. Again the population depends for its living on mining, fishing and seafood gathering, while a considerable part of the income is used for the expensive transportation of water (US$ 8 /m^3) from a long distance.

In Antofagasta the final meeting took place from 9 - 12 June 1981 in the buildings of the Universidad del Norte, with Carlos Espinosa as local coordinator and guide. Apart from the team that had travelled from Lima and some new participants who joined in Santiago, some collaborators of the Universidad del Norte completed the group. Moreover there arrived some important observers: a representative of the Water Unit of the Division of Natural Resources and Energy of the Economic Commission for Latin America and Caribbean (ECLAC) and two representatives of the Inter-American Development Bank (IDB): Johann A. Schmalzle, IDB representative in Chile, and Gustavo Adolfo Cañas Viena, specialist in agricultural economy (Photo 20). The meeting started with the following programme:

Programme of presentations

1. Francisco Díaz Donoso (Chilean IHP committee, IREN)
   Camanchaca in Peru and Chile
2. Carlos Espinosa Arancibia (Universidad del Norte) (Chile)
   Experimental results of Camanchaca studies in Antofagasta

3. Horacio Larraín Barros (Universidad Católica) (Chile)
   Hydrological and geomorphological variables which condition human settlements in the coastal zone of the IV Region
4. Ricardo Zuleta Mass (Universidad del Norte) (Chile)
   Ecological fogtraps of an elastic structure
5. Joaquín Cortés (Department Earth Sciences) (Chile)
   Recuperation of the vegetation cover in areas under the influence of Camanchaca with the use of two species of Atriplex Rapanda and Nummularia
6. Nazareno Carvajal and Pilar Cereceda (Dept. of Geography, Universidad Católica) (Chile)
   Geographic aspects of Camanchaca studies in the littoral of the Norte Çhico of Chile (IV Region)
7. Claudio Silva Hennings (Comisión Chilena de Energía Nuclear)
   Contribution of isotope techniques to the study of recharge by Camanchaca.
8. Carlos López Ocaña (Universidad Agraria La Molina , CIZA) (Peru)
   The lomas of the central coast of Peru
9. Raúl Gutiérrez Irigoyen (ONERN) (Peru)
   The use of satellite images for the evaluation of the biotic resources of the lomas
10. Jorge Valdivia Ponce (SENAMHI) (Peru)
   Obtainment of atmospheric water in the National Reserve of Lachay
11. Eric Cardich Briceño (DGFF of Ministry of Agriculture) (Peru)
   The National Reserve of Lachay

The airforce, being interested in the subject, had arranged in collaboration with Espinosa to fly the whole party by helicopter to Morro Moreno, where the macro-diamond structure was collecting water (Fig 8). Obviously the helicopter needed a blue sky to land on the top of the dry barren mountain. The still-skeptical participants, in spite of all our efforts to change their mind, lost their last bit of skepticism when in all this aridity these appeared under the macrostructure several drums filled to the rim with crystal-clear water and a little farther under a much more modest one another full container. Schmalzle of the IDB exclaimed:

"This is absolutely incredible. This is what we need to be convinced, not all your lengthy presentations! We will immediately send a cable followed with extensive explanations that IDB has to support the development of this resource."

The expression on our faces must have been like those of the followers of Moses, when they beheld the water coming out of the rock-joint in the Sinai.

"Forget the explanatory notes, fly the Bank people right in!" answered another.

Carlos Espinosa pointed down, to where 800 m lower on the coast the fishing village of "Juan López" could be observed.

"The problem is to supply this water to the inhabitants down there, for whom we have made a preliminary technical report" (19).

Juan López, in front of Antofagasta, needs 50 m^3 daily, at least during the summer when tourism doubles the population. According to previous estimations, this amount can certainly be produced with resistant three-dimensional structures installed between 800 and 900 meters as winds can be very strong on this peninsular mountain. At this level Morro Moreno offers a rough surface area of ± 9,000 m^2 at the site of "El Estampido" exposed to the western winds. However, the problem is not to obtain the water but to create storage of at least 350 m^3 for regulation, for days that Camanchaca may not occur (up to 6 consecutive days in 1979) and to bring it down first along a slope of 30°, followed by a precipice of 500 m. An installation of this magnitude would require the presence of a watchman. How would this man be able to survive in this inhospitable environment of alternating bright sunshine and mist?

An installation producing 50m^3 of water in summer would provide 100m^3 in winter and spring and about 75m^3 in autumn. Of course this water could be sold and since it is extremely pure it has a high value for some industrial processes. If moreover it is desirable to conserve water of the period March to November, huge storage room should be made available in or near the village.

If the cost of lifting construction material for the cistern over 800m could be overcome, water could be kept at temperatures below 18°C which would reduce bacteriological contamination and related treatment costs.

At sealevel the climate is different as shown in Table 8.

Table 8 - Meteorological Data of Antofagasta of 1980

Month	Evaporation	Max	Min	Rain	Rel humidity			Insolation
January	8.7	23.3	15.3	0.0	68	67	78	10.2
February	6.3	24.1	19.8	0.0	72	79	79	10.8
March	5.4	23.6	19.8	0.0	75	73	81	8.9
April	4.1	22.0	16.3	0.0	77	76	82	8.0
May	3.3	20.3	13.9	0.0	76	66	82	7.5
June	2.9	18.1	12.6	0.0	75	73	79	6.9
July	2.8	17.5	12.1	0.0	77	74	81	6.8
August	3.3	17.2	11.8	0.0	75	72	74	7.4
September	3.9	17.6	12.7	0.0	79	74	79	7.7
October	4.3	18.1	13.5	0.0	77	75	80	6.3
November	6.2	19.4	14.7	0.0	71	69	79	8.9
December	6.5	21.8	16.7	0.0	67	67	76	10.3
	mm/day	°C	°C	mm/month	%	%	%	hrs/day

Monthly averages registered at 40 m above sea level according to observations realized at the Department of Physical Sciences of the Universidad del Norte
The three columns of the relative air humidity correspond to the hours 12, 18, 24.
The atmospheric pressure fluctuated between 1017 milibar and 1006 milibar (normal pressure 1013.3)

Also the construction of a pipeline which can support pressure and is well cramped to the rocks, will be expensive. The people of Juan López should be aware that Morro Moreno, due to its topographical shape, represents a technical challenge, which may influence the project costs.

Finally, another tank at about 100 m altitude would be needed for distribution by gravity to the individual houses.

As there exists a good footpath, any material, like the macro diamond-bars, netting, tools, drums and cement, which is transportable by mule, can be brought up.

In order to intercept an average of $50 m^3$/day, ± 6,000 m^2 of netting are needed, if possible "Saran" netting, with a lifetime of over 10 years. Espinosa calculated that a macrodiamond skeleton which would support this surface of netting would consist of ± 5 tons of vulcanized iron tube bars of 16 mm diameter and ± 1 m long, assembled with 2000 galvanized bolts and nuts. Although this can be obtained locally the galvanization should be excellent, to prevent oxidation under these extreme conditions. About 3.000 man/hours would be needed to mount the fogtrap for which apart from a salary also transport and per diem should be calculated and accomodation is needed.

In spite of the fact that the exploitation of Camanchaca on Morro Moreno for Juan López would be an innovative enterprise full of unforeseens Espinosa believes that water may be obtained for about US$ 3 to US$ 6 per m^3. This will be lower than the water transported from Antofagasta, which although subsidized, arrives there from ± 400km by pipeline and contains Arsenic for which it has to undergo a special treatment.

This type of considerations cooled down the first enthusiasm, but Schmalzle stuck to his offer of a US$ 2,000,000 non reimbursable loan for Camanchaca development in Chile and Peru, which he would strongly recommend to his Headquarters in Washington.

The situation on the Morro Moreno peninsula has not always been as described above. In the fifties, biomass was still sufficient to permit flocks of guanacos to live on Morro Moreno, while at the beginning of the century people were hunting pumas over there. The Rector of the University being a detached military airforce officer, told that as a young helicopter pilot he had to land on Morro Moreno in 1954. The presence of abundant vegetation, however, made this impossible. Even in 1971 a couple of guanacos lived there but the fishermen of Juan López collecting their firewood on the mountain changed the ecology and of course the guanaco lost the competition with man as most other animal species everywhere else in the world, leaving behind the heaps of guanaco dung.

Returning to the Universidad del Norte, an action plan for the bi-national project was drafted mentioning the following points:

1 Duration of 5 years in order to permit trees to grow up to self sufficient fogtraps.

2 Modest production of fogwater at several easily accessible sites in order to convince public and authorities that capturing Camanchaca water is feasible.

3 Conservation and expansion of the loma vegetation in Lachay and El Tofo, recuperation of vegetation in Pasamayo and Morro Moreno or elsewhere near Antofagasta with the help of fogtraps, including establishment of nurseries. On this occasion the idea of the domestic use of solar cookers was introduced as an alternative to the use of firewood and as a general measure to conserve vegetation and prevent erosion.

4 Fog-water supply for the inhabitants of Chungungo and labour working in Lachay and other Camanchaca sites to be activated.

5 Normalization and standardization of fogtraps.

6 Stimulation of exchange of information among Camanchacaca investigators with similar and different professional background in order to accelerate the advance of knowledge on the subject and to emphasize the interdisciplinary approach of the rational exploitation of this non-conventional resource for which the technical visits in the field and the discussions during the meeting had made a basis.

7 The UNESCO regional hydrologist would be responsible for exchange of information and communication within as well as outside the project, looking for information in other parts of the world where the subject may have obtained attention. (See: chapter 10: Fog and Foreign Relations).

Finally it was reminded that at this historical moment of shortage of conventional energy resources, it is economically and ethically justified to change strategy, by stopping to fight against nature but to the contrary, to look for alternatives with the backing of nature. Sunshine, wind and gravity are still relatively untapped energy resources. It is logical that when the sun evaporates ocean water and wind transports the condensed humidity in the form of clouds to interceptable altitudes from where it can be distributed by gravity. Water obtained by capturing dripwater is under circumstances as here described, more economic than for instance by distillation of seawater in solar tills as some participants suggested in the beginning. (See also Table 8).

Of course the physical dimensions to which these objectives would be realized depended on the funding of the project. UNESCO/ROSTLAC promised financial, technical and moral assistance within the limits of regional MRP-budget. The Chilean authorities promised modest financial contribution and the intellectual and mechanical infrastructure of CONAF in the IV Region as material support. So did Peru in principle, but details of the support should still be defined in Lima. The exact national contributions however would depend on funding from outside. Therefore the offer of the IDB representative came at that time as a gift from heaven, although from the beginning the meeting had certain reserves with respect to the materialization of the offer, as it was conditioned by factors beyond controls.

Apart from financial cooperation through reimbursable loans the IDB proposes, for projects which are still in the research phase like the Camanchaca project, cooperation through non reimbursable funding. However, the difficulty was that since Chile had some years earlier renounced its participation in the low- interest special fund of the IDB, it could not apply for these funds.

As far Peru was concerned there were no problems, however here it was a question of a bi-national project. Therefore Schmalzle suggested that UNESCO as international executing agency seemed the most appopriate party to request this IDB support.

Having taken into consideration the funding problem, a commision, coordinated by the UNESCO regional hydrologist, was formed to elaborate a project document and to arrive at an acceptable organizational structure.

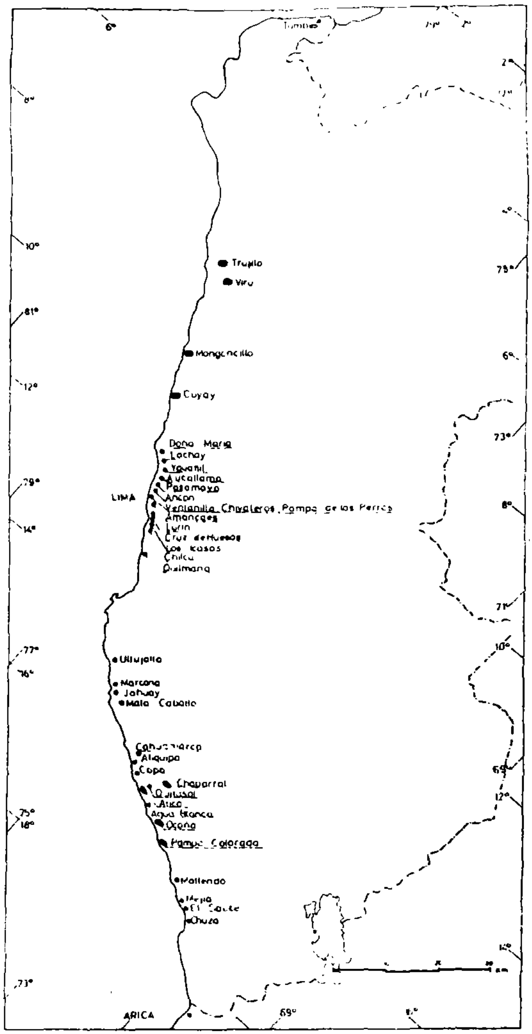


Fig. 9 - Principal lomas of the Central Andes

Photo 7 - Clouds funnelling through pass

Photo 8 - Fossil furrows, remains of cultivation at Pasamayo next to site were later macro-diamond was installed

Photo 9 - Forest relics in Lachay

Photo 10 - Forest relics with ocean in the horizon — (By Horacio Larraín)

Photo 11 - Well in Lachay almost dry in 1981 (By Horacio Larraín)

Photo 12 - Members of the excursion during a bus stop

Photo 13 - Natural Reserve of Fray Jorge seen from the drier inland with clouds cascading over a dorsal

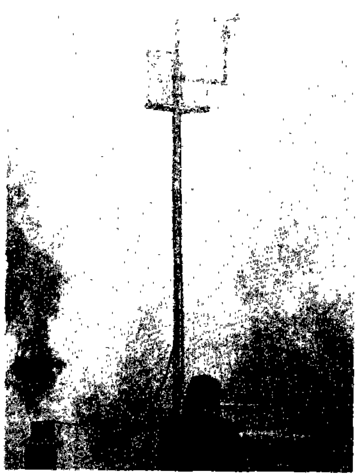


Photo 14 - Dense strips of forest in Fray Jorge Natural Reserve

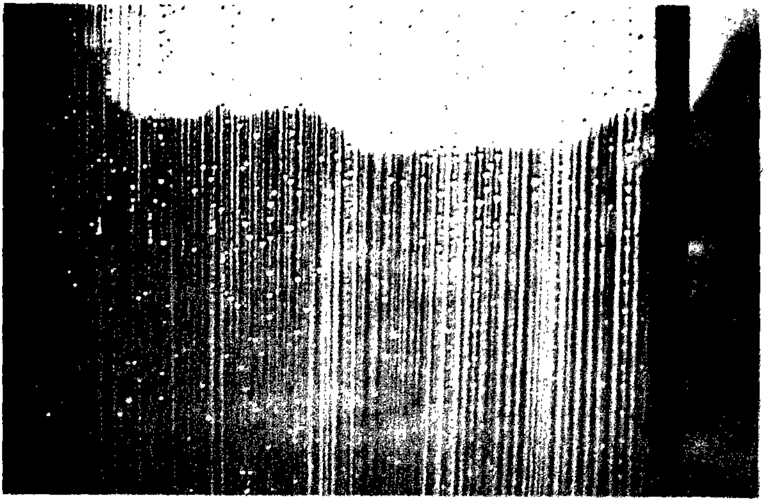


Photo 15 - Vegetation of Fray Jorge

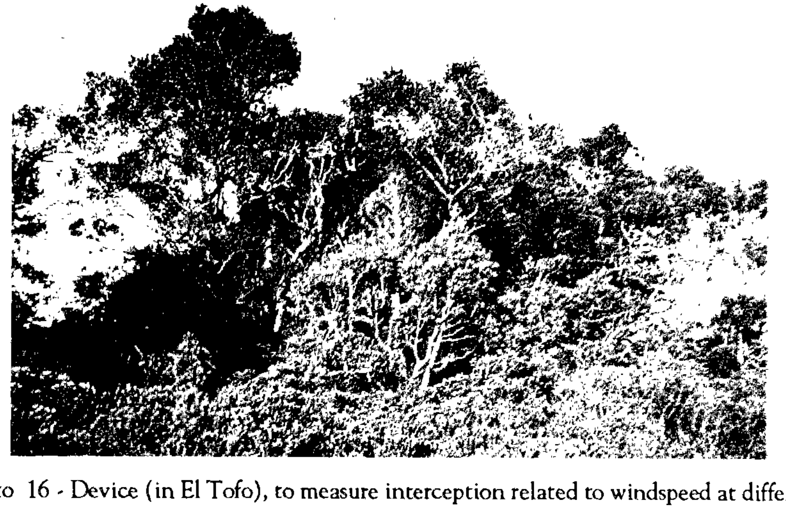


Photo 16 - Device (in El Tofo), to measure interception related to windspeed at different altitudes, in this case with two types of netting, the coarse one catching as an average 50% more than the other one

Photo 17 - Water starts to drain along vertical wiring in Fray Jorge

Photo 18 -After a while the sun shines again on the dense vegetation at the seaside of the dorsal of photo 13 (Natural Reserve Fray Jorge)

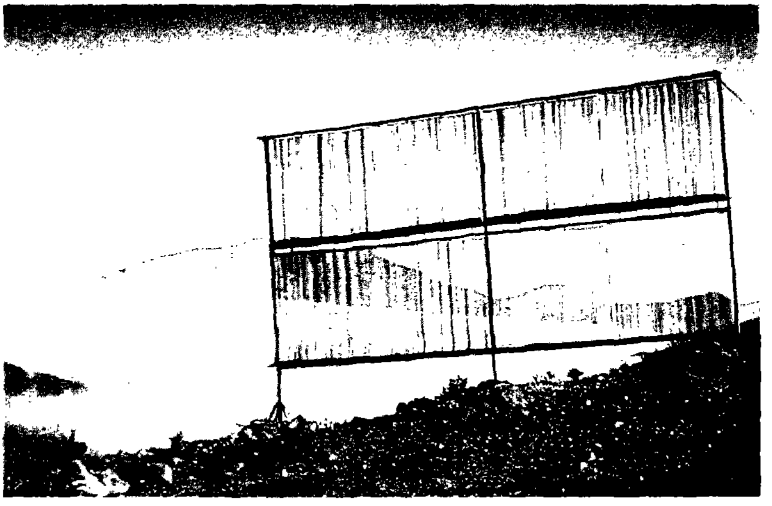


Photo 19 - Chungungo at the right, and harbour accomodation on the left of the cove seen from above

Photo 20 - From left to right Johann Schmalzle and Gustavo Cañas of IDB, Carlos López Ocaña (Perú) and Francisco Díaz (Chile) during meeting in Universiad del Norte

ARCHAEOLOGY AND ISOTOPES

6

The past of the lomas in Peru

The French pioneer archaeologist Frédéric Engel spent many years of his professional life investigating the lomas of the coast of Peru, elaborating the results of his extensive fieldwork in the previously mentioned Arid Zone Centre where Peruvian anthropologist Miriam Valleja assisted him as a faithful and reliable co-worker. He discovered and described over 1000 human settlements, and drew our attention to the lomas with regard to the prehistoric human geography, in their capacity of food and water producing areas (Fig. 9) (17) (18).

The lomas without wells have remained unoccupied, but the lomas with garbage mounds and the remains of villages, all have one or more wells. The wells and the dense vegetation - amounting in some places to a small forest (on the slopes of Cerro Mongoncillo near Haldas on the north coast, or south of Nazca on the way to Marcona) - prove the existence of phreatic lenses. The hypothesis that there existed a savannah where there are lomas today is supported by facts like the present forest relics, the prehistoric use of logs and tree trunks as beams to support the roofs of houses, and the wood remains found in the fireplaces of the pre-agricultural loma villages.

Although lomas are found presently between 200 and 800 m. a.s.l, small patches of lomas exist exceptionally down to sea level. Lomas may of course have formed at lower levels under different climatic conditions. This was confirmed by Engel, who discovered fossil lomas now covered by eolian sand and by a second living loma. A radio-carbon dating of human remains in such a loma indicated 7,000 years before present (b.p.).

Settlers representing a pre-agricultural horizon were living a sedentary life in the lomas as early as the end of the last glaciation and the peak of the Flandrian trangression. A number of these early encampments have been dated as old as 9,125 ± 200 b.p., while others can be classified at the same time range 10,000 to 8,000 b.p.. Why these settlers chose to live in the lomas is a mystery. Shellfish was their basic source of proteins; they carried tons of marine shells as far as 100 km inland, even up to the high Andean caves.

Land mammal bones are rarely found in the early loma refuse heaps, but occur in large quantities in later loma settlements of maize eaters who lived there around 3,300 b.p. The large number of projectile points suggest hunting. The shell mounds of Paloma for instance, start exactly where the loma begins and cover the plain for over a mile. Here again, we don't know what these gatherers were doing in the lomas eating enormous quantities of shellfish that they could just as well have eaten along the Pacific shore. The answer may be that either no water, or brackish ground water, was available along the coast, while a spring may have provided the settlers with fresh water in the lomas. Engel cannot prove that such a spring existed during the pre-agricultural period but one did exist at least as early as 3,000 b.p. It is not clear what the lomas have provided as vegetable food, as botanists did not identify any edible plants among the plant samples collected by Engel.

Outside the loma area, edible tubers such as potato, yuca and sweet potato, and fruits like tuna (Opuntia sp.) are present in some early Holocene settlements up to 10,000 b.p. (Fig.10a). However they are considered as products of uncultivated plants. Up to now only cotton and beans, not yet found in an uncultivated form in the Andes, are considered by botanists as the earliest products of agriculture or horticulture in this region. Later (around 4000 b.p.) settlements of bean eaters, who were wearing cotton mantles, shirts and bonnets are found close to a loma, for example in the Moya canyon in Chilca.

Little is known about the ecology of the first wave of maize eaters to reach the Pacific coast apparently around 3,500 b.p.. A link can be found between farmers in the high inter-Andean valleys and the settlers who made the best use of a loma environment. Early maize-eater villages occur in the lomas of Chilca, either on the crest of the hills dividing the canyons or directly in the lomas (Fig.10b). Such villages consist of a few rectangular houses outlined with heavy blocks and surrounded by terraces.

Engel is the first to report settlements of the second wave of maize eaters in the lomas, influenced by the so-called Chavin culture. Their most typical loma village is Iguanil. Coastal Chavinoid settlements are usually found in the damp coastal areas which permitted a black earth agriculture of the Melanesian type, but when water is available in a loma, the Chavinoids made the most of it; their village in the Teatino Canyon is quite large, surrounded by terraced gardens extending to the lomas of Lachay; what the settlers were planting or gathering remains still an unsolved problem.

While mapping in detail the Chilca area, Engel noticed that the narrow parts of the canyons, which originate in the lowlands and penetrate up to 40 km inland between the ridges of the cordillera, were all blocked by large amounts of stones, not related to geology but product of the work of pre-Columbians. These structures of the Lapa Lapa group, which seemed to have invaded the lowlands of Chilca around 2,100 b.p. (Fig.10c), were in fact ruined terraces and platforms. Inside the wide platforms, the settlers had built thousands of subterranean rooms, each with a narrow side entrance and roofed with a heavy slab supporting a layer of earth. Deep stone-built wells with helicoidal staircases are also found, sometimes several in a row, in the thalweg of the canyon. Whether the structures of around 11 m^3 were subterranean houses or storage pits still remains unanswered. They are grouped so as to form an agglutinated village surrounded by terraces, to which staircases give access. Others are too numerous to have been houses. Engel, always with the help of Miriam Valleja, mapped more than 1,500 such structures.

Whatever the answer, the fact remains that the pre-Columbian settlers dedicated enormous efforts and a large amount of manpower to colonize the narrow stretches of the loma-covered canyons. Typical Lapa Lapa pottery is found in the canyons around the wells. Around the "Metropolis", the granaries, the fort and the temple of the Lapa Lapa on the hill that divides the beach of Chilca in two, the refuse is full of maize, which was cultivated in the lowlands with the help of subterranean water. Potatoes occur in number in the refuse, but not in the depressed gardens, where the plant remains basically consist of maize. Potatoes of a different species from the one we eat today still grow wild in the lomas in the surroundings and on the terraces of the pre-Columbian villages. What we do not know is whether these potatoes grew wild and were just gathered and dried in the pits, or whether they were actually planted by the pre-Columbians.

The occupation of these terraces does not seem to be continuous as the Lapa Lapa apparently abandoned the lomas, the Chilca lowlands and the "Metropolis" during the first centuries A.D. (perhaps in response to the "Florida" cool episode, the "Roman" regression).

Elsewhere, however, there is evidence of even more sophisticated loma exploitation in the final pre-Hispanic centuries, for example by the Jaboncillo and Chala settlers (Fig.10d). The Jaboncillo system in the Chilca basin starts exactly where the loma begins, 200 meter a.s.l., and extends to over two miles, ending up around 450 m. It covers the entire valley floor and creeps along the slopes and up some of the adjacent hills. The system consists of low walls, made of stone boulders or slabs, which divide the ground into more or less rectangular patches. Paved and stepped paths make communication between the terraces easier. How the system worked is not clear. Canal irrigation is excluded on the basis of the local topography. The only source of water could have been rainfall or Camanchaca.

The Chala site is situated 600 km south of Lima on a plateau along the coast, varying from 50 to 250 m.a.s.l. Large terraced planting grounds are found on the plateau and along both upper flanks of parts of the intersecting canyon. Some of the terraces have been partly destroyed, but those that remain visible today cover some 2,000 ha. The stone edged terraces are 3 to 5 m. wide, depending on the grade of the slope. They are perfectly horizontal. Occasionally narrow stone structures cut vertically through the terraces, running down the slopes. Canal irrigation would have required the existence of powerful springs or ponds, a possibility when the overhanging hills, now deforested and bare, were covered with the savannah that is suggested by the few surviving trees. Engel believes that these lomas actually could support some crops with the help of "garúa" and some additional and temporary irrigation. At the same time the canals may have provided drainage; the occasional rains would certainly have damaged undrained terraces.

An excavated section through one of the garbage heaps found in the terraced area has yielded middle to late Nazca decorated pottery. This would date the terraces at about 200 A.D. However, also pottery of the final pre-Columbian so-called Churrajon or Arequipenian type is found. This would indicate that a reoccupation of the site occurred during late pre-Columbian times (Fig. 10d) . This is confirmed by the existence of large stone built villages, typically late Highland in style, high above the lomas, in defensive positions dominating the planting grounds.

Engel comes to the conclusion that the lomas played an important role during three very different periods:

1. The pre-agricultural episode, when the ecology was based upon seafood gathering, complemented in certain cases by hunting. (± 10,000 - ± 7,000 b.p.)
2. The archaic agriculture episode. (± 4,000 - ± 2,000 b.p.)
3. Late pre-Columbian period, when intensive and extensive agriculture were practiced and the conquest of new lands was required for reasons that still remain unknown (from after ± 300 A.D. onwards).

Of course socio-political or other factors of human nature have been the cause of the observed cycles of occupation and abandonment of the lomas. Nevertheless these factors may have been triggered by environmental changes due to climatological variations of the Holocene..

According to Fairbridge's chart for eustatic sea level changes, all three main occupational periods of the lomas fall into periods of marine transgression and warmer environment. One may wonder if the reason for abandoning the lomas was not sustained drought. Such an interpretation is suggested by present observations on the central coast of Peru: **during cooler winters, the fog has a tendency to form below the 200 meter contour line, and the lomas remain drier than during warmer winters, when the fog is carried higher up.** All the archaeological fishermen's settlements studied by Engel in the 200 km-long desert south of Paracas, seem to have been abandoned around 200 or 300 A.D., when also the Chilca and Chala lomas seem to have fallen into disuse.

As a result of Engel's detailed observations, he concludes that in arid land water is the controlling factor, and the lomas seem to be an excellent ground for studies in the field of arid land prehistoric geography.

Returning to our subject, from Engel's account and other archaeological studies including own observations from northern Chile to Ecuador, the occurrence of the Camanchaca coincides with a region of outstanding pre-historic civilizations famous for their skills in water management, which was sublimated to a real water-culture, and as such was integrated in their religious convictions. In the western world this characteristic is better known from civilizations such as the Nabathaeans in the Negev desert, the old Egyptians in the Nile valley, etc. The rise and fall of these civilizations was closely related to the management of their most critical resource: "the water" in the territories they occupied, and the technology they could master in order to control their water resource in a sustained and rational way. This is also proved by the density of pre-Columbian population which these dry coasts could support on the basis of simple but ingenious technology of low energy level, more than the rural population of today, in fact practically non-existent outside the 53 cultivable perennial river valleys that reach the ocean. However there were some limiting conditions with which even their technological skills could not cope. In order to evaluate the risk and the effort of developing the exploitation of Camanchaca, it is useful to compare these limiting conditions with the governing climatic conditions of today; because one thing is certain: the pre-Columbians knew how to make good use of the Camanchaca. It should not be forgotten, however, that under similar conditions the pre-Columbians disposed of an invaluable capital: a fragile but vital arborous vegetation, which was not yet destroyed by over-exploitation, induced later by immigrants from Europe.

Climate change

The most suitable areas to study climate change are cold and dry deserts. Here accumulated ice in cold deserts and sediments are likely to provide pertinent information on global climate change. Moreover, as deserts are situated in high pressure zones of subsiding air masses between the major low pressure circulation belts, small fluctuations in the pressure distribution in the past should immediately influence this zonal pattern and should be preserved in characteristic fossil formations like dried up lake sediments, soil development and old age ice caps permafrost and periglacial features on high mountain ranges or isolated extinct volcano tops.

To analyze and synthesize climate history is a complex interdisciplinary task requiring inputs of climatology, study of environmental isotopes, hydrology, pedology, geomorphology, geology, palaeontology, limnology, biology and archaeology, to mention a few. Climate change in the extreme arid Andes of northern Chile around the Tropic of Capricorn is presently in the process of being studied by an interdisciplinary group of scientists from Bern, Vienna, and Vancouver (48).

Their preliminary findings indicate results of importance to the subject under discussion:

The simultaneous interaction of the Southeast Pacific High Pressure Centre, the cooling and therefore drying influence of the Humboldt Current, the low altitude blocking from the West of the ocean moisture (Camanchaca), by the Coastal Range (as an average 1,500 m high near Antofagasta) and the blocking from the east of the moist Low Pressure Zone of the Amazon Basin with extension into the Chaco during the southern hemisphere summer by the Central Cordilleras de los Andes and Altiplano, cause the extreme arid conditions of the Atacama desert (Fig.11) on the western Cordillera slopes between the temperature inversion near Antofagasta of 900 m. a.s.l. and 6739 m.a.s.l., corresponding to the top of the Llullaillaco volcano. A weakening of the Southeast Pacific High Pressure Centre - mainly observed during the El Niño phenomenon with higher ocean temperatures - permits the Chaco Low Pressure to penetrate with a time gap of 9 months in 1983, farther to the west, until above the Altiplano, producing a distinct increase of summer precipitation known as "Bolivian winter". Even during these occasions the west sloping Altiplano is in the lee side of the Andes weather barrier. The same weakening of the Southeast High Pressure Centre, also affects more intensive winter precipitation from Pacific frontal systems known as "Chilean winter", normally blocked near La Serena at 30° south, to reach the Altiplano.

Considering the El Niño phenomenon of the years 1972, 1975, and 1982/1983, compared with normal years in the period 1969-1984, the altitudinal distribution of precipitation in Chile was as shown in next Table 9.

This demonstrates the likelihood that climate changes which influenced the higher elevations affected the lower levels, protected by the Andes weather barrier, in a much more moderate way. Between the Camanchaca inversion and 2500 m a. s.l. arid conditions with minor fluctuations always persisted. Of course this does not count for the north of Peru.

Table 9

Altitude	El Niño summer	Normal summer	El Niño winter	Normal winter
2000 - 2500	20 - 100 mm	0 - 20 mm	0 - 20 mm	0 - 5 mm
2500 - 3500	50 - 200 mm	20 - 50 mm	5 - 20 mm	0 - 5 mm
3500 - 4500	150 - 300 mm	50 - 100 mm	5 - 30 mm	5 - 10 mm

Ecological observations demonstrate that current vegetation is restricted to a zone between 3200 - 4500 m elevation. The lower limit is controlled in the first place by lack of moisture, the upper limit by low temperatures. The best soils with most developed B- horizons were found between 4000 and 4500 m, but this does not coincide with the best vegetation which has its maximum 500 m below that zone. If one uses the temperature gradient of 0.75°C for every 100 m in elevation, found on the basis of observations from 2400 m to 5100 m, this difference of 500 m coincides with a rise in temperature of 5 X 0.75°C = 3.75°C in the past. Other measurements comparing average air temperatures with paleo-permafrost in the bottom also indicate a temperature rise in the past of the same order of magnitude.

Inactive periglacial features on the slopes of Mount Llullaillaco at 3650 m, far below the present snowline at 4400 m, however, indicate that these higher temperatures were preceded by temperatures about 7°C lower than the present ones.

Also in the area between the Altiplano and the coastal zone between 18°S and 30°S specifically along the Río Loa (the only perennial river which reaches the Pacific in this region), evidence exists to suggest that environmental climatological changes have taken place since 11000 b.p. Settlements existed either above 2500 m, along the Rio Loa and along the coast, mainly depending on marine resources.

Before 12000 to 11000 bp at the end of the Pleistocene hunters settled only south of 30°S.

From 10000 to 8500 bp a considerable rise in temperature associated with a warmer and wetter climate, allowed settling on the slopes in the north and roving hunters and collectors on the Altiplano. *The occurrence of El Niño was probably more frequent and even an annual phenomenon*, which *offers the possibilities of groundwater recharge and floral and faunal development*.

From 8500 to 5000 bp, *settlements in the Altiplano are interrupted and human activities are restricted to the Rio Loa and along the coast.* Evidence of trans-human migration.

The climatic conditions might have been similar to the current ones.

From 5000 to 3000 bp, *warmer and wetter, similar to period from 10000 to 8500 bp, with first evidence of animal domestication at Puripica, related to optimum resource use in certain altidudinal belts*

From 3000 to 2000 bp, *there is some evidence that precipitation decreased, but this was compensated with improved resource use such as animal domestication and irrigation in the oases of San Pedro de Atacama, Tulor, Toconao Oriente, and other sites.* Combined use of marine and terrestrial resources as well as migration indicate uncertain conditions in the semiarid north influence of Southeast High Pressure Centre increases.

From 2000 bp to the present: *Current arid climatic conditions prevail, resulting in diminishing water supplies, which likely resulted in the abandonment of Tulor (1400 bp). Human activities were reduced to stable oases such as San Pedro de Atacama, Chiuchiu, Lasana and other settlements that received water from river systems of the high Cordilleras. Improved terraced agriculture with rational water use become more and more important.*

Most of the datings in the previous text are based on radio-carbon (or C-14) determinations, compared with the non-radioactive carbon (or C-12) in organic material or carbonates in minerals or aqueous solutions.

As it was proposed that Camanchaca could be a possible source of recharge of groundwater, feeding in turn coastal springs (Gischler 1977), Aravena, Suzuki and Polastri studied a great number of water samples to investigate the contribution of Camanchaca to groundwater. Samples were collected from the Parque Nacional Fray Jorge at latitude 30°42' and El Tofo at latitude 29° 21'. Water was collected from springs, wells, rain, and fog from fogtraps and tree leaves. Water was also extracted under vacuum, at about 80°C, from leaves. All samples were determined on their stable O-18 and Deuterium (or H-2) content and if relevant for groundwater on their unstable or radioactive Tritium (or H-3) content.

Results according to Aravena et al (2) demonstrated that *rainwater was characterized by k values between -4.8‰ to -6.8‰ for O-18, and -34 ‰ to -44 ‰ for H-2.*

Isotope data on precipitation on the central and southern coast show a similar isotope range.

The isotope content of fog water ranges between -1.0%o and -3.2%o for O-18 and -1.0 %o to -18 %o for H-2. These values are similar to others reported for this type of water by Gischler (1977) for groundwaters in the Antofagasta region where rainfall is practically non existent.

The rain- and fog water show a distinct isotope composition, which reflects the different history of the air masses that provide the moisture of fog and rain respectively. The groundwaters from both study areas are characterized by an isotope composition similar to the rain. This suggests that the fog water does not play a significant role as a source of recharge for the coastal aquifers of Fray Jorge and El Tofo.

The low Tritium contents expressed in "tritium units" (TU) of the ground waters at El Tofo (< 1.1 TU) suggest the absence of thermonuclear tritium, which implies that the residence time of the water is more than 35 years. The situation in Fray Jorge with Tritium contents < 1.5 TU implies that the residence time is more than 30 years. This means that fog water *does not play a significant role as a source of recharge for the coastal aquifers* at the studied sites. *The very low Tritium content of the groundwater suggests that the groundwater was presumably recharged at some time in the past under conditions that must have been more moist than those of the present. Carbon isotope analyses (C-14 and C-13) on the groundwater could provide additional information to this topic.*

Isotope data of leaf water show the importance of the Camanchaca to the vegetation of these coastal ecosystems, and reflect the isotopic enrichment of plant waters that occur in the leaves during evapotranspiration. The degree of isotopic enrichment of the leaf water is mainly controlled by the temperature and the relative humidity of the environment. Isotopic interpretation of the results point out without any doubt that *fog water is the moisture source for these trees in this (dry) environment.* Indeed this is consistent with the empirical observation made by the principal investigator and author of the isotope study during days with dense fog: *"The wetness inside the forest is similar to a light rain; the tree leaves are covered by water drops and the soil is clearly wet".*

The authors agree that in view of orientational studies of Gischler in 1971 in Antofagasta (28), and the proved fog water contribution from monsoon clouds to recharge of groundwaters in the Salalah area and the Dhofar Mountains in the south of the Sultanate of Oman (Clark et al, 1987), **the question of recharge potential of fog water needs further studies.**

Considering the studies made by Aravena et al (1987) (2), it should be noticed that incidental rains in arid areas are normally rather short and intensive, and therefore fall in quantities that plant roots are not able to assimilate in its totality, letting the excess seep through to the groundwater table. Also it is not known from what sites and depth well waters in or near the Camanchaca area have been collected for the isotope examination carried out by Aravena and others. On the other hand, the interception capacity of the Camanchaca vegetation, determining its growth and survival, should be balanced as much as possible with the water assimilation capacity of the root network in the subsoil.

From the above it can be concluded (human habitation during the warmer periods which with increased accumulated technology can be gradually continued into slightly cooler periods) that the average ocean temperatures in front of the Chilean-Peruvian coast and the acquired skills of the settlers to manage the scarce water resource are the main factors that determine the possibility of human habitation along the coast. On the basis of archaeological evidence it appears that global warming seems even to favour development of the Camanchaca loma zone, on the condition that vertical obstacles permit a high interception capacity of the coastal fogs.

Fig. 10 - Human occupation of the Chilca Basin during the ecological or cultural periods of the Holocene (17) (After F. Engel).

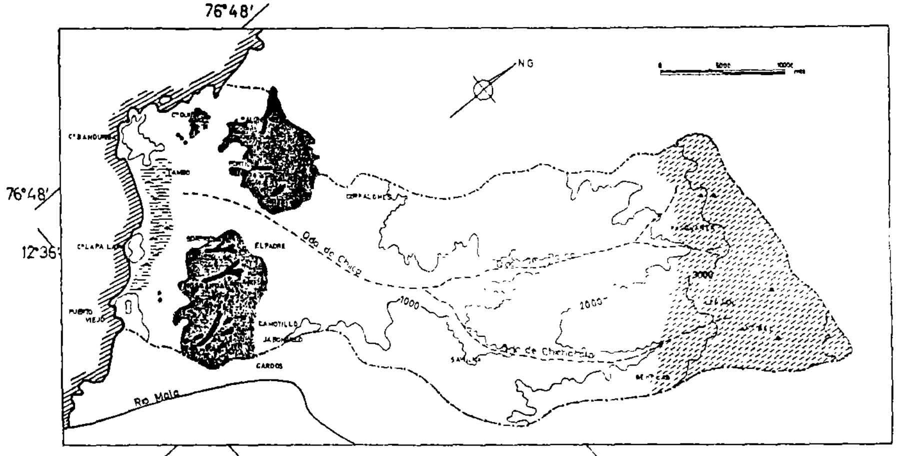


Fig. 10a - Pre-agricultural groups: 10.000 to 6.000 years bp

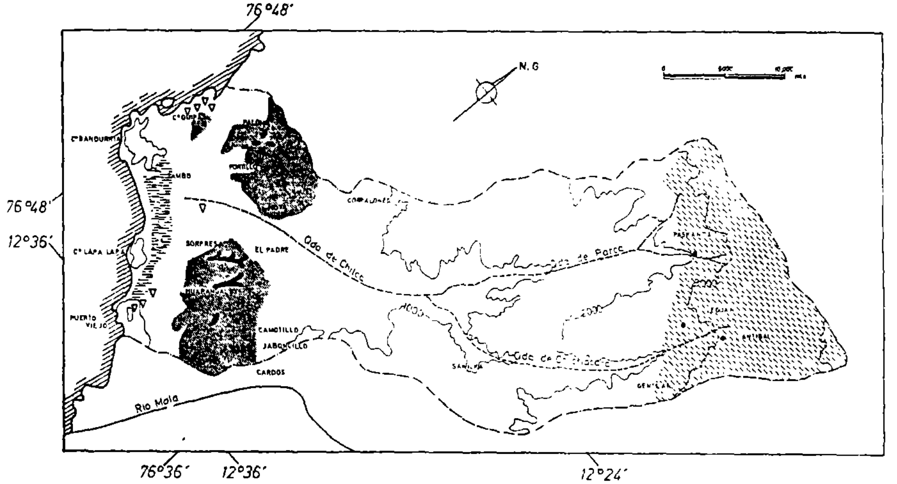


Fig. 10b - Agricultural maize-eating groups not yet influenced by the Chavin culture: 3.600 to 2.800 years bp

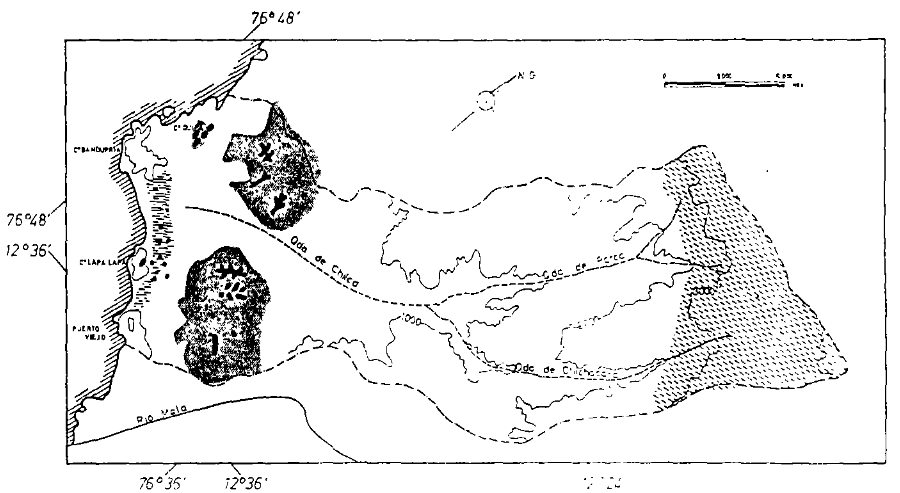


Fig. 10c - The "systems" of the Lapa Lapa group

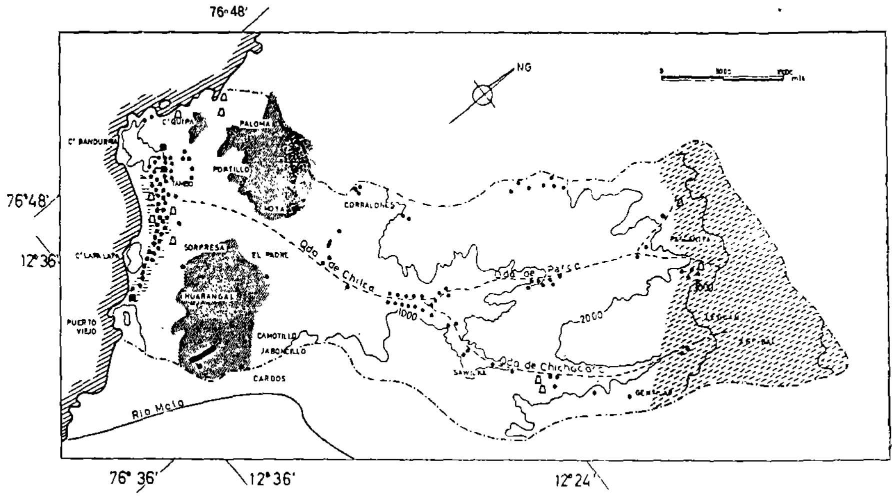


Fig. 10 d - Sites occupied during the last pre-Columbian centuries

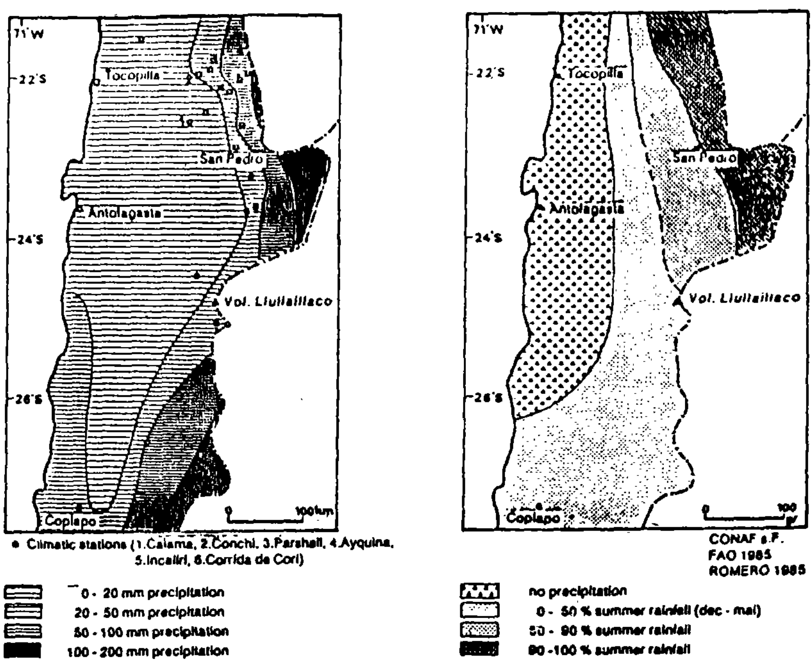


Fig. 11 - Precipitation pattern in Northern Chile: a) Precipitation, b) Seasonal distribution

PROJECT WITHOUT FUNDING

7

In order to arrive at an acceptable project structure, UNESCO/ROSTLAC had to adapt to internal and external demands.

Internal UNESCO demands

The Vienna Conference on Science and Technology for Development (UNSTD) held in August 1979, approved the need to focus on the problem of the technological dependence of developing countries and the urgency of promoting technological development in order to solve the problems of underproduction, unemployment and quality of life.

Soon afterwards the Third Session of the Intergovernmental Council of the IHP took place, during which the Director General of UNESCO, Mr. A. M. M'Bow stated:

UNESCO contributes to the application of the recommendations of the United Nations Conference on Desertification relative to hydrological resources by:

- *carrying out studies and experiments relative to adapting imported or innovative technologies, keeping in mind the available resources and the prevailing social and environmental conditions;*
- *assignment of priority to activities which support the development of technologies making full use of local experience and resources;*
- *preparation of an inventory of the traditional systems of water collection and distribution, and their improvement through appropriate techniques.*

UNESCO's Triennial Budget and Programme for 1981-83, approved at the 21st Session of the General Conference in Belgrade (1980), reflected the priority given to the Organization's scientific and technological activities in duplicating financial contribution for these activities.

UNESCO's Executive Council established guidelines for regional projects of an operational character within the sphere of Science and Technology. Point 93 of the introduction to the Document of the 21st Session of the UNESCO General Conference specifies requirements to be met by these projects:

- *It makes all the functions of research, training, demonstration, data circulation, technological options and economic decision-making as fully consistent as possible;*

- *it facilitates operational links among institutions in developing countries and between them and the corresponding institutions in the developed countries;*
- *it allows for flexible coordination of work through the exchange of personnel and information or the establishment of appropriate regional working groups;*
- *it is addressed to the solution of practical development problems through the establishment or strengthening of endogenous scientific and technological capabilities in specific fields;*
- *it brings about as thoroughly interdisciplinary an approach as possible through the cooperation between specialists in the natural sciences, the human sciences and the socio-economic sciences;*
- *it encourages participation in decision-making concerning project preparation and implementation, not merely by scientific personnel themselves but also as far as possible, by economic agents and representatives of the populations concerned.*

The integral character of the approach and strategy for executing the projects is the salient point which prompted UNESCO to carry out the so-called Major Regional Projects. In this framework, the **Major Regional Project on Use and Conservation of Water Resources in Rural Areas of Latin America and the Caribbean** was conceived.

The author felt satisfied and gratified by these guidelines as in a way he had indirectly contributed to this new approach. Having prepared a document on Arab Water Resources for the Conference on the Application of Science and Technology in the Arab Countries (**CASTARAB**) held in Rabat, Morocco in 1976 (later published with complementary notes as *Water Resources in the Arab Middle East and North Africa* by MENAS Ltd.), he received the following constructive criticism: "*Why did you forget to mention the importance of traditional Arab waterworks?* " Although it was a matter which had his full interest he did not feel competent to discuss the subject. Backed by a recommendation to give this subject the necessary attention, the support of Mr. Dumitrescu, Director of the UNESCO Division of Water Sciences, and the help of three appreciated colleagues Dr. Kassas, Professor in Botany at the University of Cairo and during that period Chairman of the International Union for the Conservation of Nature (IUCN), Dr. M. C. Safadi from Syria and the late Mr. M. S. el Amami from Tunisia, he could start an inventory of traditional waterworks. By studying the old technologies, he found out that more important than the individual works are the underlying principles and philosophy.

Traditional waterworks enable a sustained development of aquifers, small water-courses and sporadic seasonal rainfall. They make full use of naturally available energy sources, like the local geomorphology implications of gravity, the variability of the climate, and can (or better, could) be produced and maintained locally. These works are of low cost because of the perfect adaptation to the human and social surrounding as well as the natural environment. These waterworks are normally ingeniously associated with water supplies for man, animal, and plants or agriculture in general, to fully integrated land- and water-use systems which required a well specified, often legislated use. They formed part of a culture in which man always treated nature and the environment with the highest respect, feeling that he was part of it.

The experience in North Africa and the Middle East formed an excellent apprenticeship for traditional systems. Many Berber, Egyptian, Nabathaean and Persian technologies (to mention a few), consolidated and standardized by the Romans within their empire, including their own magisterial contributions, have been continued, expanded, and often kept in working order by the Arabs (not only in their golden age) forced by the obligatory adaptation to their arid and semiarid environment, until the oil boom. Even due to Arab occupation of large parts of Spain, just before the Conquista, this technology was brought to the New World, especially to Mexico, but disconnected from the underlying principles and philosophies.

After desertification was recognized a worldwide problem (Nairobi 1977), traditional integrated land and water systems inspiring also the appropriate technology, offered obviously the best chance of success in poor arid and semi-arid countries.

Unfortunately for the Arab countries, the moment to give attention to traditional technology was not well chosen as many of them enjoyed the economic advantages of the oil boom. Many of the Arab states could afford for the first time in their history, the (temporary) use of non-appropriate energy and consumptive technology (related to over- exploitation and exhaustion of resources), even in great parts of the rural areas. Of course this was not the case in most of the other developing countries.

Latin America was just plunging into probably the worst crisis of its history. Due to shortage of financial and energy resources, the idea of huge investments that require other ditto investments and again other investments, to finally obtain a productive system, fell into discredit.

The technological systems of pre-Columbian civilizations on the Pacific coast and in the Andes can often compete with those in the Old World. However they were not yet very well known to the large public. This has changed considerably during the decade of the Eighties. Further investigations will certainly reveal astonishing facts about these civilizations as archaeology is only starting in the New World as compared with archaeology in the Old World.

In 1982 the Minister of Foreign Affairs of Brazil declared during the regional IHP meeting celebrated in the Itamaraty building of the Ministry of Foreign Affairs in Brasilia, that at present appropriate technology was more suitable for Brazil than projects like, for instance, Itaipú. He referred to one of the biggest hydroelectric schemes in the world, needing moreover an extensive high tension electrical power network, an adapted electrodynamic infrastructure and a massive training and reconditioning programme for adequate manpower in order to become productive. The challenge was just to link with imagination un- or under-productive technical infrastructures, with the minimum of investment, to productive systems. For the rural areas, with massive unemployment, this was an especially interesting option. It only required the availability of characteristics which made traditional technological systems work: constructive collaboration among specialists of different background who are willing to listen with patience to the needs and suggestions of rural people, and plan with them realistic solutions for sustained and integrated development. In this spirit, and with the extra budget, (never more than US$ 200,000/year for all IHP activities, including MRP, for the entire region of Latin America and Caribbean), the Camanchaca project fitted very well in the Major Regional Project, known as MRP. Although the acronym does not make sense, MRP (or in Spanish, PRM) has become the current press-mark that stands in Latin America for this Multidisciplinary Rural Programme and its associated philosophy.

External demands

After returning to their respective home countries, both groups from Chile and Peru, started working on the elaboration of the basic principles developed during the meeting, in the light of the directives which the IDB had established for the application for financial assistance.

UNESCO/ROSTLAC, apart from having informed both governments about the outcome of the Antofagasta meeting, also stayed in touch with the Chilean representatives of the IDB. The latter had already informed their colleagues in Peru on the matter. The IDB financial assistance would be in national currency of Peru and Chile, equivalent to the amount of dollars of their contribution, rectified on a three-monthly basis, during five years. Since it was the opinion that this project concerns a local phenomenon, both countries did not consider that foreign inputs were needed, or were even desirable, except to pay the regional coordinator, who should be a foreigner, for political reasons. IDB, as a matter of general strategy, would not finance the regional coordinator. This should be done either with national contributions, and/or UN funds. The amount foreseen to remunerate the coordinator could also cover his other activities for MRP in Latin America. This last task in combination with the first one would generate a feedback for the coastal fog project, being a specific subproject of the MRP.

An intensive consultation campaign of the Latin American countries interested in MRP resulted in a list of practical techniques, to be presented in the inaugural MRP meeting in Mexico City, in March 1982, for inclusion in the project's exchange and development programme. Some items seemed very attractive for fertilization of the Camanchaca project, like porous pot irrigation, an economic alternative for small-scale drip irrigation, use of windmills for pumping and generation of electricity, cheap dosing equipment of Chlorine for disinfection of consumption water in rural settlements, ceramic domestic water filters. Later items could be added like computation of the volume of roofwater collection cisterns related to irregular entries of water and a fixed water-demand and, last but not least, the domestic use of solar cookers during the still frequent hours with sunshine, to preserve with the vegetation also cloud water intercepting capacity of the terrain.

In the meantime it was noticed that also in Ecuador there exists a 110 km-long coastal strip with the same characteristics. Only the area has a denser population than the coastal strip in Chile and Peru. No investigation had been carried out to obtain water from the clouds, although the need was great and increasing due to deforestation. The resident population is leaving the area little by little to settle in the big towns. Maybe also in Baja California conditions would be similar.

This information was sent to UNESCO HQ and to the Regional UNEP office in Mexico City, hoping that this might provoke positive suggestions or even offers for assistance.

In end October 1981 there came the answer from the Chilean Ministry of Foreign Affairs to the Director of UNESCO/ROSTLAC, Dr. Gustavo Malek, mentioning that the Chilean Government had decided to support the project. However, the national technical organisms stressed to amplify the socio-economic antecedents of the area involved, and also insisted to digress on the planned activities in both countries and their respective budgets. The first aspect concerned the productive activities of the population living in the area, describing their present difficulties with water supply. The second referred to the convenience of describing the activities in terms that permit the easy extraction of the elements required by the project, in order to determine the budget with appropriate detail. This last observation should clearly indicate the national components contributed by each counterpart institution. With reference to the Chilean members in the binational project commission, the following persons were appointed:

— Mr. Joaquín Montes, Ministry of Foreign Affairs;
— Mr. Francisco Díaz, engineer, member of National IHP Committee;
— Mr. Guido Soto, engineer, CONAF.

On 15th October renewed contact with IDB revealed that although the project report was informally well received in Washington, it had obtained negative comments from the Chilean member of the board of directors, for Chile had renounced to its participation in the IDB Special Fund, and it was doubted if UNESCO as an international organization could administrate regional funds. In this connection, Mr. Cañas of the Chilean IDB office asked if ROSTLAC had the same status as ECLAC, as the latter could receive and administrate IDB funds, and if UNESCO was prepared to finance the regional coordinator (CTA) by itself or together with the countries,

On the other hand, during a meeting of the Chilean IHP committee, who invited for the occasion Mr. Joaquín Montes, Chief, Environmental Department of the Ministry of Foreign Affairs, the project had been received with great enthusiasm. The I, II and IV Regions would allocate part of their regional funds as counterpart contribution to the binational project (this had already appeared in the newspapers of the IV Region). Mr Montes assured the meeting that the Chilean-IDB relationship would be negotiated internally with the Chilean IDB director. Further, he mentioned that in reply to Mr. Malek's letter of 17th August, the Chilean Ministry of Foreign Affairs would authorize UNESCO/ROSTLAC to apply for financial assistance to the IDB on behalf of Chile.

In December 1981 the Peruvian representation to the Binational Commission, as a result of meetings with UNESCO/ROSTLAC, IDB representative, ONERN, SENAHMI and the Universidad Nacional Agraria La Molina (UNA), was set up as follows, coordinated by the Consejo Nacional de Ciencia y Tecnología (CONCYTEC):

Mr. Jorge Valdivia Ponce, SENAHMI;

Mr. Eric Cardich Briceño, INFOR;

Mr. Carlos López Ocaña, UNA and CIZA;

Mr. Eduardo Armas Autero,ONERN;

Mr. Manuel Enrique Rubio, Director CONCYTEC;

Mr. Manuel Vegas Vélez Director de Investigación Tecnológica de Recursos Naturales, CONCYTEC.

Since Manuel Vegas, a biologist specialized in oceanography, is a highly appreciated former UNESCO/ROSTLAC colleague, his contribution was most welcome.

In June 1982 (one year after the Antofagasta meeting) a decisive letter was received from IDB informing that in spite of the interesting idea to obtain water from the clouds along the Pacific Coast, the binational application for assistance lacked grounds to consider financing. "*What is the productive potential of the resource, in terms of volume per area; its stability; its estimated cost and scope of the total area to be developed? What is the annual growth rate of the biomass in the mentioned arid zones, since this would be one of the indicators of the agro-silvo-pastoral potential of these zones, and would indirectly affect the development of human settlements and improve the environmental quality in the arid zones of the south Pacific? What are the social, economic and environmental cost benefits?* "

In this connection IDB suggested to analyze the experiences of Japan and other countries and the activities carried out in high altitude rainforest in Latin America. The letter signed by Mr. Hernan Aldabe ended mentioning that this additional information would allow to take a definite decision with respect to the request.

Mr. Hernan Aldabe and IDB should understand that with the availability of the requested information a normal loan would have been sufficient. The non-reimbursable funds were just needed to answer these questions. Indeed the only thing that would make sense was "fly the bank people right in" (page 42).

At UNESCO's request Carlos Espinosa wrote a report on the stability, productivity and areal occurrence of the resource (21). At least this satisfied IDB as far as part of the first request was concerned.

A personal visit of the Regional Hydrologist to Washington, unfortunately coinciding with the Malvinas/Falkland conflict, made it quite clear that with the transfer of Schmalzle to an isle in the Caribbean, for the time being the chances for an understanding and constructive contact with IDB had gone. The political animosity against Chile could be sensed inside IDB, as Chile was the only Latin American country siding with Great Britain in the conflict. This was due to their ongoing Beagle conflict with Argentina in Tierra del Fuego and had driven Chile into complete isolation. Already after the military coup d'état on 11th of September 1973, technical assistance for Chile by western democratic nations became politically unacceptable.

The general conclusion was that banks like IDB and the World Bank are not the best organisms to support the introduction of innovative technologies, as their conventional structure and criteria don't leave space for adaptation to new developments unless a special person or group with clear concept of the matter and sufficient power inside the bank, is motivated to create this extra space. Being aware of this fact, what should then be the task of banks and many other conventionally structured organisms, in a quickly changing world full of innovative activities?

Now UNESCO/ROSTLAC, with its limited project budget approved by HQ and the support of collaborating national organisms and professionals with much enthusiasm but little means (in Peru practically zero) and the blessing of the two governments, had to continue the struggle. The sincere attention given to the project by the IDB representative and the continuous coverage by the news media had an awakening influence on the public. The following criticism of the Bank at least defined in what direction to pursue: namely to create one or more small but self-sufficient productive units fuelled by Camanchaca water.

In Lima an idealistic group of the Universidad Nacional Federico Villareal, guided by geography professor Alfonso Valverde Torres and assisted by Manuel Belaúnde Suárez, a promising graduate, offered to work at the Pasamayo site 62 km north of Lima. Jorge Valdivia Ponce, lecturing at that university, had obviously sparked this initiative by explaining what could be done with fog water intercepted at that site. SENAHMI would provide some meteorological equipment and material but could not supply manpower or regular transport. Therefore the University applied for UNESCO support.

Eric Cardich and Carlos López Ocaña with some infrastructure of INFOR, UNA and CIZA but also without any money, proposed to work on fog exploitation in Lachay, of course scientifically and logistically better prepared than Valverde and his group. Passing Pasamayo on their way to Lachay, they could at least keep an eye on Valverde's activities.

Already from 20th to 23rd April 1982 the third meeting on the coastal fog project had taken place in Lima with the complete Peruvian representation of the binational committee including Valverde.

Jose Jullián, regional representative in the IV Region of the Planning Office (SERPLAC) and of the National Planning Ministry (ODEPLAN), Montserrat Palou of Foreign Affairs and Guido Soto of CONAF formed the Chilean team. UNESCO/ROSTLAC was charged with the coordination. On this occasion IDB had kept a suspiciously low profile but Lima's influential newspaper "El Comercio" produced its historical comic (Fig.12), making it clear that independent from international funding the project had taken root.

In El Tofo CONAF planned to undertake the study of the impact of the water resource on soil-water-plant relations, making use of the experiences gathered by the Universidad del Norte. After having investigated the ecological effect, and the applied technology given satisfaction, the system should be submitted to a financial analysis. If results were favourable, it could be recommended as an attractive investment. Parallel to this, other potential uses as drinking water for man and animal would be examined.

CONAF was able to interest Jose Jullián to spend regional funds on Camanchaca experimentation and investigation in El Tofo. SERPLAC invited tenders for the execution of the research plan made by CONAF.

Horacio Larraín, archaeologist-anthropologist and former researcher at the Catholic University who had also participated in the binational meeting in Peru and Chile, presented the lowest bid. He had already produced an audiovisual slide show on Camanchaca (financed by UNESCO) summarizing artistically the practical experience gained during the UNESCO excursions and previous work in El Tofo. Together with Pilar Cereceda, geography professor at the same university and the competent technical support of Nazareno Carvajal, who was finishing his physical geography studies, he accomplished the first research phase controlled by CONAF. For this an equivalent of US$ 35,365 had been assigned in 1982.

At the same time Larraín offered to make a documentary on the subject, but this became too expensive for UNESCO. First technical progress had to be obtained. The audiovisual demonstrated in Mexico as an illustration of how a simple technology inspired by natural phenomena could become productive, had been received with enthusiasm (9). The same slide-show, this time with English sound track using the voice of Geoffrey Matthews (presently working with the World Bank and also developing his new ideas on credit worthiness which have been introduced into the MRP philosophy), had facilitated the explanation of the project in UNESCO Paris and later in Washington (9) but had not produced any extra funding. In reality all these public relation and fund-raising efforts had paralyzed the research at a moment when all project collaborators, tired of negotiating were more keen than ever to get down to the job.

Fig. 12 - The El Comercio comic

HANDS ON

8

El Tofo 1982-1983

In 1982 the MRP coordinating counterpart organization in Chile, CONAF IV Region, had repeatedly asked the UNESCO Regional Hydrologist (URH) to visit them, meet the local collaborating authorities and see the progress made since June 1981 when the binational excursion visited the Camanchaca sites in the IV Region.

Finally, on 18th August the control visit took place. Espinosa was invited to come south to use the opportunity for exchanging ideas. The latter had applied for a research grant of US$ 10.000 from his university which had been granted, but shortly afterwards withdrawn due to the economic restriction measures. So he was paralyzed for the time being.

In the IV Region, SERPLAC, thanks to the influence of CONAF, helped substantially. They financed Larraín's activities which were a first intuitive and constructive step ahead. His merit as an archaeologist /botanist/anthropologist was his imagination and knowledge of the terrain. He had just left the department of geography of the Universidad Católica, where he was attached as investigator, because of hidden political reasons. On the basis of their earlier working contacts, Pilar Cereceda, heading the department, kept her interest in the subject. They investigated the potential quantity of interception with a small portable cylindrical fogtraps, which could be located at different sites. The altitude range with high potential was between 600 and 900 m. with a maximum in El Tofo at 700-780 m. This was also verified by natural indicators like vegetation density per 100 m^2, altitude of shrubs, availability of plants like ferns which require more water, and an indirect indicator as organic matter content of the soil. This last testimony also showed the altitude persistence of the fog phenomenon through the centuries, as soil needs a very long formation period. He introduced some fogwater capturing near the Panamerican highroad crossing the Buenos Aires pass, a beautiful eye-catcher and propaganda object, collecting at that moment the amazing amount of 10 $l/m^2/day$ (Photo 21)

During one of his flights from Montevideo to Santiago the URH happened to be invited inside the cockpit of a KLM DC 10, where he had an animated conversation with the captain. On the question "What makes you travel to Chile?" the subject changed to Camanchaca. The captain stated that he was not an atmospheric scientist but that he had acquired a certain amount of practical experience on the subject. He pointed to the the droplets that formed on top of the wings although the sky was cloudless.

"Do you know what that means?" he said, and answering himself: "The humidity of the air is getting locally saturated because of the low air pressure above the wings. To get maximum interception," he continued, "try to locate your fogtraps in low pressure areas like passes and saddles in the mountain chains. Remember the low pressure vortex in your emptying bathtub."

Indeed, cloud masses cascading down from mountain passes was quite a familiar panorama, looking from the interior to the coastal chain and not only along the Andes coast. Also, flying once above the Sahara the URH remembered how he had seen the same phenomenon on a huge scale but this time at levels exceeding 3000 m. Large masses of clouds controlled by a temperature inversion were funnelling through the passes of the Atlas mountains, falling down into the sandy extension of the Sahara, where they dissipated; a most impressive sight!

Communicating this cockpit chat to Horacio Larraín and Pilar Cereceda, the geographic attention drifted to the geomorphological implications of Camanchaca, an investigation which was later successfully executed by Professor Pilar Cereceda and her students, financed by a university grant approved by CONICYT (see (10) *Factores Geográficos que determinan el comportamiento Espacial y Temporal de la Camanchaca, Informe Final*).

The capturing at the site of the Cuesta Buenos Aires was later abandoned to concentrate all efforts in El Tofo.

While visiting El Tofo, a large 90 m^2 two-dimensional fogtrap immersed in a cloud bank was capturing 20 l/minute. Since the only storage consisted of a 200 l barrel, the excess water spilled over and got lost. Some of the water was used for new plantations, covering about one ha, a few hundred meters from the fogtrap. Some of the trees were Pinus Canariensis from seeds received recently by CONAF from the Canary Isles. Larraín had complained that the SERPLAC budget did not cover the purchase or construction of a tank. So UNESCO/ROSTLAC immediately provided the money for the second-hand tank, which had been located somewhere by Larraín. (*).

(*) N.B. As the UNESCO/MRP financial resources were always limited with respect to the actions that should be initiated with it, a special type of financial tactics had to be applied consisting of the following approach:

1. To be always watching for: a) small incongruent incidents; e.g. A problem turns up, a specialist who can handle it is passing by, but there is no contract or agreement that makes him get involved; b) missing objects; e.g. The carpenter with his hammer are there, but the nails are missing; c) conditioned financial support; e.g. A budget does not allow to cover the purchase of fuel, while transport is available, etc, etc.
2. These common and frequent incidents create **bottleneck situations** that paralyze the action and discourage the people involved, especially on isolated sites; time and money are getting lost. Bottleneck situations can appear always and everywhere due to normal gaps in the planning (often independent of funding).
3. To spend money with priority on the removal of bottleneck situations. To this end, small amounts of money should be available on the spot.

200 meter higher than the fogtrap a ground-based platform of the Chilean NASA group had been installed for the duration of one year, measuring up to twelve parameters every hour to enable the correlation of the accurate weather conditions with the production of the fogtraps. A photovoltaic panel fed the batteries to provide energy for emission of the data to the Geo Stationary Satellite (GEOSS) from where the message was transmitted to the GEOSS station near Santiago.

Nazareno Carvajal, who by now had finished his studies at the Universidad Católica and who had also constructed the fogtraps, was in control of the functioning of the platform.

This was the first step to relate Camanchaca water production to meteorological conditions, which could be observed from GEOSS images, but also from LANDSAT images, recorded since 1972 at least once every eighteen days at about 9.30 hours a.m.

Knowing, on the basis of one or more years of detailed observation, the mean daily distribution of the overcast, the Landsat passages could be used for extrapolation over a longer period. In the same way, using both types of images, other sites with frequent cloud cover could be examined anywhere in the world.

Remote sensing

It had been the author's feeling for a long time that the enormous investments made in many developing countries on remote sensing receiving stations and satellite image retrieval laboratories, should overcome the status symbol phase, and at last provide more direct practical information for farming and water-management purposes. Many remote sensing specialists in developing countries were working at that time in close contact with NASA and the World Meteorological Organization in Geneva, but had not yet come out of their ivory tower to produce a positive national impact on the rational exploitation of natural resources. An exception in this connection was Dr. Carlos Brockmann, former director of the Technological Satellite Programme on Natural Resources (ERTS-Bolivia) and presently working with P.L.480 in La Paz, Bolivia in environmental projects.

Within the scope of IHP (of which MRP was a more applied offshoot), ROSTLAC had produced at that time with the collaboration of distinguished scientists of the region, the *Methodological Guide for the elaboration of the Water Balance of South America.*

The next step was to produce regional water balances, an action which was implemented first on a national scale by Bolivia and Chile on the basis of obviously insufficient conventional data. The "Guide" had wisely foreseen methods to bridge these gaps as best as possible. However, no remote sensing establishment could be found in South America which was seriously willing to start effective researches to deduce water balance parameters from recorded remote sensing data, like surface temperature, humidity of the air, etc., in order to produce this data as a routine in the future.

MRP and IV Region

The governor of the IV Region, Commander Claudio Guzmán, explained how the IV region in Chile was the transitional zone between rainfed cultivation in the south and deserts in the north. Depending on the dry and wet years, the prosperity of the region varies. Therefore the specialists in the region will concentrate on low-cost technology to optimize the use of the irregular water supply from snow in the mountains, exceptional rains and regular Camanchaca along the coast, the latter being, in spite of its limited capacity, the most reliable resource. That is why there existed a general consensus to develop the IV Region into an open air laboratory of low-cost water and soil conservation pilot projects. For this reason the governor invited UNESCO to hold its second MRP meeting in La Serena.

This positive attitude made it clear that the leading research site for Camanchaca had become El Tofo, nearer to the capital and therefore within more convenient reach for decision makers.

Macro-diamonds

To keep up Antofagasta's reputation as the oldest research centre, ROSTLAC offered Carlos Espinosa a contract to produce four fogtraps of his macro-diamond design; each composed of 420 bronze anti-corrosive bars, and 132 pairs of bolts and nuts for the same amount of junctions, packed in a wooden case with dimensions 20 cm X 32 cm X 80 cm, weighing 80 kg, and which could be assembled in a light but firm structure of alternating octahedrons and tetrahedrons. At will this could be mounted and dismounted on different sites with different shapes, ideal for irregular barren rocky surfaces (23).

During the binational meeting it was agreed upon that this would be the best standard structure to start experimentation. Unfortunately the different groups would take standardization in the most literal sense, even the overall pyramidal shape of the combined tetrahedral and octahedral structure, annulling its characteristic versatility and adaptability. This was one of the reasons why the fogtrap would not give the expected positive results.

The manufacturing of the macro-diamonds took more time than expected. Espinosa had to make the construction a private affair instead of a university-executed task because of the many restrictions imposed by the university administration in spite of the previous assurance to facilitate the execution of project activities by the various lecturers and students involved. The energy of the teaching staff was increasingly absorbed in the intensive lecturing schedule, leaving no time for research and fieldwork. This, with the worsening financial problems of the universities and the growing student unrest, requiring frequent changes at the top, became a continuous drawback.

When the fogtraps for Peru were ready for transport, the instruction was to ship the cases to the CONAF office in Arica, where the URH would collect them for further shipment to Lima. Due to change in flights, however, caused by bad weather in Uruguay, he left Montevideo two days later than foreseen and could only call Espinosa from Santiago, telling him that he had to skip Arica-Tacna and fly directly to Lima. The packing cases, however, could be delivered to the Peruvian Consulate in Arica. Later it appeared that at that very moment the consul was absent and the cases were returned to Antofagasta a fortnight later. Dr. Vegas of CONCYTEC called Espinosa and they agreed finally to ship the fogtraps by boat from Antofagasta to Callao, Lima's harbour. So again plans were changed. Finally, after all people involved were again duly informed about the changes, it appeared that the cases had already been cleared out by the customs in Antofagasta and were waiting for shipment. The transport procedure which started beginning of April 1983 came to a happy end at the beginning of October of that same year but accompanied by a considerable bill due to harbour duties and storage charges. Fortunately, this was an exception although it would have been normal if one had stuck to the rules.

Peru

In November 1983, with joined forces, the macro-diamond fogtrap was assembled in Lachay and established on three beams across an open concrete cistern (Photo 22). A sheet of BIDIM (a polyethylene blanket) received from the factory in Brazil as a contribution to MRP, between the fogtrap and the beams, prevented evaporation from the tank, and filtered the dust particles from the intercepted water so that only pure water could reach the tank.

After a hot summer, Lachay was barren and dusty in April, but it was greener than ever in November, covered with man-high herbs and grasses, like the savannah after the rainy season (Photo 22). This was due to the "Niño" phenomenon in the period covering end 1982 and first half 1983, producing heavy rains in the north and causing disastrous floods in the Peruvian-Ecuadorian frontier. The disasters in the north lasted until June while an intensive Camanchaca period had set in only since August 1983 (Fig.7). Pasamayo, to the contrary, over a hundred meters lower immediately on the coast, surprisingly had a rather desertic look: no watchman, and only part of the planted trees surviving after the severe summer, creating soil temperatures of over 45°C. The relatively warm ocean had raised the temperature inversion layer with characteristic overcast at levels beyond reach of the Pasamayo vertical obstacles.

The Geography Department of the Universidad Federico Villareal had no means whatsoever to provide logistics. Therefore it was important that SENAHMI, as promised, established a meteo-station observed by a permanent watchman. The macro-diamond could only be put into function at higher levels east of the Panamerican highroad on the condition that a watchman be available (Photos 8 & 23). The need for more financial resources to help the people involved in the project became dramatic. CONCYTEC tried, with UNESCO's knowledge, to contact IDB and IDRC again on a national basis. To that end, in November 1983 a project proposal was presented.

Reforestation in the National Reserve of Lachay had started in 1940 with diverse tree species i.e. Casuarina spp, Cupressus spp, Grevillea spp, Tammarix spp, Agave spp, Eucalyptus spp. From 1980 onwards emphasis was more on native species: Caesalpinea inctorea (Tara), Capparis prisca (Palillo), Carice caudicus (Mito) y Saponaria (Choloque). Before 1980 plantation took place in the valleys or flat plots but afterwards plantations were carried out at individual favourable sites between rocks, on slopes near old tree trunks, etc. In this way 50 ha were covered with 7000 plants, mainly Tara.

In trial plantations the following characteristics were studied: the survival percentage, best space interval between trees, correlative measurements of size, vigour, age and fertilization, drought resistance, fog adjustment, vegetation dynamics: periodical influence of animals, ephemerals, biennials, perennials related with drought and fog periodicity. Also a start had been made with the examination of interspecies relations like antagonism, competition and mutual stimulation with respect to the smooth cycling of nutrients, propagation of pests, etc.

The Peruvians wanted to continue this line of research, but now replacing the water tankers which supplied the water by fogtraps, in order to expand their investigation with the same routine investments, and making on-the-spot labour independent from water import.

Financing was also requested for regional meetings to exchange information with other groups for their mutual benefit. In total, technical assistance and modest financial support was requested.(*)

Neither IDB nor IDRC reacted. Other agencies and embassies showed some interest, like the Dutch and the English diplomatic representation but still some social aspects were missing to make the project more attractive for western non-profit funding organizations.

(*) The frequent error made with applications for financial support, especially in developing countries, presented by enthusiast and dedicated national investigators for new researches (of course with a practical objective), is always that they ask too little for a too ambitious development project. The investigators think it is always better to receive something than nothing, so that they can carry on with their preparatory investigations, often made in their spare time or with private, non-remunerated efforts.

The funding agencies, alarmed by the obvious incongruency between requested support and pretentious project objectives, refuse support or in the best case try to come to a better balance between support and action programme. Confused by the initially proposed low budget, negotiations have started already on the wrong basis. Either more prominent government sectors are requested to sponsor the project as a kind of security measure, normally increasing considerably the project costs or calculations are made by the funding agencies according to standards in their own country, underestimating the efforts which can be made by small motivated groups in developing countries. Development projects seldom receive the correct amounts to carry out their proposed objectives. Normally too much or too little is obtained, both with the associated negative consequences. Also fundamental in this connection is that the funding organization evaluates as accurately as possible the moral creditworthiness of the group applying for financial support.

Once more water was intercepted and conducted by a small pipeline to the resthouse in the valley. Eric Cardich worked hard to stimulate social and especially educative aspects during the Camanchaca period. A nursery was established for local plantations, school excursions were organized during which each boy or girl could fill his flask and drink fogwater, for the first time, while eating his package lunch. The visitors' book in Lachay contained more and more interesting observations of tourists of all kinds, impressed by this surprising small-scale exploitation. Eric said that of course the water, from an exploitation point of view, could better be kept for longer dry intervals during the Camanchaca period, but he agreed with UNESCO that propaganda and publicity, even if it concerned only hundreds of people, should not be neglected. The modest contributions of UNESCO just served as a bait to catch if possible, a whale, so that this embryonic trial could really come to life and obtain self-sufficiency.

For the same purpose the Pasamayo initiative was supported although prospects looked gloomy. This project was situated right on the Panamerican highroad and had an eye-catching potential. With time the meteorological station was installed, primitive fogtraps appeared and the plantations in an acre or so were recuperated and completed. A watchman was available from time to time, but once he was away unknown people stole building material, tubes, hoses and working tools, kitchen outfit, etc, all brought together with tremendous efforts by the students, who were even hitchhiking to the site to carry out their task.

The advice given to make the rotating student community serve fogwater tea for a voluntary contribution, or even to sell naturally distilled water for car batteries in order to raise money for the petty cash, and to create an opportunity for the public to read the explanatory notes on the sign-boards so as to make them aware of the efforts, was never followed in Peru or in Chile.

Further, these kinds of local exploitations serving local well-being and interests, should attract at the earliest the involvement or at least concern of the local community or neighbouring people, as a measure of preservation of the effort (and it might have deterred the thiefs). This active involvement of the beneficiaries of an experimental exploitation is one of the basic concepts of the MRP philosophy.

Los Nidos

On 9th August Carlos Espinosa, as representative of the Universidad del Norte, started the new integrated Camanchaca research in Los Nidos. This site, 30 km south of Antofagasta, carefully selected in consultation with ROSTLAC, with no vegetation and 820 m above sea level, provided some advantages. It was accessible to four-wheel-drive vehicles (Photo 24) and offered a cultivable sedimentary plateau, if water were available, with possibility of expansion over 1000 ha. to neighbouring flat areas separated from each other by shallow basement outcrops. On the western side, the locality was facing the coast down below at 4 km distance.

This site was already known from the 1968-1972 research phase, as old capturing artifacts demonstrated (Photo 3). Of course Camanchaca does not reach here the exceptional high production rates of the practically inaccessible Morro Moreno, but with a potential of ± 1 liter/m2/day is very representative of the entire northern coast. In Los Nidos, a mule track of mineral prospectors following the coastal cordillera range links up with a footpath to the coast for seafood gatherers to reach their fishing grounds .

At the beginning the university assigned 38 hours/week for research, distributed over 4 university collaborators: Carlos Espinosa, Ricardo Zuleta, Roberto Espejo and Alexis Correa.

In June 1984 a group of 7 participants with two 4-wheel-drive cars among whom the author, took the 30 km road to Los Nidos with 2 km obligatory use of 4-wheel-drive. The previous day an engineer had explained what works had to be carried out to improve these two km. and make the track accessible for ordinary cars as 4-wheel-drive vehicles were not always available. They arrived before sunset when a slight breeze made the sea fog invade the collection site. Three 3-dimensional fogtraps with different netting had been installed: two small tube-shaped ones of 4 m^2 and 7 m^2 respectively, mounted on water collecting barrels, and the large macro-diamond structure which still had to be placed on top of a water collector system (Photos 25 & 26).

After the fog had covered the netting, it took some time before the mazes were filled up by intercepted minuscule droplets. Once the netting was saturated vertical drainage started along the warp (vertical thread of the netting) to the collecting gutter at the base of the netting, while the amount of intersecting wefts (horizontal threads) caused each time a little friction. Later in the night the breeze practically disappeared. The tiny little droplets became clearly visible in a torch ray, describing so-called Brownian movements. In spite of the absence of wind the capturing devices worked intensively. Once the fog diminished, the netting dried up little by little and interception stopped. This took place before midnight. Because of less cloud cover and increased nocturnal radiation the temperature dropped from 12°C. to probably near to 4°C. In the morning before dawn fog returned, but only at 8-9 a.m the netting was completely saturated again. The small size netting started to drain before the large size one.

Conclusion

Anisotrope netting with more warps than wefts per unit length, producing in this way mazes with vertically-oriented rectangles, will be the best collector. The wefts are needed for general strength of the netting, and also to prevent that the wind makes the warps cling together, so that two or more warps function as only one thread and the netting loses interception capacity. When the duration of Camanchaca is short, small mazes seem to be preferable to obtain saturation of the mazes as soon as possible. When Camanchaca duration is long as an average, a larger size maze is better. Moderate wind seems favourable to saturate the netting. Too much wind blows the droplets off at the leeside. Once the netting is saturated, wind seems to be less important. Cohesive forces of the saturated sheet attract the "Brownian" droplets, and once their original space is emptied, it is immediately replenished by other "Brownian" droplets which expand their action radius to optimize their freedom of movement. In this way, the author supposes that a stagnant cloud mass also serves interception but as a finite process, in contrast with the unending process, if wind supplies new cloud masses continuously. It is obvious that in the case of a stagnant cloud mass, a three-dimensional fogtrap is as good, or even better, than a 2-dimensional one, due to the more effective spatial drainage capacity of a stagnant cloud mass.

In case of wind, saturated netting will function as a closed wind barrier deviating the air-flow by forming a turbulence cushion in front of the netting. Heavier droplets with more inertia under the influence of centrifugal forces will still hit the netting, but large saturated intercepting surfaces must decrease fogtrap efficiency, interception being no more proportional to the size of intercepting surface.

The effect of the colour and material of the netting itself should be studied by comparing interception under similar circumstances. Dark colours are anyhow more weather resistant. In any case the capturing of moisture from the clouds is a rather occult process which starts at (sub)microscopic level of which only the end product is easily visible and measurable. Wind direction and velocity, type of mist, nocturnal blackbody radiation or daily solar radiation previous to the interception, which respectively speeds up or slows down the physical contact of the arriving cloud banks, with intercepting obstacles, types of netting and fogtrap configuration, are factors that induce small variations which make the phenomenon every time slightly different at a certain Camanchaca site.

A macro-diamond frame served as a firm skeleton for the tent, which offered adequate accommodation for five people. Ivan Ordenes, Arturo Neira, and Cadudzi Salas had lived there for some weeks to prepare the existing infra-structure provided by the Universidad del Norte: a meteo-station to measure meteorological parameters: temperature, evaporation, relative humidity, precipitation, solar radiation and wind, and other equipment. The ideas of Espinosa and his colleagues were most interesting although too ambitious for the limited means. They had in mind to change Los Nidos from an uninhabitable place to a productive and self-supporting experimental station of the Science Faculty, by scientifically exploiting the peculiar environmental characteristics of the spot. In this connection, Dr Alcayaga, a solar energy specialist, and professor Espinosa demonstrated the use of solar energy for the solar cookers, the photovoltaic cell panel to charge the nickel cadmium batteries for lighting and radio contact with Antofagasta, and explained the plans elaborated for the permanent housing accommodation using a heat storage system in combination with hot air circulation. A portable macro-diamond fogtrap changing position every day would serve to drip on successive parts of the horticulture bed, returning to the same spot after three or four days as a function of the water captured from the clouds, water holding capacity of the soil, and the plants' water needs. The availability of nitrate in large quantity makes the soil very fertile once water is available. Do not forget that Los Nidos is situated in the Atacama desert, probably the driest desert of the world, where even the very soluble nitrate salts precipitate.

The *chili salpetre* was exploited and exported since the last century to the western world, until after World War I Germany brought on the market the cheaper synthetic nitrate fertilizers obtained from nitrogen extracted from the air.

Also for the conservation of food, nocturnal blackbody radiation which is intensive under circumstances of the clear desert sky (even for a few hours per night between periods of Camanchaca interception) may produce ice. During experiments in Antofagasta at sea level, temperatures of -5°C had been reached, while in Calama at 2300 m above sea level a temperature of - 31°C was obtained. (See studies made in Atacama desert from 1968 to 1971, by Marcelo Robert and Sergio Alvorado of the Departamento de Mecánica de la Universidad de Chile, in collaboration with J. Fournier from France, using the nocturnal blackbody radiation for "*Desalination through freezing, by natural radiation exchange*").

It is even suggested that with improved thermal isolation technology, eventually the required temperatures could be obtained for the liquefaction of Nitrogen (N^2).

Sodium sulfate was used as a temperature regulator, as it absorbs water in the crystal lattice under liberation of heat, and vice versa liberates water under the absorption of heat. This reversible chemical reaction allows anyone to charge the pieces of Na^2SO^4 + n (H^2O) with heat, by exposing the salt to sunshine or another heat source. Once the Na^2SO^4 has lost its crystal water, it can be kept in a sealed plastic bag until the heat radiation under absorption of water is required, at a constant temperature of 32° C, keeping the tent or sleeping environment at the same time hot and dry. Na^2SO^4 has been used by tramping mineral prospectors to keep themselves hot during the cold desert nights. The Andean deserts with their salt lakes producing all kinds of salts and extreme daily temperature fluctuation of up to 40 °C and more, offer many unusual ways of energy generation and storage.

It was discussed that the present average production of 50 l of water per day is insufficient for permanent habitation of Los Nidos without extra supplies from Antofagasta. Only with a production of 200 liters/day some kind of systematic small-scale experimentation could be started. Espinosa was in contact with a group of young volunteers, who wanted to execute a research programme guided from Antofagasta, as a kind of low-cost astronaut mission guided from a terrestrial space centre.

These volunteers, sponsored by CETAL (Centro de Tecnologías Alternativas de América Latina) with office in Valparaíso and contacts in Europe, tried to find financial support for this purpose, but probably for political reasons mentioned before, did not succeed. The comment was that although the scientific part was interesting, the social need for such an experiment was not recognized.

Since economic and political conditions were bad, especially in Antofagasta, and no alternative occupation was offered, these volunteers started to man the "Los Nidos" station by turns, without any proper provision of a salary, until they could get a visa for Switzerland, and left. This was an alarming situation on which no research could be based. The most complicated financial and logistic sacrifice in such type of project is to maintain the regular transport contact, in this case between Los Nidos and the University. Therefore to make the station self-sufficient to a certain degree was the first immediate objective, so that apart from daily radio contacts Los Nidos could be left alone for a week or two. This was unfortunately never obtained.

After a while the University stopped the use of their transport and Espinosa had to rent a four-wheel-drive car each time. ROSTLAC warned Guido Soto in La Serena, 1000 km farther south, to do something. Guido contacted the newly-established CONAF office in Antofagasta for the II Region. CONAF obtained a small budget to support Camanchaca, and their trucks could be used to maintain the lifeline with Los Nidos. Espinosa lost his autonomy, and CONAF II Region started their less idealistic but down-to-earth support in 1985.

At the turn of the year another ROSTLAC-MRP control visit took place. During a long discussion with Alejandro Hepp, the new regional CONAF director, the administrative, logistic and financial difficulties of the original setup were discussed. The university gave Espinosa less and less opportunity to spend time on Los Nidos. However, management of the UNESCO funds by CONAF, in close relation with Espinosa, had improved the progress of some activities. The macro-diamond fogtrap had been definitively installed on a zinc funnel structure draining the captured waters into barrels. The cistern for which cement had been obtained as a donation to Los Nidos from the neighbouring Portland factory, 20 km farther inland, had never (or not yet) been constructed. CONAF had established two improved 2-dimensional fogtraps of 40 m^2 each of a more aerodynamic type according to the design of Nazareno Carvajal, tried out in El Tofo (Photo 31). These devices had been functioning successfully for three days when they collapsed due to winds stronger than occur normally in El Tofo. The new design fogtrap captured considerably more than the existing ones. This accident provided credit to both arguments which kept alive the continuous debate between CONAF and Espinosa on the best fogtrap.

Espinosa, who could not rely on regular transport facilities, wanted a reliable fogtrap which functions under all weather conditions, although it may have a lower yield. CONAF, with its own transport to maintain regular contact with the site, and who had planted 108 trees in an area of about 1 ha.(Photo 27), for which they needed minimum 1.5 liter/tree/week, or say 160 l/week extra, obviously wanted the maximum amount of water for the lowest investment in fogtraps, and took certain risks (later corrected) to obtain higher water production rates. Both parties forgot however, that with the octahedral-tetrahedral frames of Espinosa's diamond structure, wall-shaped configurations could be composed, with two dominating dimensions perpendicular to the wind direction, and the third dimension mainly for strength. By leaving at intervals sectors uncovered with netting, the structure would never become a windproof barrier, but would force the current of moist air to zigzag through the structure sweeping the heavier droplets against the netting. However, with the new type of aerodynamic fogtrap (to be discussed later on) the 2-dimensional one was undoubtedly winning.

Anyway, CONAF liked the site of Los Nidos chosen by Espinosa, offering ample planting space for trees in fertile soil. They had started there a nursery to obtain well adapted trees for this peculiar environment. Among the 108 trees were Prosopis Tamaruga, Algorrobo, Acacia cianophyla, Acacia vilca, Schinus molle. End 1985 the trees had reached lengths between 34 cm and 1 meter. Only one tree died. As an experiment, a group of trees had been left without irrigation during an intensive Camanchaca period of two months, to obtain again irrigation afterwards. At the end of December 1985, the difference between the trees with continuous irrigation and the trees which were left alone, was almost invisible.

In the night two hours of moderate Camanchaca were observed, which made all fogtraps work, at that moment three tube-shaped ones, mounted on barrels, and the macro-diamond pyramid on the zinc funnel construction (Photos 25 & 26). The production was 20 liters, compared with 200 liters in a half-hour time in El Tofo two days later.

The general organization of Los Nidos had improved. The watchman/observer, who had replaced the volunteers, was doing well and his work had the full approval of CONAF. Unfortunately, some items covered by UNESCO contracts had not been carried out, while others had been added. For instance, for more effective water application to the trees, porous pot irrigation, developed in Brazil, adapted to Chilean conditions and improved in La Serena, had been recommended but not yet implemented, not even in the planted area of El Tofo. The responsible MRP researchers of La Serena had been sent to Antofagasta to transfer this technology, in the same way Brazil had transferred its technology to Chile and also to Bolivia, Argentina, Peru, Ecuador and the Dominican Republic within the MRP scope.

CONAF II Region had grown from a director and secretary to a staff of ten professionals. From SERPLAC II Region (the local planning organization, which was the positive result of decentralization) an amount of US$ 3,000 had been reserved for the development of Camanchaca. This together with some MRP assistance gave some hope for the future.

El Tofo 1984

End 1983 in El Tofo, the NASA meteorological platform had been withdrawn, and was replaced by a conventional met-station. The large 90 m^2 fogtrap had been removed from the pass giving access to the mining area and had been reconstructed about 200 meters higher (Photo 28) at a site with more frequent fogs, where the water could also be used better. It produced at that time 1 m^3/day. An ingeniously improvised water metering device measured the instant water production (Photo 29). Next to the 90 m^2 one, a macro-diamond type fogtrap was installed, producing little water.

SERPLAC had obtained a house from the former El Tofo mine concession, to be used as a project field-office and resthouse. It accommodated at that time five labourers and one agricultural technician. The discontinuously intercepted waters were drained into a three m^3 regulation and storage tank, providing the house and its inhabitants with a regular water supply.

SERPLAC was supporting with another US$ 10.000 to study the water supply possibilities for Chungungo. This time the contractor was CONAF IV Region. The porous pot irrigation system obtained end 1982 from the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) during the first MRP-organized *Interregional Technology Exchange Encounter* in Northeast Brazil, was now adapted by CONAF to Chilean conditions. Certainly this system would have a water-economizing influence, improving at the same time the water application to the trees.

With the improved observation method, more problems appeared to be solved. The wind factor is important: production increases with augmenting wind force to a certain critical value, but with little wind the cloud bank lasts longer compensating for the higher instantaneous interception in the first case. Different netting colour and structure have their very pronounced influence. In one case black netting captured 50% more than green netting. Sometimes the specific productivity of the 3-dimensional fogtrap is better than the productivity of the 2-dimensional one, although normally the latter captures much more per m^2 of netting (see also the conclusion on page 84 and 85).

El Brillador Camanchaca site

At the beginning of July 1984 an exceptional storm with wind velocities up to 160 km/hour seriously damaged the 90 m^2 fogtrap. Also the macro-diamond one was destroyed because it was badly attached to the concrete floor. In El Brillador where the macro-diamond survived, the structure was well anchored to the ground. However, this did not keep Eduardo Rozas from changing the structure, abandoning the pyramid shape, so far used everywhere (51).

In 1983 Eduardo Rozas, professor in geology at the Universidad de La Serena and friend of Espinosa, bought a macro-diamond fogtrap with university funds, to be installed at the site called El Brillador, north of La Serena at 780 m altitude and 9 km from the coast. He started systematic observations from 6th June 1983 onwards. A construction of 5 m X 5 m X 4.5 m high, resting on nine vertices served as collectors of the 45.2 m^2 of ordinary green mosquito netting covering 23 octahedral skeletons. Rozas developed a system to measure the individual yield of each octahedron. At the moment of the visit in December 1983 the production was 200 l/day, or as an average around 4 l/m^2/day. The octahedron on the windward side captured 18 l/day (Photo 30, Fig. 13) while the one on the leeside collected only 1 l/day. A standard meteorological station provided atmospheric data, which were read daily at 11 hrs a.m. The intercepted water was used for the surveying personnel, labourers of the nearby Mina Brillador belonging to the University of La Serena and for plantation of trees in the mining settlement. The idea was to produce later after increasing the potential of the station, water as a bacterial lixiviant for the minerals to be oxidized in situ, reducing in that way transport costs and part of the exploitation costs. Rozas, a newcomer in this group, made a valuable contribution in a short time.

Water supply for Chungungo

With all the data from El Tofo collected systematically over a period exceeding one year, it became time to apply the gathered knowledge to provide the 70 families of Chungungo (6 km further down the coast) with a total of 460 inhabitants, with Camanchaca water.

In 1984 every ten days tank-trucks delivered water at US$ 4 per m^3 which was 50% subsidized by the municipality of La Higuera, serving in its extensive district also another ten hamlets This water supply is completely unreliable because of the bad condition of the trucks, the temporary impassable condition of the unpaved mountain road (after the sporadic rains the road can be closed for several days due to landslides, intersecting erosion gullies etc.), and last but not least, the quality of the water itself, pumped from a number of open wells ± 60 km away, or because of the contamination in the tankers during the transport. In this way the residents suffered dramatic situations which contribute in no way to their well-being. The local system used to store the water is in 200-liter metal containers. With the intensive use and the humid coastal environment these barrels oxidize quickly, adding a new negative component to the water quality. On the other hand some families do not dispose of a barrel while others have two and others do not have the money to buy one. In short, this deficient storage system provokes obvious discrimination in the delivery of an average eighteen liters per person a day.

As a consequence of this situation the hygienic situation is deficient and causes illnesses like scabies and pediculosis. Although these illnesses are kept more or less under control at the local school this is often not the case in the family.

With the valuable assistance of civil engineer F. Elicer C., working at one of the astronomical observatories near La Serena, and of his brother Luis R. Elicer C., later engineering consultant at CONAF, a first serious feasibility study was made of a piped Camanchaca water supply for Chungungo. These two brothers, fascinated by the scope of the project, used every spare moment and weekend (next to their own work) to accurately survey the distance of about 6 km which separates El Tofo from Chungungo. On this basis the best option for the pipeline design was obtained (19).

To justify the use of Camanchaca water from a series of fogtraps and pipe it to Chungungo the first necessity was to examine the quality of the water. For this purpose water from the tanks in El Tofo was analyzed. The resulting chemical composition is shown in Tables 10 & 11 & 12.

In general the desalinated water needs a little adjustment by adding salts, stabilizing the pH between 6.5 and 8 to become good drinking water. The high iron content, which is probably caused by the combination of the aggressivity and the iron of the frames (or maybe dust of the iron deposits in the environment) could be avoided to a great extent by preventing, as much as possible, that intercepted waters have direct contact with iron of the fogtrap construction.

The slight contamination by micro-organisms might be due to deficient maintenance of the tanks and could easily be solved by chlorination.

During dry intervals between fog occurrences, airborne dust is blown against the netting and settles in the drainage gutters. This dust is evacuated at the beginning of the next Camanchaca period and precipitates during storage but could certainly be a source of contamination.

In order to determine the quantitative capacity of the plant, two main points had to be considered:

— The total surface area of fogtraps should guarantee a yearly production equal to the required consumption of Chungungo.
— Considering the seasonal variations of the coastal fogs, the plant should have a storage capacity to be filled up during periods of excess production, balancing the deficit during the critical periods.

To start with, the actual supply was analyzed:

—	Actual consumption in February 1985:	8,400 l/day
—	Average specific yield	3.1 l/m2/day
—	Required intercepting surface	8,400/3 = 2,800 m2

Specific yield was calculated as the average of interception of F90, being 2.6 l/m2/day, and interception of prototype F1, being 3.7 l/m2/day.

The water transport from the fogtraps to the storage tank would need 5,820 m of polyvinyl-chloride tube. At altitude intervals of 50 m, stress proof concrete tubes must be installed in vertical position to gradually depressurize the water on its way down through the pipeline to the coast.

In these first approximations a tube diameter of 1›" was calculated for the evacuation of a higher than average total collection.

For a maximum period of 15 consecutive deficient production days a storage capacity of roughly 8.4 m^3 X 15 = 126 m^3 will be needed, multiplied by a factor to be on the safe side. It happened that abandoned cisterns are still available near Chungungo, with a potential volume of 350 m^3 Therefore it is better to make these 350 m^3 operational.

The following considerations were observed in connection with the preliminary economic evaluation:

1. To justify the piped water supply the exploitation should be better and more economic than the present supply by means of tankers.

2. To compare the total costs of the different options, the initial investment and annual operational costs were considered on the basis of a supposed project life of 10 years, and the annual discount percentage valid in that period.
3. Of course, the preliminary calculations made were based only on one year of observations while at least three years should be needed.
4. The economic analysis did not consider the adequate treatment and distribution of the water, which should be evaluated and analyzed by the competent organism, in this case the Servicio Nacional de Obras Sanitarias (SENDOS).

UNESCO's financial support covered the preparation and publication of the scientific document on Camanchaca:"*Evaluation of the coastal fogs (Camanchaca) in the sector El Tofo*" prepared by the entire CONAF staff involved, on the basis of all the experiments and measurements made so far, including the first technical and economic estimation of a water supply system for Chungungo made by the Elicer brothers **(19)** (see also **chapter 9**).

In mid-1985 Nazareno Carvajal introduced a new fogtrap design which did not consist of a series of rigid metallic frames in the way F90 was composed (Photo 28) but had a more flexible construction of the netting, fixed between eucalyptus wooden poles, with a polyester collector for the evacuation of the intercepted waters, firmly attached to the basis of the netting, which in this way can slightly move with the wind like a galleon's sail with squared yards. This intelligent improvement reduced the shock between the droplets and the netting, with the result that the losses at the leeside of the netting were considerably less. With the introduction of this type of slightly aero-dynamic fogtrap the production increased with about 50% per m^2 with respect to the F90 performance (Photos 31 & 32).

One of the latter type of fogtrap of 40 m^2 surface area was introduced in El Tofo and another in El Brillador. Two were installed by CONAF in Los Nidos, which collapsed during a storm (as has been mentioned before) but could be restored afterwards. Copies appeared in Totoralillo near Tongoy south of La Serena were the NASA platform had been installed after El Tofo, providing water for the watchman and visitors to the platform, as Carvajal still worked with NASA.

Also a few km south of Copiapo close to the Travesía railway station, CONAF III Region had put up a Camanchaca station. The peculiarity of this station was that capturing here was over 2 $l/m^2/day$ at a maximum distance of about 50 km from the Pacific. Clouds reached the site through the transversal valley of the Rio Copiapó which formed a breach in the coastal range. Later the infrastructure was transferred to the National Reserve of Pan de Azúcar, 25 km north of Chañaral, where CONAF had already installed some fogtraps to provide water for field personnel and new plantations.

Lachay 1986

In January 1986, also in Lachay, a 2-dimensional 45 m^2 fogtrap was constructed with Monolon Weathashade netting (25 X 1.8 m). This netting imported from USA presented great advantages in resistance and efficiency over the ordinary mosquito netting used previously. Regular recordings with the macro-diamond had started here since its establishment in November 1983 and during the entire next Camanchaca season starting in June 1984, with daily readings made at 7 am and 7 pm. The water was used by the eleven park wardens to replace water that otherwise had to be transported by tank-trucks from over 40 km away. For the distribution of water from the fogtraps various devices had been set up. The macro-diamond was now installed over a 7 X 3.0 X 1.6 m concrete cistern of 33 m^3. The cistern is connected to a 280 m " plastic tube, buried 30 cm underground, with taps and two spouts installed in concrete basins, one 20 meters from the fogtrap along a visitors' path, and the other one near the Reserve's Interpretation Centre.

The 2-dimensional fogtrap, also located next to a cistern of similar dimensions as the first one is connected through a 270 m long " plastic tube to a water distribution system.

Again Chungungo water supply

Anyhow, the improvement made by Carvajal would make the Chungungo Camanchaca water supply more attractive.

On 16th August 1985 UNESCO/ROSTLAC was informed by CONAF that the project to construct a water supply system for Chungungo would finally obtain financing of US$ 50,000 from IDB funds for the International Drinking Water Supply and Sanitation Decade channelled through SENDOS to CONAF. The work would start in January 1986 and was expected to be completed in October 1986; it would be executed and supervised by CONAF in collaboration with the local inhabitants of Chungungo, according to the MRP principles. Hopefully, the first results of the construction might be demonstrated to the participants of the second MRP meeting to be held in La Serena in June 1986.

In early January 1986 a meeting took place in the SENDOS IV Region's office. In the presence of Guido Soto, Lionel Fuentes Espinosa, SENDOS Regional Director, presented their recent report on "*Rural Water Supply for the locality of Chungungo, Municipality of La Higuera, Province of Elqui - IV Region*" There would be a pipeline from almost 900 m to sea level, with valves for pressure relief, and 47 projected fogtraps of 40 m^2 each. The workplan illustrated by accurate maps and designs was forwarded to the SENDOS HQ in Santiago for approval. Everybody was certain that the work would go ahead with the scientific assistance of IDRC (see **chapter 11**) and the technical assistance of SENDOS.

On this occasion Lionel Fuentes was informed that apart from helping the population of Chungungo, this water supply system would be the first of its kind in the world and would become a showpiece for SENDOS, CONAF, IDRC and UNESCO. He had not yet been aware of it.

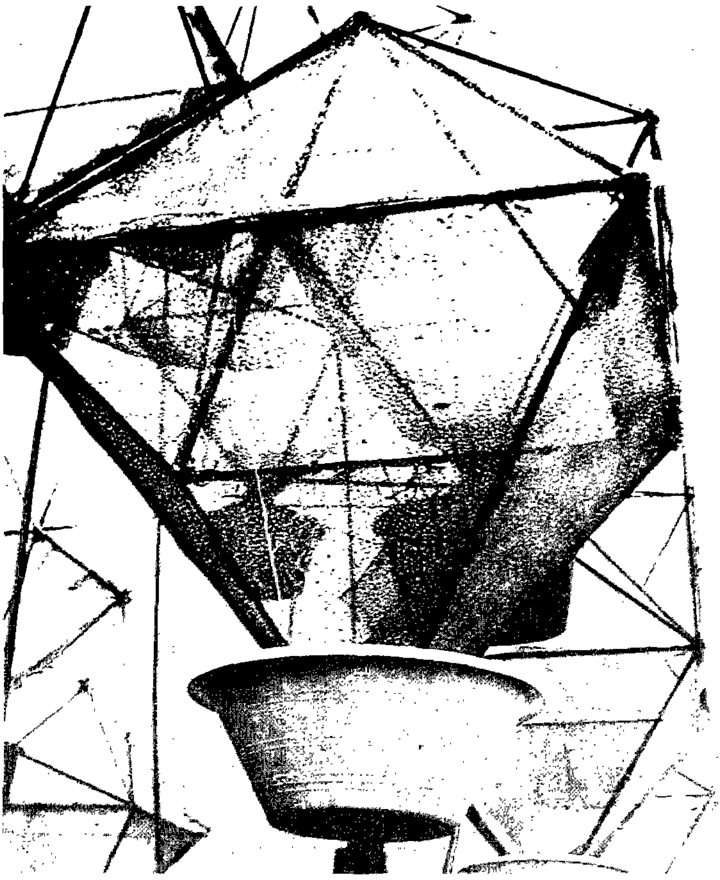


Fig. 13 - Although so far all investigators, except Carlos Espinosa, have expressed without any hesitation their preference for two-dimensional fogtraps at a perpendicular position to the ruling wind direction, it is worthwhile to return to the observations of Eduardo Rozas in El Brillador. He mentions that the macro-diamond fogtrap covered with 452 m^2 netting distributed over 23 octahedrons captures 2001/day varying from a windward octahedron capturing 18 l/day to a leeside one collecting a minimum of 1 l/day.

If this statement is true, this means that 18 l/day is collected by 45.2 : 23 = 1.9652 m^2 or 2 m^2 for a 3-dimensional fogtrap with projected surface area of maximum 0.78 x 0.78 = 0.608 m^2 would produce a specific yield of 29 l/m^2/day.

This excessive yield never obtained means that three-dimensional structures may have advantages certainly when they are located in their totality at the windward side in a surrounding which forces the wind to blow around the three-dimensional obstacle.

Table 10

	Mean value
Conductancy/cm/25.0°C)	95.0
Apparent colour (Pt-Co)	60.0
Larson pH saturation	9.4
Langelier index	- 5.5 (corrosive tendency)
Total residue (mg/l)	55.0
Dissolved residue (mg/l)	45.0
Fixed residue (mg/l)	30.0
Volatile residue (mg/l)	15.0
Suspended residue (mg/l)	10.0
Sedimentable residue (ml or mg/l)	

	Expressed as	Concentration Measurement (mg/l)
Acidity	$CaCO_3$	0.0
Total alkalinity	$CaCO_3$	7.0
Phenolphtalein alkalinity	$CaCO_3$	0.0
Aluminum	Al	0.320
Carbon dioxide	CO_2	6.0
Bicarbonates	$CaCO_3$	7.0
Carbonates	$CaCO_3$	0.0
Calcium	Ca	1.60
Total hardness EDTA	$CaCO_3$	9.0
Magnesic hardness	CaCO—3	5.0
Calcic hardness EDTA	$CaCO_3$	4.0
Total iron	Fe	-
Phosphates	PO_4	0.30
Total nitrogen	N	-
Albumin nitrogen	N	0.120
Potassium	K	0.68
Silicates	SIO_2	0.0
Sodium	Na	9.70
Chemical demand, D.Q.O.	0	-
Biochemical demand, D.Q.O.	0	-
Dissolved oxygen	0	-

Observations: Desalinated water with very intense corrosive tendency. Low pH. Turbidity and apparent colour induced by it, objectionable. Ammoniacal nitrogen and iron content exceeding the maximum acceptable by INS Standard NCh 409/1.Of.84. The remaining components determined in accordance with it.

Table 11

IDENTIFICATION OF THE SAMPLE
Region: Fourth
City/Locality: El Tofo
Province: Elqui
Source/Origin: Fog water from netting
Date and time of sample: 3-12-84
Reference: Corporación Nacional Forestal
Date of reception in laboratory: 12-12-15.15 hs
Preservers used: Nitric acid (5 ml/l)

1. PHYSICAL PARAMETERS	Maximum limit	Value measured
Turbidity (N T U) Each DR-EL/1	5	25.0
Colour (Pt-Co)	20	Apparent 60.0 Real 0.0
Odor	odorless	ictico ,weak
Taste	tasteless	tasteless

2. CHEMICAL PARAMETERS	Expressed as	Maximum limit (mg/l)	Concentration Measurement (mg/l)
Ammonium	N	0.25	0.410
Arsenic	As	0.05	0.02
Cadmium	Cd	0.01	0.0
Cyanide	CN^-	0.20	0.0
Cloride	Cl^-	250	14.60
Copper	Cu	1.0	0.0
Phenolic compounds	Phenol	0.002	0.0
Chromium hexavalente	Cr	0.05	0.0
Detergents	SAAM	0.50	0.0
Fluorine	F^-	1.5	0.0
Iron	Fe	0.3	0.490
Magnesium	Mg	125	1.20
Manganese	Mn	0.1	0.0
Mercury	Hg	0.001	0.0
Nitrates	N	10	0.80
Nitrites	N	1.0	0.001
Lead	Pb	0.05	0.0
Filterable solid residues		1000	45.0
Selenium	Se	0.01	0.0
Sulphates	$SO_4^=$	2250	4.0
Zinc	Zn	5	0.0
			Measured value
PH / 25.0°C		6.8.5	3.90

Table 12 - Bacteriological examination

Bacteriological tests and residual chlorine of drinking water

Region Month Year

N° Sample	Identification	Date Collection	Hours Container	Free chlorine Residual mg/l	Coliform Totals/100 ml NMP o FM	Turbidity NTU
	El Tofo Tank in forest	27/11	48	s/i	11.0	-
	Tank in resthouse	28/11	48	s/i	4.0	-
	Netting	28/11	24	s/i	14.0	-
	Outlet capturing 90 m^2 CONAF	..	24	s/i	6.8	-

Note: Contamination of aerogenic type. For drinking purposes it must be disinfected with chlorine.

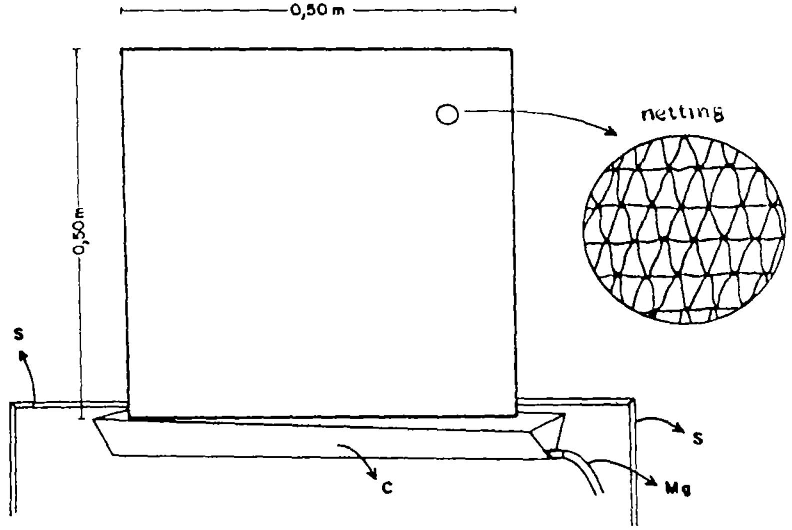


Fig. 14 - Schedule of fogtraps F1 F2 F3 and F4 with detail of Rashell netting

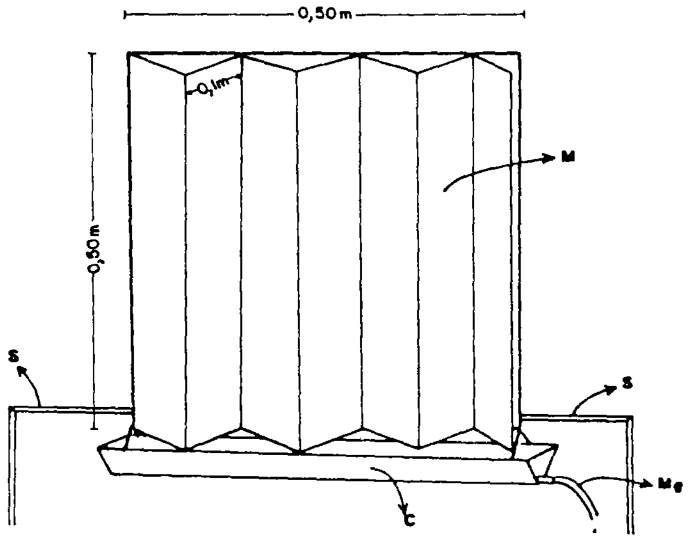


Fig. 15 - Schedule of fogtrap F5

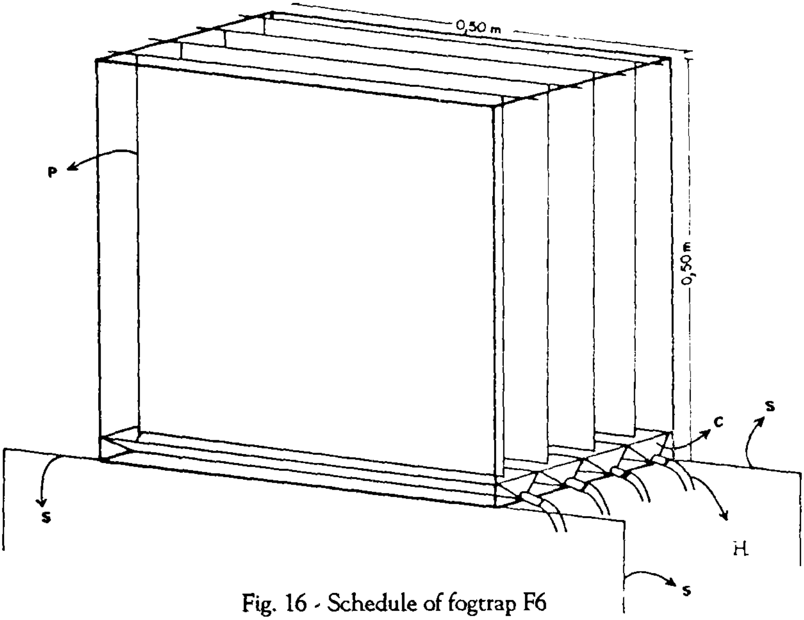


Fig. 16 - Schedule of fogtrap F6

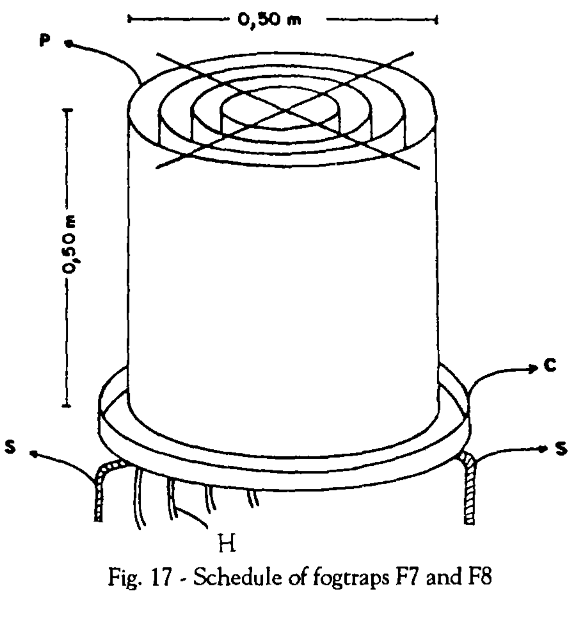


Fig. 17 - Schedule of fogtraps F7 and F8

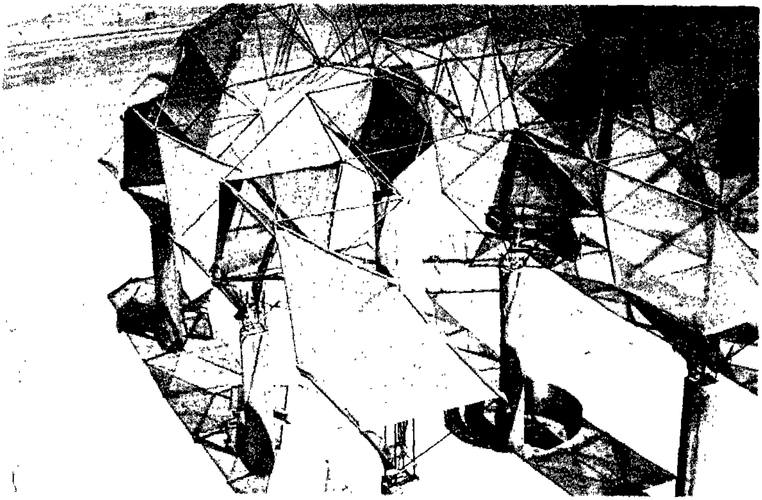


Photo 21 - The vertical wiring eye catcher at the Buenos Aires pass

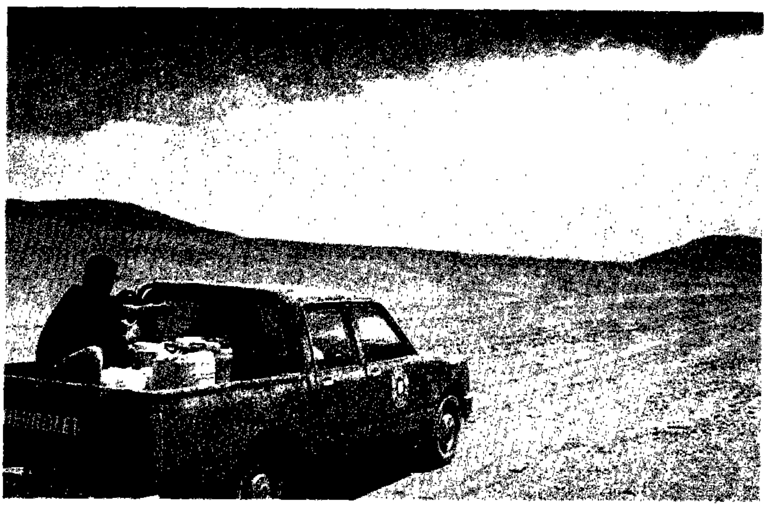


Photo 22 - Macro-diamond carried in Lachay through the high short-living Camanchaca vegetation

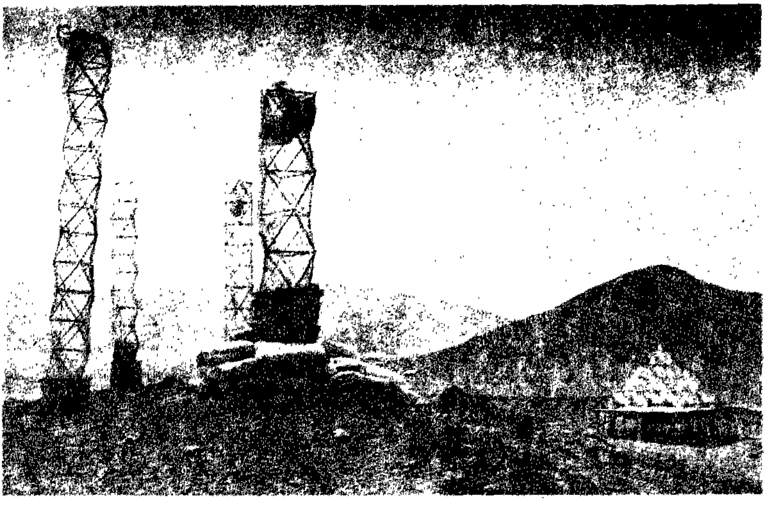


Photo 23 - Macro-diamond in Pasamayo

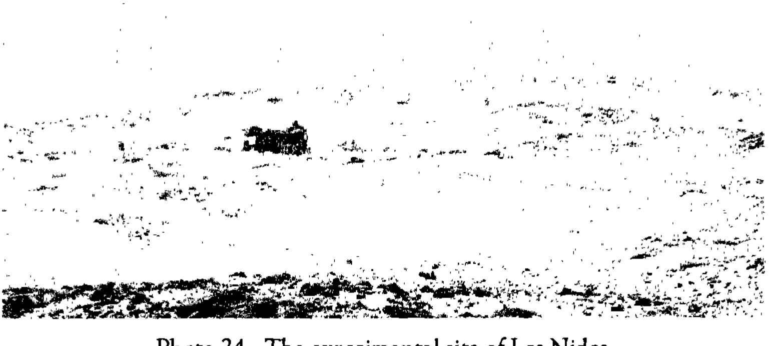


Photo 24 - The experimental site of Los Nidos

Photo 25 - Fogtraps in Los Nidos

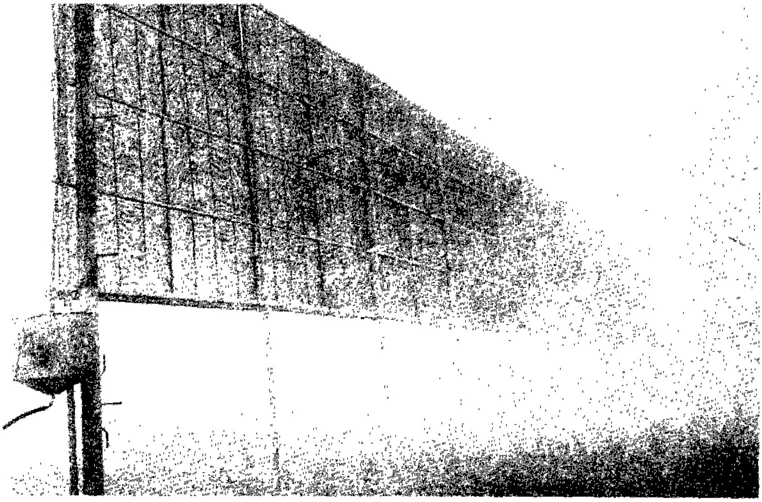


Photo 26 - Fogtraps and encampment in Los Nidos

Photo 27 - Planted area in Los Nidos

Photo 28 - The fogtrap with 90 m^2 surface area (F90) composed of a series of rigid panels

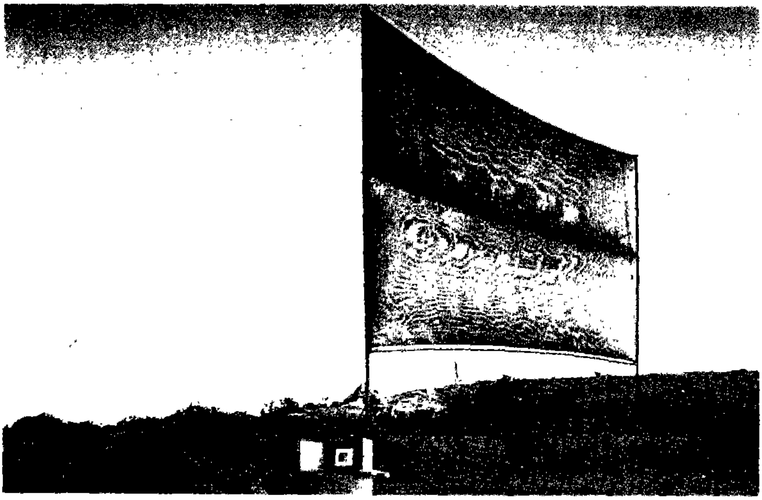


Photo 29 - Water metering device of F90

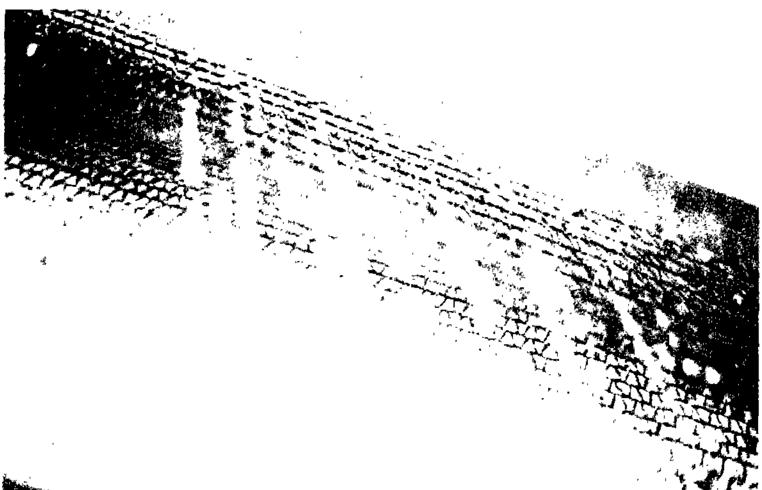


Photo 30 - El Brillador Camanchaca site, where interception of each octahedron is measured individually, see also Fig. 13, capturing at that moment the maximum maximorum of 18 l/day

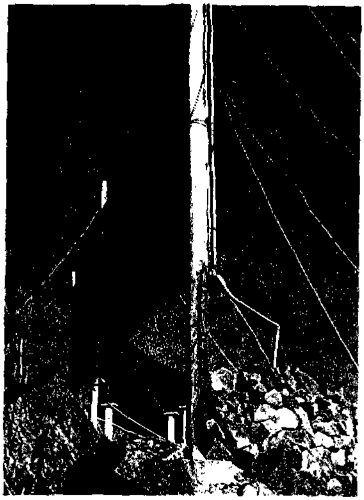


Photo 31 - The new aerodynamic fogtrap designed by Nazareno Carvajal, and example for future constructions in El Tofo

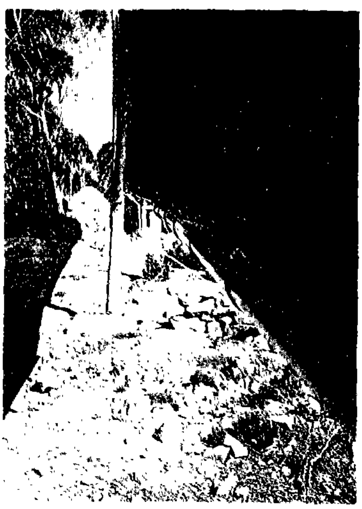


Photo 32 - The Rashell mesh losing less droplets at the leeside

EVALUATION OF CAMANCHACA IN EL TOFO, extract of (59)

9

Considering the advantage offered by the old mining-residential sector of El Tofo, an area of 18.400 m^2 was properly fenced for experimentation on interception of cloud-water.

The different fogtrap designs: 2-dimensional (F1, F2, F3, F4), cylindrical (F7, F8), parabolic U (Fll), angular V (F5, F12), and compound systems, consisting of several parallel screens (F6, F7) served to find the best aero-dynamic characteristics to optimize collection.

The differences in fogtraps F1, F2, F3 and F4 consist in the way the netting is arranged: F1 and F2 have a single sheet of netting covering the front-side and back-side of the frame (to compare the collection in El Tofo with that of Fray Jorge, 175 km farther south, F2 is an exception in the sense that it is installed in the National Fray Jorge Park), F3 has a double sheet of netting covering the front-side of the frame only, and F4 has a double sheet of netting covering the front- and back-side of the frame.

The cylindrical ones offer a geometry which presents total symmetry with respect to any wind direction.

Among the 2-dimensional ones, various systems with funnel-shaped side screens, with the following angles of incidence: 30° (F9'), 60° (F9"), 90° (F10), were tried out to maximize the air volume which traverses the netting. The black plastic netting (n) was of the Rashell type, characterized by a triangular section with 8 mm base and about 10 mm height. The frames of all fogtraps have supports (s) at the sides, affirmed by cables. The supports keep the base of the frame at an uniform 1.75 m above ground level. All fogtraps have a gutter-shaped water collection system (c), which conducts the water through a hose (h), to a 5 lt tank (or larger cistern).

The following models were tried out in 1984:

Fig.14, Fig.15, Fig.16, Fig.17, Fig.18, Fig.19, Fig. 20 and Fig. 21.

Comparative analysis of the yields

Without any doubt the 2-dimensional fogtrap (F1), oriented perpendicular to the wind, has the overall maximum efficiency.

Nettings placed at angles of less than 90° to the wind are less porous with respect to the wind direction and disperse the wind energy, provoking micro-turbulences which prevent the wind from traversing the netting.

This observation shows a negative aspect of the macro-diamond. Figure 22 shows the regression lines of the different geometrical models F2, F3, F4, and F5 compared with F1. The slight advantage of F5 compared to Fl is compensated by the major complexity and higher construction costs of the former.

Effect of compound 2-dimensional structures

Considering that the intercepting efficiency of the netting is not 100%, the effect of parallel nettings in compound structures (F6) was tried out. Although the interception increases slightly with a second netting screen, it is not worthwhile to use parallel panel structures. The slight increase obtained with 2 (F6"), 3 (F6') and 4 (F6) successive netting screens does not only drain off the fog droplets but also decreases strongly the wind force due to the aero-dynamic resistance of the system.

Figure 23 shows the regression lines obtained by comparing yields of F6, F6' and F6" with the yields of F1.

Cylindrical structures

The interception of a cylindrical fogtrap diminishes with the addition of more concentrical cylinders. This is related to the increasing wind-resistance of the concentrical cylinders, becoming in this way more compact.

Figure 24 shows regression lines obtained by comparing the yields of F8 with 1-, F7" with 2-, F7' with 3-, F7 with 4-successive cylindrical netting screens, with the yields of F1.

Effect of side screens

F10 with rectangular side screens to direct and accelerate the air-flow to the netting (0° angle of incidence) shows a lower rate of interception than F1.

F9' with funnel-shaped side screens (angle of incidence 30°) has an efficiency similar to F10.

F9" with funnel-shaped side screens, (angle of incidence of 60°) has slightly better yields than F1. However, the higher construction costs do not justify this modification.

Figure 25 shows the regression lines obtained by comparing the yields of F9" (60°), F9' (30°) and F10 (0°) with the yields F1.

Dimensional proportions

Among the aero-dynamical characteristics which modify the efficiency of 2-dimensional fogtraps, the proportions between the height and the length are determinative.

Comparing fogtraps with dimensions of length 1-, 2-, 5- and 10-times the height, relative yields decrease according to the diagram represented in Figure 26. It is quite clear that the square shape and still the rectangular shape with length 2 X height are the most efficient ones, while fogtraps with protracted shapes: length 5 X height, length 10 X height, have a lower efficiency, 30% less in the last case. This result is relevant for design of large-scale fogtraps.

Figure 26 shows the relative yields of fogtraps with different dimensional proportions.

Size versus yield

Comparing the specific yield of the 30 m X 3 m = 90 m^2 fogtrap (F90), with F1 with surface area 0.50 m X 0.50 m = 0.25 m^2, F90 produces systematically less than F1. This can be explained partly due to the greater water losses of F90 and partly due to the difference in aerodynamic behaviour. Large fogtraps produce more turbulence, deviating the humid air or diminishing the airflow towards the netting.

Figure 27 shows the regression lines obtained by comparing the specific yields of F90 with the specific yields of F1.

Effect of the application of Rashell netting

Also the way the netting is applied (single or double, covering one side of the frame or both sides of the frame) has an effect on the yield.

Figure 28 shows the regression lines obtained by comparing the yields of F3 (double sheets covering both sides of the frame), F4 (double sheets covering one side of the frame), F4" (one single sheet covering one side of the frame), with the yields of F1 (single sheets covering both sides of the frame). The double sheets (F3, F4) tend to lower the efficiency about 5%. Due to lack of intercepting capacity with one single sheet of Rashell, F4" has the lowest yields.

Rashell netting versus nylon wiring

Yields obtained by Rashell netting (F1) are generally superior to the yields obtained by vertical nylon wiring (Fw), except when collection levels are low.

Figure 29 shows the regression lines obtained by comparing yields of Fw with those of F1.

Macro-diamond

The yields of the macro-diamond (M) are generally deficient. Not only the yields are low but also its complicated geometry causes considerable loss of the intercepted waters. This means that an efficient collection of the captured waters has so far not yet been solved.

On the other hand its construction is complex and its application at a large scale does not seem to be feasible.

The continuous dripping under the structure while in operation requires an expensive impermeable substructure of concrete, zinc or some other chemically resistant material which allows also a good collection of the waters. Of course this system is sensitive to contamination and collected waters will require treatment afterwards.

Figure 30 shows the regression lines obtained by comparing the yields of F90, FM1 and FM2 with those of F1 (FM1 and FM2 represent yields before FM was damaged by a storm (FM1) and after it had been reconstructed with a slightly different design (FM2). FM1 X 4/3 and FM2 X 4/3 simulate yields of 30% more if losses could be recuperated.

Orientation of the fogtraps

With the objective of finding out the best orientation of the fogtraps, the wind direction was studied during the occurrence of Camanchaca (Table 13).

Conclusion: The predominant wind direction is west (W) 68.6% of time, and in the second place east (E) 12.6 % of time. That means that during the water production the wind is blowing in 81.2% of the time parallel to the E - W axis.

Table 13

Hs obs. / Direction			08	%	14	%	19	%	Total[1]	%
N			3	4.7	1	2.2	0	0.0	4	2.3
N	N	E	0	0.0	0	0.0	0	0.0	0	0.0
N	E		3	4.7	0	0.0	0	0.0	3	1.7
E	N	E	1	1.6	0	0.0	2	3.0	3	1.7
E			18	28.1	0	0.0	4	6.1	22	12.6
E	S	E	1	1.6	0	0.0	1	1.5	2	1.1
S	E		3	4.7	0	0.0	1	1.5	4	2.3
S	S	S	0	0.0	0	0.0	0	0.0	0	0.0
S			0	0.0	0	0.0	0	0.0	0	0.0
S	S	W	0	0.0	0	0.0	0	0.0	0	0.0
S	W		5	7.8	1	2.2	1	1.5	7	4.0
W	S	W	0	0.0	5	11.1	2	3.0	7	4.0
W			30	46.9	37	82.2	53	80.3	120	68.6
W	N	W	0	0.0	1	2.2	0	0.0	1	0.6
N	W		0	0.0	0	0.0	0	0.0	0	0.0
N	N	W	0	0.0	0	0.0	2	3.0	2	1.1
Total			64	100	45	100	66	100	175	100

(1) 130 fogs observed out of a total of 246 fogs (52,9%) between May 1984 and January 1985

Analysis of water production during 1984-1985

As a consequence of 224 days of interception, or 62% of the year, the yield of F90 was 85.4 m^3 in 1984, or 947.8 l/m^2, or as an average 2.6 $l/m^2/day$, varying between a minimum of 38.2 $l/m^2/month$, to a maximum of 128.2 $l/m^2/month$. The average production of F1 was 3.8 $l/m^2/day$.See Table 14.

Figure 31 shows graphically the daily yields of interception of F90 between 1st January 1984 and 31st January 1985.

Figure 32 shows graphically the daily yields of interception of F1 during the same period as Figure 31.

Figure 33 shows the monthly yields of F90. The figure in each bar indicates the number of capturing days in each month.

In order to estimate the capacity of a production plant it is useful to analyze the daily yields in terms of probability.

Figure 34 shows the probability of obtaining a volume of water on a day of interception, or in the second case, on any day of the year.

Analysis of dry periods

The analysis of dry periods (the number of consecutive days without capturing) is important to determine the storage capacity of the plant, in order to supply water during the dry days.

The longest period without interception was 9 days. Periods of 1 to 3 days without capturing were more frequent. If the dry period is defined as the number of consecutive days that production is less than the demand (supposing 3 $l/m^2/day$ is the demand for 2.800 m^2 of interception), the maximum duration of a dry period were 15 days.

Figure 35 shows the probability of obtaining a dry period of a definite duration.

Comparison of yields in El Tofo with yields in Fray Jorge (175 km farther south)

Capturing in El Tofo is 12.8% more than in Fray Jorge, calculated over the total from February to December of 1984. This does not mean that production was always more in El Tofo (Figure 36). In reality, the individual analysis of the fogs shows that there is no correlation at all between the days of Camanchaca occurrences. This proves that we are dealing with a rather local phenomenon.

Table 14 - Yield of Fogtrap F90 ($l/m^2/day$) El Tofo

Month	1984											1985	
Day	E	F	M	A	M	J	J	A	S	O	N	D	E	TOTAL
1	0	1.9	2.7	0	0.6	2.8	-	2.6	3.6	2.6	0	3.4	0.9	
2	0	3.9	8.8	0.1	0	0.6	0[1]	1.8	20.6	0	0	0.9	5.6	
3	0	4.6	1.3	0	0	0	0[1]	0.2	4.5	1.3	0.2	4.3	3.4	
4	2.0	0	3.5	0	0	0	0[1]	2.7	0	0.9	0	9.1	3.5	
5	0	0	19.2	9.4	0	0	0[1]	2.0	0.5	1.8	1.2	4.3	0.3	
6	0	0.1	11.9	5.0	0.1	0.3	0	3.6	0	3.8	2.7	13.8	0.2	
7	1.3	0	0	0.6	4.6	0	0	9.3	7.5	0.6	0	2.0	0	
8	0	0	1.0	3.8	4.2	0	0[1]	0	10.7	0.2	0	0	0	
9	0.5	6.9	0	8.9	0	0	0[1]	0	10.7	0.2	0	0	0	
10	1.3	0	2.0	18.3	0	0	0[1]	0	0.2	5.2	3.4	3.9	0.2	
11	1.7	0	6.1	2.7	0	2.3	1.3	0	12.5	10.0	0	4.0	12.2	
12	0	0.2	0[1]	5.8	3.6	0	0	0	6.8	3.4	0	0.2	7.8	
13	0	7.0	3.7	3.5	0	0	4.5	0.4	1.8	0	1.7	0	0	
14	0	10.3	7.7	3.5	0	0	4.5	0.4	1.8	0	1.7	0	0	
15	0.1	4.5	0	0.1	1.8	0	0	2.7	0	0	0.2	0	7.6	
16	0.5	0.9	4.4	0.8	0	0	0	8.2	0	0.2	5.4	0.6	1.7	
17	0	0	5.1	0.9	0	6.6	0	6.0[1]	1.5	2.7	1.5	14.4	5.6	
18	2.5	0	12.5	9.8	0	0	0	13.6	0.2	25.7	0	19.8	0.2	
19	10.0	0	0	0	5.8	0	0	5.2	14.3	20.1	9.7	1.5	3.4	
20	18.8	1.7	4.6	0	7.3	6.7	9.1	10.3	0	0	5.9	1.7	02.	
21	0	0	0.8	0	0	0.1	3.8	4.7	0	0	3.6	0.7	2.0	
22	0	1.7	0	0	0	0.9	1.1	1.7	0.7	0.2	2.1	0.8	0.2	
23	1.6	4.6	0	0	0.2	4.9	7.0	0.5	1.3	1.8	0.2	0	0	
24	0.7	6.9	0	0	0	3.6	4.1	0	0.9	9.8	0.9	0.2	0	
25	11.5	0	0.1	2.6	0	1.9	0.8	0	0.2	0.2	0.2	2.2	0.2	
26	12.6	0	0	5.8	0	0	0	1.5	0.2	2.2	1.1	11.3	4.5	
27	5.7	1.0	0	0	0.1	0	0	2.7	0	3.6	0.8	0.7	0.2	
28	4.9	0	0	0	0	0	2.8	0	5.2	2.7	5.1	0.2	2.5	
29	0	0	0.1	0	0	5.5	12.1	0	27.6	0	1.0	0.2	0.2	
30	0		0	0.2	2.5		5.8	11.0	0.2	3.0	9.0	3.4	0.2	
31	0		0		0		3.5	3.4		3.6		7.7	0	
Ex	75.9	56.2	95.5	31.2	32.8	38.5	63.8	97.3	128.2	110.6	57.0	112.8	62.8	1010.6
n	16	15	18	1911	13	13	23	23	25	22	26	23	247	

Assessing the meteorological factors which determine fog interception

The total amount of captured waters (Wc) by the fogtraps:

$$Wc = \xi . V . CL$$

x - efficiency of capturing (fraction of the total liquid content of the fog which is intercepted by the fogtrap).

V - volume of air mass which passes the fogtrap.

LWC - Liquid water content of the fog or cloud (g/m^3).

$$V = S . U . T$$

S - surface area of netting

U - wind velocity

T - duration of Camanchaca occurrence

The meteorological variables have an influence on ξ U, T, and LWC On the other hand ξ must be influenced by wind-velocity (U), design of the fogtrap, and size of the droplets.

In order to obtain a general idea of the relative importance of each of these factors, all the Camanchaca occurrences produced with western wind (perpendicular to the orientation of the fogtraps) were selected. For these periods a multiple regression was computed of those variables that may determine the total water capturing.

The following results were obtained:

1. The most important variable is the duration of the Camanchaca occurrence (T), the second is the temperature during the process of interception (t). Wind velocity (U), visibility (v) (indicator of the density of the cloud) and relative humidity (Hr) are not significant.
2. The lack of correlation with the relative humidity (Hr) is due to its limited variation, between only 95% and 100%, during Camanchaca. Probably the instrument readings within this narrow difference in values are erroneous, as the air is practically saturated during Camanchaca.
3. Temperature (t) is important, for at higher temperatures saturated air contains more H^2O.
4. The bad correlation with wind velocity (U) is surprising. The velocity was measured and summoned during the entire period of Camanchaca occurrences,

and measurement errors cannot be significant. This fact allows to believe that the cloud characteristics, like the liquid water content and the size of the droplets, are more important than the wind velocity.

5. Visibility (v) is a factor which was visually and instantaneously measured. The degree of error may be important, which could explain the total lack of correlation.

Change with altitude of the meteorological variables during Camanchaca

In order to better understand the dynamics of Camanchaca, a well equipped vehicle, starting from sea level, measured at altitude intervals of 100 m temperature, relative humidity and wind during Camanchaca.

The temperature was measured with a sensitive thermo-couple, the relative humidity with an Assman-type psychrometer and the wind with an anemometer velocity meter. The thermal profiles generally indicate a decrease of temperature with altitude of 0.5° to 0.6° C per 100 m. This decrease generally reverts, reaching the condensation ceiling (base of the cloud bank) and continues this tendency through the entire thickness of the overcast. This is related to active condensation, which liberates the latent heat contained in the atmospheric vapor (Fig. 37).

The relative humidity increases gradually with altitude. At sea level it is normally 80%, and goes up to 95% or 100% at the ceiling of condensation. Frequently a sudden decrease of relative humidity exists above the top of the cloud cover. This demonstrates a poor mixture with air immediately above the cloud deck (Fig.37).

The wind is normally rather capricious. After noon, the most typical profile demonstrates a western wind which increases with altitude. This profile coincides probably with the period of maximum convection in the interior behind the coastal range. In the early morning, frequently an eastern wind can be observed, associated with a decrease in velocity at higher altitudes. Probably at that time, marine and continental air masses interchange with maximum intensity in the coastal zone. This is associated with the different thermal behaviour of the two media: the ocean, with rather constant temperature, and the arid interior, with extreme temperature variations between day and night (Fig. 38).

Efficiency of fog interception (ξ)

In the absence of direct measurements of absolute liquid content of the fog: ξ = (water intercepted/volume of filtered air) g/m^3

About thirty Camanchaca occurrences were selected with entirely western wind to determine the efficiency of interception (ξ).

ξ varied between 0.02 g/m^3, and 0.20 g/m^3, with an average of 0.09 g/m^3. According to Fuenzalida (1984) the liquid content of the coastal fog is approximately 0.2 to 0.3 g/m^3 of air. The efficiency to retain water from the fog by the fogtraps should be about 30% (0.09/0.3). This is higher than the figure of 10 % estimated by the same investigator.

Analysis of instantaneous interception

A Hellman-type pluviograph was adapted to collect and register water volumes captured by a fogtrap (50.6 cm high and 24 cm wide) installed at 4 m above ground level, with the objective of studying instantaneous water capturing and to describe its variation in time. Because of the time-consuming trial and error procedure to modify the pluviograph, reliable readings of the very small volumes captured per unit of time could be obtained only from May 1984 onwards. This device became the *neblinógrafo* or fog-graph. The hourly recordings made month by month appear in 9 tables: Table 16 to Table 25 (pages 89 to 93) covering the period from May 1984 to January 1985. The values are expressed in:

10 times nº of liters/m^2 of intercepting surface area/hour

to maintain a precision of one hundredth of a liter; i. e. 5.8 means 0.58 l/m^2/hr.

In general terms interception of cloud water took place during all hours of the day. Only between 15 hrs and 17 hrs during January 1985 there was no interception. The most frequent capturing occurred from 4 hrs to 10 hrs in the morning and from 17 hrs to 22 hrs in the evening. The major intensity of interception took place between 11 hrs and 15 hrs and between 16 hrs and 20 hrs. Camanchaca normally stayed away between 0 hrs and 4hrs of the night.

The average period of capturing was 6.9 hours, with a maximum of 54 consecutive hours in the period from 17 to 19 December 1984.

Figure 39 shows recordings of the fog-graph from 28th November to 1st December 1984.

The recording system of the fog-graph expresses the water volumes received, in mm of water, by means of a writing-pin on the system's subdivided paper roll. On the abscissa the time is marked in units of days and hours, and on the ordinate, mm and tenth of mm of incoming water are registered. The total length of the ordinate corresponds to 10 mm of incoming water, equivalent to 1.65 l/m^2. The horizontal lines correspond to dry periods, while the vertical jumps correspond to water capturing. The more vertical the recordings the more intensive the Camanchaca.

In figure 39, Friday 30th November, from 17hrs to 21 hrs, represents the maximum intensity.

Temperature

The hottest months are January and February (mean monthly temperatures: maximum 18.3°C, mean 14.9°C, minimum 11.0°C) and the coldest one was June (mean monthly temperatures: maximum 14.5°C, mean 9.7°C, minimum 5.9°C).Temperature maximum maximorum was 25.2°C on 24th April, and minimum minimorum 2.6°C on 5th June. Mean annual temperature was 12.3°C.

Soil temperatures at 5 cm depth followed air temperature: maximum 29,3°C during January 1984, and minimum 13.8°C during July (Fig.40b).

Relative humidity

The monthly mean maximum values were lowest in autumn: 93.3% in June, and increased in winter and spring, reaching highest value in summer: 99.8% in January. The monthly mean minimum values varied from a minimum 48.5% in September to a maximum 74% in January. The mean annual values varied from 91% in January 1985 to 78.2% in May. The maximum maximorum was 100% in all months, while the minimum minimorum was 8% on 25th August and 6th June.(Fig. 40a)

Wind

Wind velocity is less in the months of autumn and winter, it increases in spring and reaches maximum values in summer. The periods with less wind are also the periods with less Camanchaca.

The mean monthly velocity at 4.8 m above ground level varied from a maximum of 13.0 km/hr in January to a minimum of 6.6 km/hr in May 1984. At an altitude of 2 m above ground level these values were respectively 11.8 km/hr and 5.6 km/hr.

Wind was measured at 8hr, 14hr and 19hr (see Tables 24, 25 and 26) (Fig 41b).

Solar radiation

Solar radiation is less in autumn and winter and maximum in summer. The mean annual value is 365.2 cal/cm^2/day, varying from 561.4 cal/cm2/day in February to 173.1 cal/cm2/ day in June. (Fig.42b).

Sun hours

Figure 42a gives the real daily sun hours (n), and the potential values (N) for the latitude of El Tofo. The great difference is caused by the Camanchaca. The fraction n/N indicates the relation between real sun hours and potential sun hours for this latitude and obtained a maximum of 0.6 in May and a minimum of 0.3 in March and December 1984.

Visibility

The visibility of the fog is low and does not exceed 100 m. During the observation hours at 8, 14 and 19 hrs normally the visibility during Camanchaca was between 75 and 100 m.

Rainfall

Rainfall in El Tofo in 1984 was: 76.5 mm, almost concentrated in its totality (75.1 mm) in 6 days during the first fortnight of July, 0.4 mm on 12th March, and 1.0 mm on 17th August (Table 15).

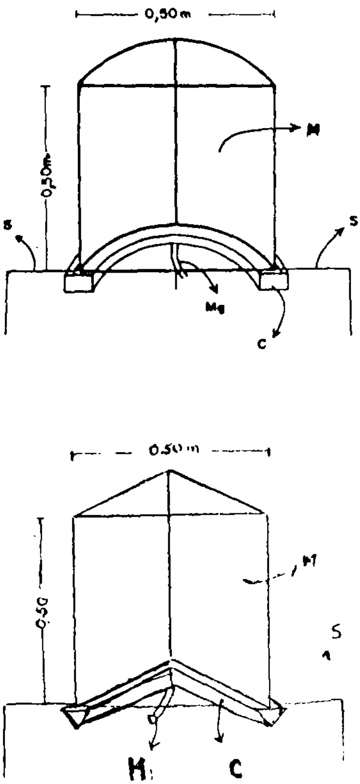


Fig. 18 - Schedule of fogtraps F11 and F12

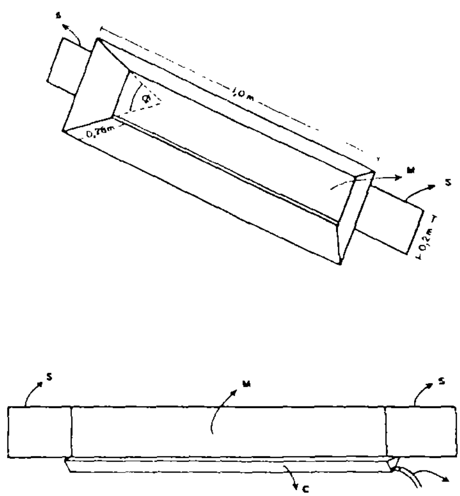


Fig. 19 - Schedule of parabolic fogtrap F11 and angular fogtrap F12 (59)

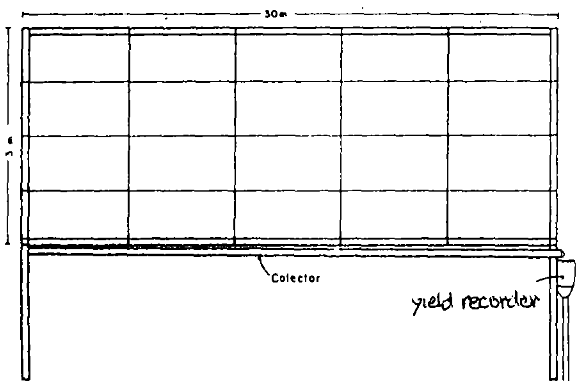


Fig. 20 - Schedule of fogtrap F90

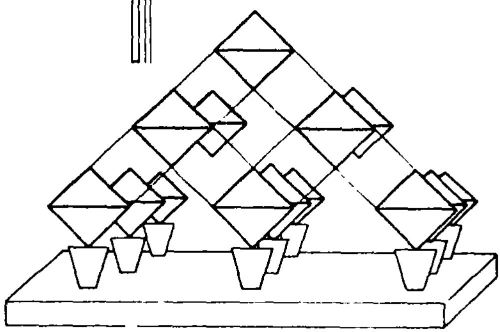


Fig. 21 - Schedule of macro-diamond fogtrap (59)

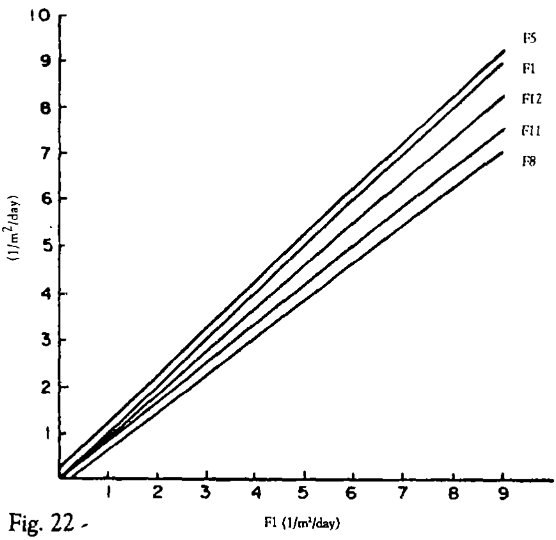


Fig. 22 -

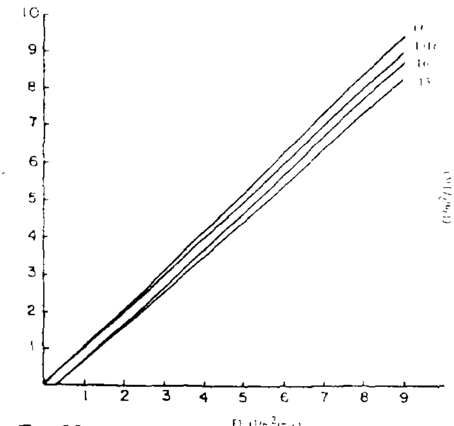


Fig. 23

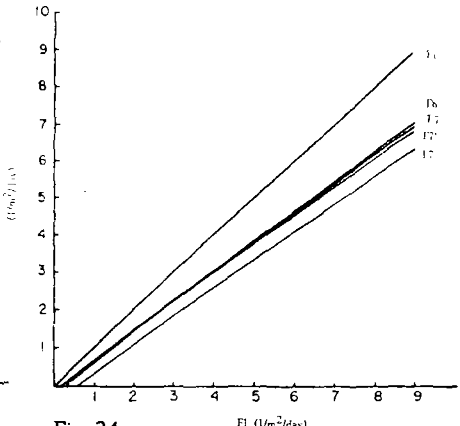


Fig. 24

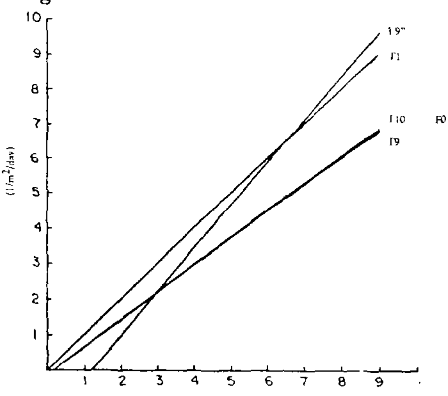


Fig. 25

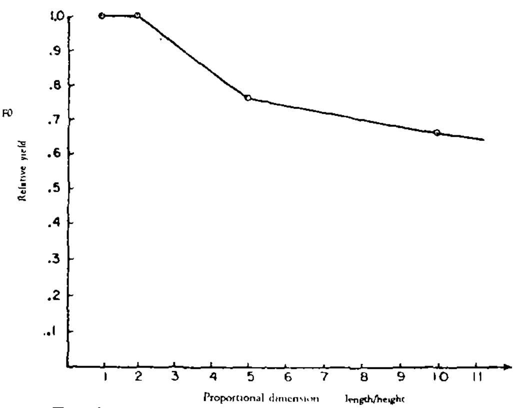


Fig. 26

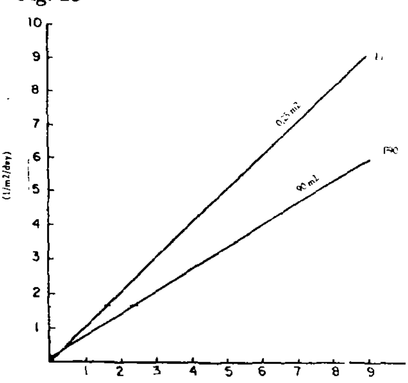


Fig. 27

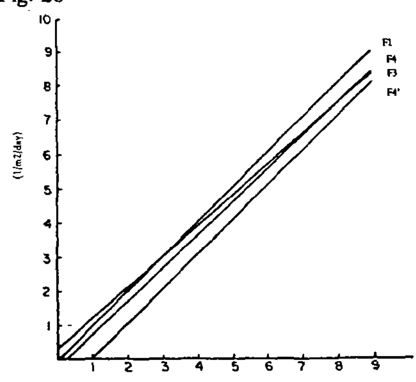


Fig. 28

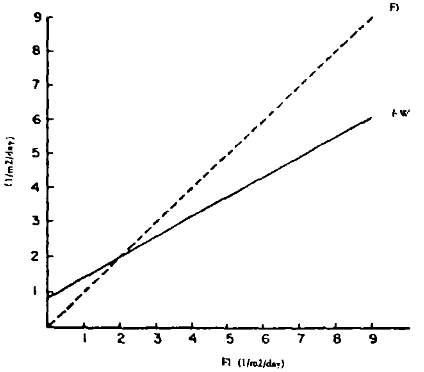


Fig. 29

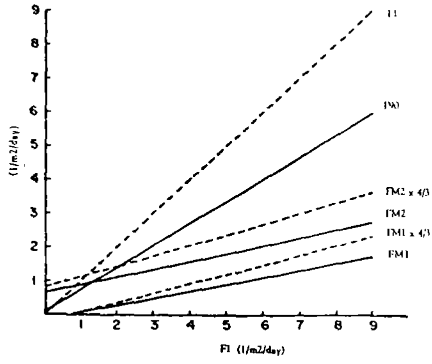


Fig. 30

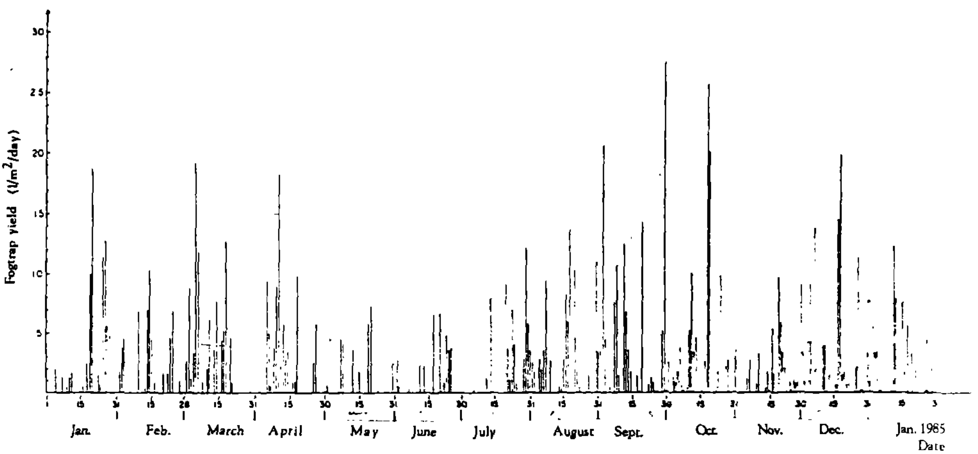


Fig. 31 - Daily yields of interception of fogtrap 90 m²(F90) from January 1984 to January 1985 (59)

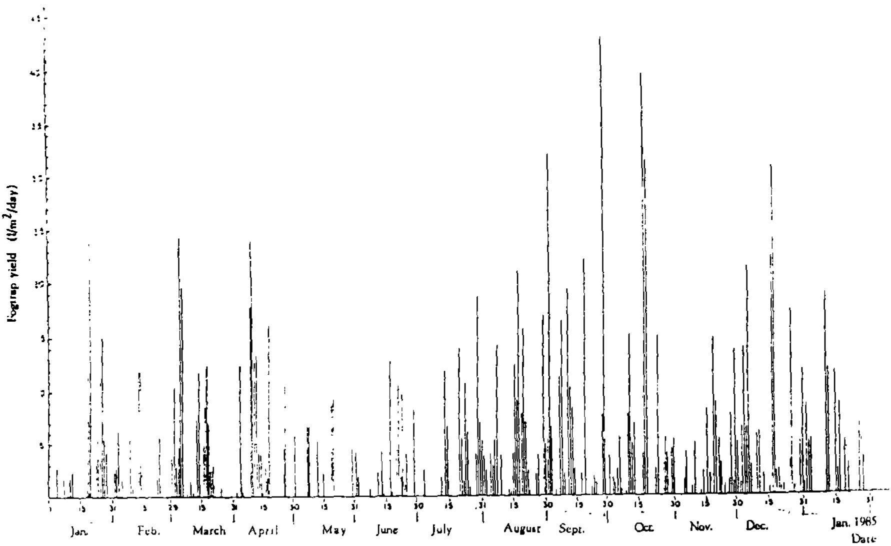


Fig. 32 - Daily yields interception of F1 from January 1984 to January 1985 (59)

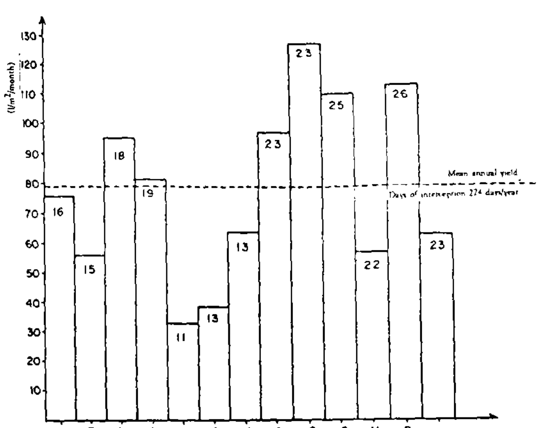


Fig. 33 - Monthly yields of F90. The figure in each bar indicates the number of days of capturing in each month (59)

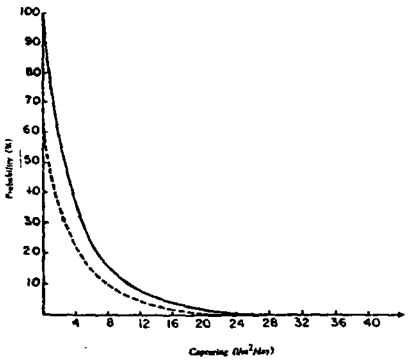


Fig. 34 - Probability of obtaining a volume of water on a day with interception (- - - - - - - -) on any day of the year (————) (59)

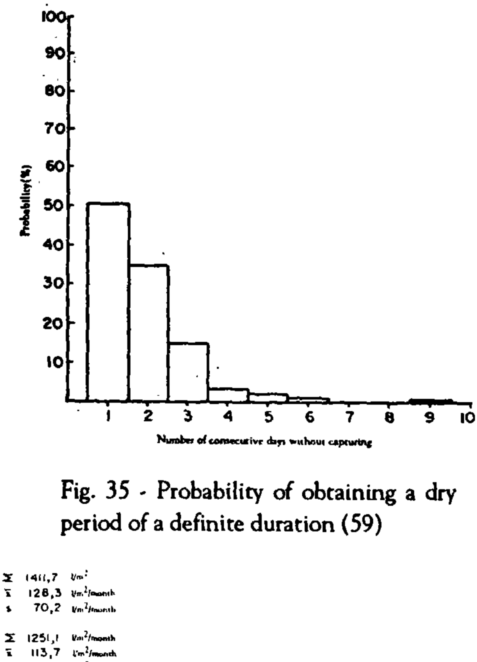


Fig. 35 - Probability of obtaining a dry period of a definite duration (59)

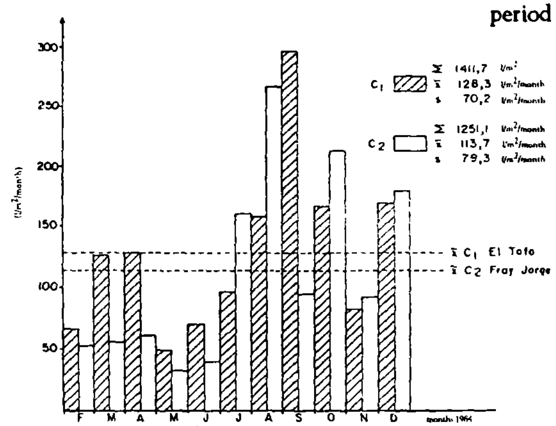


Fig. 36 - Comparative yield of sea fog in El Tofo F1 and Fray Jorge F2 (59)

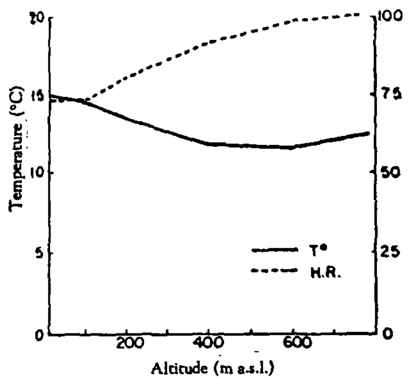


Fig. 37 - (59)

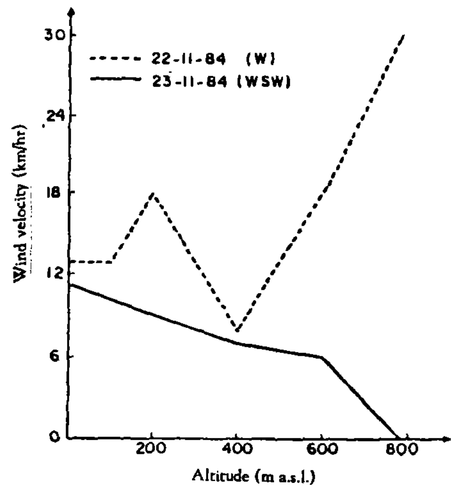


Fig. 38 (59)

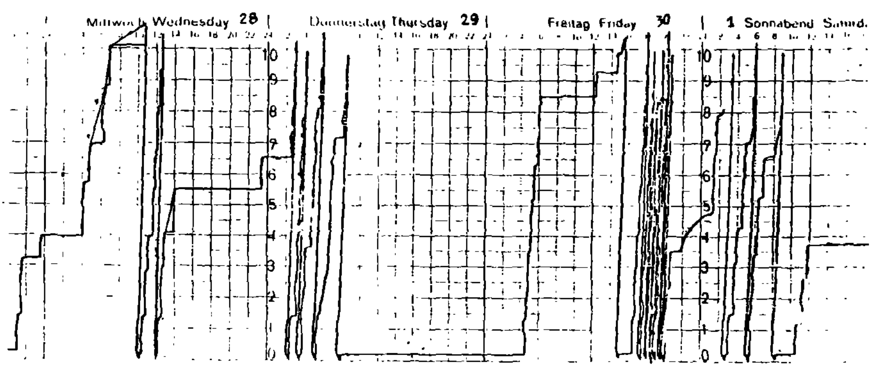


Fig. 39 - Fog-gram of 29th and 30th November, and 1st December (59)

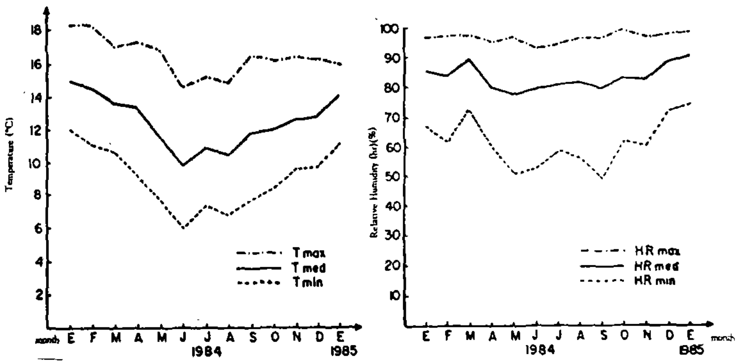


Fig. 40 - Yearly cycle of variation of temperature and relative humidity (hr) in El Tofo (59)

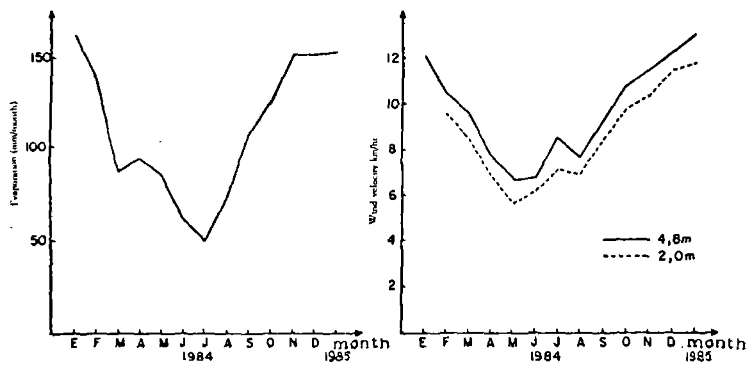


Fig. 41 - Yearly cycle of variation of evaporation and wind velocity (59)

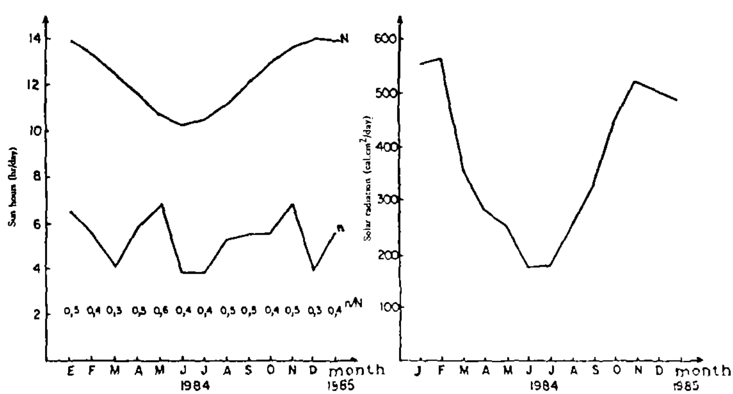


Fig. 42 - Yearly cycle of variation of sun hours and solar radiation(59)

Table 15 - Precipitation (mm) El Tofo IV Region

Month Day	E	F	M	A	M	J	J	A	S	O	N	D	E
1	0	0	0	0	0	0	-	0	0	0	0	0	0
2	0	0	0	0	0	0	4.8	0	0	0	0	0	0
3	0	0	0	0	0	0	-	0	0	0	0	0	0
4	0	0	0	0	0	0	18.3	0	0	0	0	0	0
5	0	0	0	0	0	0	1.2	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	23.1	0	0	0	0	0	0
9	0	0	0	0	0	0	1.2	0	0	0	0	0	0
10	0	0	0	0	0	0	26.5	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0.4	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	1.0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0		0	0	0	0	0	0	0	0	0	0	0
31	0		0		0		0	0		0		0	0
Ex	0	0	0.4	0	0	0	75.1	1.0	0	0	0	0	0
n	0	0	1	0	0	0	6	1	0	0	0	0	0

Table 16 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - May 1984 (59)

Día \ Hr	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	5,8	2,6	0	0	0	0	0	0	0	0	0	0	0	0	0	1,8	9,2	9,6	4,1
2	2,6	1,0	11,0	15,0	1,5	1,6	1,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,0	2,5	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	4,6	1,3	1,3	1,2	1,0	7,4	28,5	5,3	2,1	11,6	13,5	10,5	15,3	9,9	1,8	7,1	4,9	2,1	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	2,3	2,0	18,0	18,3	8,4	2,5	6,1	2,3	2,6	2,0	0,7
13	0,7	0,5	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	5,6	6,4	7,9	2,6	3,6	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,3	0	0	0	0	0	0	0
20	0	0	0	5,1	33,8	24,4	11,2	9,1	4,6	3,8	0	0	0	5,7	14,0	13,3	10,7	3,1	2,1	3,1	15,6	17,1	4,6	3,1
21	0,9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,6	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	1,2	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,5
31	7,9	2,8	2,5	3,5	10,4	8,2	6,9	1,2	1,5	0,7	0	0	0	0	0	0	0	0	0,8	2,0	0,8	0	0	0
Σx	12,1	8,9	15,1	30,5	53,3	48,9	31,9	42,4	11,9	6,6	11,6	13,5	11,7	25,3	25,9	33,1	37,4	18,4	10,0	12,8	20,5	28,9	16,2	14,5
n	4	4	4	5	5	6	6	4	4	3	1	1	2	3	3	3	4	4	5	4	4	3	3	4

Ex = total hourly collection

n = number of days with collection

Table 17 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - June 1984 (59)

Día \ Hr	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,4	17,8	5,1	2,8	5,3	1,0	0	0
2	1,6	1,0	0,8	0,5	0,7	0,7	0,7	0,5	0,7	0,7	0	1,8	0	0	0	0	0	2,6	0	0	0	0	1,2	1,3
3	1,0	2,6	2,8	2,3	1,6	1,3	0,8	0,7	0,5	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	1,5	3,1	6,4	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	24,0	8,1	6,1	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	4,2 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,3	5,1	13,0	2,3	1,8
14	1,0	1,2	1,2	0	0	7,7	2,1	2,8	1,2	1,0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,8	32,3	16,5	9,9	7,1	10,2	1,8	2,8	2,0
18	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	1,6	1,2	0,8	0,7	0,3	0,3	0,3	0,3	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	1,8	15,8	9,1	6,9	1,3	1,3	0	0	0	0	0
21	4,6	2,1	16,0	12,7	3,3	4,9	5,1	6,3	6,4	4,9	3,6	1,6	4,0	1,3	6,1	5,1	14,7	19,4	17,0	15,5	8,9	5,3	3,3	-
22	-	-	-	-	-	-	-	-	-	0	0	0	0	0	3,6	14,3	7,7	2,3	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	16,5	5,3	0	1,3	0	4,0	4,9	5,1	3,3	2,5	2,3	1,2	4,9	4,9	0
24	1,3	5,3	4,6	2,5	0	4,4	7,7	6,6	3,6	2,1	3,1	4,9	3,0	2,1	0	0	0	0	0	0	2,8	0	0	0
25	0	0	0	0	0	2,6	2,5	2,8	4,1*	8,6*	5,1*	16,0	8,1	2,1	5,4	15,8	6,4	4,9	2,3	1,6	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	13,5	15,8	23,6	0	7,4	9,6	-	-	-	-	-
30	15,8	15,2	7,9	7,9	7,7	0	0	0	-	-	-	14,8	16,3	9,7	9,6	6,6	5,4	7,9	4,1	9,2	6,3	7,9	0,3	0,5
Σx	27,6	29,0	34,5	26,7	14,0	21,9	19,2	19,2	14,2	23,7	18,4	39,1	32,7	30,5	61,1	123,2	99,0	89,5	51,8	43,8	39,8	33,9	14,8	5,6
n	7	7	7	6	5	7	7	7	7	6	4	5	5	6	8	9	9	11	8	7	7	6	6	4

(*) = corresponds to rainfall

Table 18 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - July 1984 (59)

Día \ Hr	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1,2	1,2	1,0	1,2	1,3	0,8	2,3	13,8	0,8	1,2	0	0	0	0	0	0	3,8	6,4	0	0	0	0	0	0
2	0	20,8	0	0	0,5	31,3	15,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-	0,3	0,3	0,3	0,2	0	0	10,7	1,3	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,2*	2,6*	4,0*	0,2*'	0	2,0*	0,8*	2,8*
5	0,3*	1,5*	1,5*	0	0,2*	0	0	0	0	2,1*	0	0	0	0	2,5*	12,4*	6,3*	9,9*	1,3*	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	3,8*	2,8*	0	0	0	2,5*	2,1*	5,6*	0,8*	5,8*	4,1*	6,1*
9	12,0*	4,4*	0,3*	0	15,5*	16,6*	0	15,8*	0	0	0	0	0	0	0	1,8*	9,1*	5,1*	7,2*	6,6*	0	0	0	0
10	2,5*	14,2*	1,2*	0	0	0	0	0	0	0	0	0	0	0	13,8*	3,5*	12,7*	0,2*	4,1*	11,5*	0,5*	31,8*	13,8*	15,9*
11	18,3*	31,9*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,5	3,6	3,8	3,0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3	1,8	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	5,4	10,7	5,6	4,9	5,1	0,5	0,5	16,3	3,0	8,6	4,4	0
14	16,1	0	0	0	0	0	0	14,8	0,5	0	1,3	25,0	5,4	0	0	0	0	0	1,8	3,3	5,6	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	4,9	1,3	3,0	6,1	15,8	10,0	16,1	10,9	2,8	15,6	7,1	3,5	1,5	7,7	7,9	2,1	0,8	1,5
21	2,1	2,0	0,2	0,2	0,2	0,2	0,3	0,2	0,8	1,3	1,3	1,6	1,5	0	0	0	0	4,6	5,1	3,6	8,2	0,8	3,6	0
22	0	0	0	0	0	0	0	0,5	2,6	12,8	0,3	1,6	0	0	0	0	0	1,6	0,2	0	0	0	0	0,3
23	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,0	2,3	1,2
24	1,8	1,8	1,5	1,2	0,8	0,5	0,3	2,5	14,7	1,8	0,7	0,5	0,3	0	0	0	0	3,1	7,1	2,0	0	0	0	0
25	0	0	5,9	1,3	1,2	2,0	2,0	2,0	1,8	2,1	1,6	3,1	2,1	0	0,3	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,7	7,1	0,5	0,3	0,5	13,8
29	0	0	0	0	0	0	0	0	0	0	0	0	0	13,2	3,3	13,2	0	0	0	-	-	-	-	-
30	-	-	-	-	-	-	-	-	1,3	0,8	0,2	0	0	6,9	7,7	5,9	3,6	2,1	2,0	0,8	0,8	1,2	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Σx	21,4	25,8	8,6	3,9	3,5	34,8	25,4	34,6	25,5	26,1	21,2	41,8	31,1	42,0	20,0	39,8	19,6	25,3	33,2	45,2	30,8	16,0	11,6	15,9
n	5	4	4	4	4	5	6	6	8	7	7	6	7	5	6	5	4	8	10	10	8	6	5	4

(*) = corresponds to rainfall

Table 19 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - August 1984 (59)

Día \ Hr	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	1,8	5,3	2,5	3,3	2,5	0,7	2,8	5,6	1,5	1,8	1,6
2	0,7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,6	0	0	0	0	0	5,4	3,3	4,1
3	4,3	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1,6	0	0	0	0	0	0	0	0	0	0	0	0	1,2	0,3	0	0
5	0	0	0	0	3,1	9,1	1,2	8,2	3,1	0	0	0	0	0	0	1,5	1,8	2,3	3,8	11,5	-	-	-	-
6	-	-	-	-	-	-	-	0	0	0	0	0	2,8	10,0	1,6	0	1,0	20,4	3,0	2,6	2,5	3,6	0,8	0
7	0	0	0	0	2,0	11,5	2,1	0,7	0	0	0	1,8	13,8	11,0	14,7	10,0	14,5	16,1	12,0	5,3	-	-	-	-
8	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	4,1	7,2	10,5	4,8	1,0	10,4	9,6	1,6	4,6	1,2	0,3	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	3,1	2,5	0	0	0	0	0	0	0	0	0	0,3	5,4	0,5	0,2	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,7
16	11,2	6,9	3,0	0,3	-	-	-	-	-	0	0	1,8	7,4	24,2	17,1	16,8	16,8	16,8	7,9	8,9	4,8	0	0	0
17	5,4	5,8	4,4	3,8	7,4	6,6	2,5	0,2	0,3*	0,3*	10,0*	5,8*	12,4*	1,2*	3,1*	13,8*	2,1*	0,3*	1,5*	3,8	5,3	3,6	'2,6	4,0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	1,2	4,8	10,0	-	-	-	-	-	-	-	-
19	-	-	-	0	0	0	0	1,3	10,9	1,2	1,3	1,3	1,5	0,5	2,0	6,6	6,9	0,8	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	0	1,8	0,2	0,8	12,8	16,5	16,0	16,0	0,7	0,3	1,0	7,9	7,9	0	0
21	0	0	0	0	0	0	0	0	0	1,6	13,0	11,5	4,1	1,6	9,7	14,3	9,7	15,1	14,2	15,1	6,9	4,1	2,1	2,8
22	9,4	0,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	4,4	1,0	2,0	2,5	3,5	5,6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	2,1	0,5	0	0	0	0	0	0	0	0	0	1,2
27	1,5	0,5	0	0	0	6,4	18,6	2,1	0,7	0,7	1,2	7,2	7,4	7,4	18,8	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,0	0,5	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,6	16,5	33,3	16,8	6,4	8,4	4,1	2,0	4,0
31	1,8	2,0	2,0	2,6	6,6	6,1	4,0	0,3	0	1,0	0	0	8,9	6,6	29,8	20,3	11,4	6,9	0	0	0	0	0	0
Σ x	34,3	15,9	9,4	6,7	23,5	43,8	32,9	16,7	1 ,2	10,1	17,3	27,9	56,0	88,1	125	104	110	130	60,7	62,2	43,8	30,8	12,6	29,4
n	7	6	3	3	5	7	7	7	4	5	4	7	10	12	11	12	13	13	10	11	9	9	6	7

(*) = corresponds to rainfall

Table 20 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - September 1984 (59)

Día \ Hr	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,0
2	0	0	3,5	6,3	21,4	5,9	6,4	6,3	4,4	3,6	18,0	16,6	15,8	17,6	30,3	20,9	33,1	33,4	30,5	11,0	19,4	15,8	19,4	16,3
3	6,1	2,0	3,6	12,2	6,8	1,8	0,3	0,5	0,2	4,4	3,5	3,3	3,8	1,6	16,6	13,7	2,6	4,0	9,6	3,6	5,1	1,2	2,1	1,8
4	2,8	3,1	9,1	0,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,9	3,6	3,5
8	6,1	9,6	17,1	13,7	18,1	16,3	17,5	10,2	4,3	1,6	0,5	0	0	0	14,7	12,3	16,6	29,6	4,9	3,1	3,0	4,9	2,5	4,3
9	5,1	5,6	9,4	4,0	3,0	5,9	2,0	1,2	0	0	1,8	1,8	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	1,5	2,5	0	0	0	0	0	0	0	0	8,7	1,3	7,7	16,6	18.0	0	0	4,4	0,2	0
11	0	0	0	0	0	0	0	0	0	0	0	0	1,0	9,1	32,6	26,5	4,6	17,0	49,0	14,5	4,0	2,1	1,3	0,8
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,3	24,7	14,8	35,4
13	5,4	2,5	0	0	0	0	4,9	3,3	33,1	16,8	5,8	7,1	33,4	25,0	7,1	3,5	1,0	1,5	4,6	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,1	17,1	6,1	11,2	1,8	0
15	0	0	0	3,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,0	5,8	3,8	3,3	4,1	4,0	36,2	8,4	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,4	9,6	18,8	2,6
19	0,7	0,7	0,8	0,8	0,8	1,8	8,1	0,7	0,8	2,6	7,2	7,1	3,8	6,8	32,9	33,3	14,7	12,3	28,8	19,9	10,0	13,8	4,3	0,3
20	0,3	0,7	0,5	0,3	0,2	0,3	0,3	0,2	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,6	0	0	0	0	0	0	0	0	0
23	0	0	2,3	3,5	2,6	4,1	0	0	0	0	0	0	0	0	0	0	0	0	0	2,5	2,3	2,8	0,5	0,5
24	0,5	0,5	4,3	4,1	3,8	4,6	1,5	4,1	3.6	14,0	0	0	0	0	0	2,0	2,0	4,3	6,4	7,2	1,0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,8	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	1,8	6,1	4,0	3,6	32,4	27,8	0	0	0	0	0	0
29	2,0	1,6	1,8	14,5	2,3	0	0,5	0	0	1,0	29,8	29,0	28,5	26,8	33,9	32,3	26,4	23,7	20,3	15,6	4,1	4,1	13,0	22,1
30	18,3	11,0	11,0	10,7	15,3	9,4	4,4	1,8	0	0	0	0	0	0	0	0	0	0	0	0	4,0	2,0	1,3	0
Σx	47,3	37,3	62,9	74,2	75,8	52,3	45,9	28,3	46,7	44,0	66,6	64,9	88,1	93,0	184	161	146	150	162	95,6	71,5	142	92,0	91,6
n	10	10	10	12	11	9	10	9	7	7	7	6	7	7	10	11	11	11	12	10	14	14	14	11

Table 21 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - October 1984 (59)

Hr / Día	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	2,0	0	1,0	2,3	1,5	0	3,6	17,3	8,2	3,5	4,8	3,6	1,0	3,3	2,0
2	1,8	1,3	1,0	1,5	2,3	4,3	0,5	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	6,1	3,8	5,3	1,0	1,2	0,6	0,7	0,5	0	0	0	0	0	0	0	3,8	5,4	2,0	3,8	4,0	0	0	0
5	0	2,0	0	0	0	0	0	0	0	1,5	1,6	0	0	0	0	0	0	0	0	3,6	2,0	0	0	0
6	0	0	2,1	8,6	2,1	4,3	1,8	2,0	0	0	0	0	0	0	0	0	1,6	4,0	6,8	7,6	4,0	1,5	1,8	0
7	0	4,0	2,0	4,9	17,0	11,2	1,8	2,1	1,6	3,6	2,1	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,8	0	0	0
9	0	0	0	0	0	0	0	0	0	0	9,1	6,3	1,6	0	0	0	0	5,3	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	1,8	1,6	5,1	11,4	9,6	3,6	0	0	0	0	0	0	5,6
11	16,1	4,1	11,7	4,1	15,5	11,0	12,2	10,9	9,9	1,3	4,8	9,7	19,9	26,7	36,9	21,6	46,4	32,4	0	0	0	0	0	0
12	0	0	0	0	0	6,1	0	0	5,9	0	0	0	0	0	0	0	0	18,6	0	0	0	0	0	0
13	0	0	0	0	0	0	0	2,0	5,1	0	0	0	0	0	0	11,9	26,5	1,6	0	0	0	0	0	0
14	0	0	0	2,0	18,9	15,3	0,7	0,5	4,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,8	19,6	2,0	0	0	10,4	14,2	1,8	0	0
18	0	0	0	0	0	4,6	4,4	0	0	11,0	16,8	15,8	49,2	32,9	46,4	17,5	33,8	46,9	28,2	22,7	32,3	15,6	12,2	8,6
19	0	0	0	4,8	32,6	16,1	15,6	15,6	10,4	0	38,7	32,6	30,3	32,6	47,9	35,6	25,7	6,6	0	16,3	47,9	10,5	20,9	11,9
20	-	-	2,3	9,7	0,8	1,3	1,2	0	1,2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	8,7	10,9	0	0	0	0	0	0	0	0	9,6	4,6	0	0	25,0	37,4	35,0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	14,0	21,2	16,6	12,7	0	0	20,1	49,4	65,4	46,1	10,0	2,1	3,3
25	0	0	0	0	0	0	0	0	0	1,2	0,7	0,8	1,6	6,4	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,8	3,3	0,3	0	0
27	0	0	0,2	1,0	1,6	11,5	15,5	10,2	4,9	3,3	0,8	0,3	13,5	10,0	0	0	0	0	0	4,4	4,1	0,5	0,5	11,5
28	5,4	4,9	9,2	1,8	7,7	2,0	1,2	5,8	13,0	4,4	16,0	1,3	3,0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	6,6	5,9	2,3	0	4,1	9,9	2,6	14,3	16,3	16,1	7,9	3,1	3,3	2,8	1,0	1,6	3,0	4,8	0	0	0
Σx	23,3	22,4	32,3	59,0	116	31,2	55,7	52,4	66,5	30,9	104	99,9	160	149	167	122	163	175	129	149	168	41,2	40,8	40,9
n	3	6	8	12	12	13	11	11	11	9	10	11	11	10	9	8	10	12	7	12	12	8	6	5

Table 22 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - November 1984 (59)

Hr / Día	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	1,6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	8,9	4,9	1,3	1,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,8	2,0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	4,4	8,2	14,8	9,2	2,6	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,3	10,5	16,5	9,9	9,1	2,6	2,0	2,5
10	2,0	1,8	2,6	0,2	0,3	0,8	1,0	1,3	1,3	2,3	2,8	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	2,0	0,7	0,7	1,3	0,7	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	1,6	1,5	5,1	9,7	6,9	2,6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	2,1	2,5	0,7	0,8	0,7	0,7	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	2,0	14,7	11,4	13,0	9,9	16,3	6,4	9,6	11,0	4,8	12,7	0	0,3	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10,0	9,7	16,3	9,2	6,6	14,8	14,7	16,0	11,4	3,8
20	3,0	0,7	0,5	0,5	3,5	9,9	19,8	25,5	24,4	27,8	21,0	32,9	16,3	13,2	0,8	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,5	20,6	5,1	5,8	1,6	2,1
22	10,7	6,1	3,1	4,9	3,3	2,5	1,6	0,2	0,2	1,5	0,2	0,2	0	0	0	0	0	0	6,3	6,6	5,6	6,9	3,8	3,6
23	2,8	0,5	4,0	0,3	0,3	0,5	0,3	3,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	4,1	3,1	2,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	1,3	4,6	5,6	1,0	1,2	1,3	0	0	0	0	0	0	0	0	0	0	0	4,8	0	0
28	1,3	0	0	0	5,3	1,8	3,0	0,3	0,3	0,3	1,8	4,3	12,7	6,9	0	0	0	0	0	0	0	0	0	1,6
29	0	0	6,1	14,8	10,5	8,2	8,2	3,6	4,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	5,3	7,6	0,8	0	0	0	0	0	1,3	0	1,0	0,8	3,3	14,0	32,6	30,5	25,0	0,7	0,5	0,5
Σx	19,8	9,1	19,9	36,9	57,2	66,3	61,6	61,5	42,7	51,9	45,7	57,0	52,2	22,7	12,1	10,5	23,9	33,7	77,5	85,2	61,5	36,8	19,3	14,1
n	5	4	7	7	12	13	13	13	10	11	7	5	5	3	4	2	3	3	5	6	6	6	5	6

Table 23 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - December 1984 (59)

Hr / Dia	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0,3	6,9	1,6	3,8	9,1	5,3	8,7	2,1	5,4	1,3	1,8	2,8	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	3,8	11,9	2,1	2,0	2,8	4,1	0,3	16,6	14,3	4,9	18,8	16,5	20,9	9,9	0,5	0,2	0,3
4	0	0	5,8	6,3	4,8	4,0	3,3	1,6	0,3	4,1	36,6	48,4	31,9	15,8	15,0	1,8	7,9	0	0	0	0	1,6	3,0	0
5	0	0	0	3,6	4,8	2,8	4,9	1,5	1,5	0,3	1,0	10,9	4,3	1,6	0	8,7	6,8	1,2	16,1	32,3	16,1	6,9	0,8	8,6
6	2,0	4,3	0	0	0	4,8	6,8	16,1	14,8	17,8	11,2	4,4	32,3	2,0	3,5	2,0	20,4	37,8	16,1	6,9	0	0	0	0
7	0	0	0	0	0	0	4,9	8,1	12,4	26,2	1,2	1,2	1,6	0	0	0	0	0	0	1,3	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1,8	13,7	3,1	0	0	0	0	0	6,6	8,1	25,4	4,9	0	0
11	0	0	0	8,9	4,6	4,4	4,0	4,9	0,3	0,2	0	0	0	0	0	0	0	2,0	20,9	16,8	16,3	4,3	0,2	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,3	4,4	0	0	0
13	0	0	0	0	0	0	0	0	0	1,8	6,8	14,0	16,8	1,0	1,2	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	6,1	0,7	0,7	19,8	33,1	10,4	15,8	9,6	3,5	5,8	13,3	32,3	16,3	4,4	16,5	29,8	18,9
18	3,0	2,0	2,8	2,0	3,0	20,1	14,0	15,1	4,4	16,1	16,6	5,3	35,6	33,4	17,0	32,1	30,8	20,6	16,3	26,8	23,7	11,9	9,4	2,8
19	2,0	4,3	3,0	16,0	13,0	14,2	5,4	13,7	2,0	14,7	10,0	7,6	2,1	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,1	0	0
21	0	0	0	0	0	0	0	0	2,0	4,8	2,5	3,1	10,5	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	4,4	14,8	8,7	0	0	0	0	3	0	0	0	1,8	4,9	3,1	6,8	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,6
25	6,6	3,1	6,4	1,3	0,8	0,8	0,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,3
26	4,1	0,8	0,7	0,8	1,2	1,6	4,1	2,5	1,3	3,3	31,5	31,9	34,6	16,6	7,6	6,8	14,2	20,1	26,0	6,4	16,0	22,4	23,4	9,1
27	3,3	1,0	1,6	1,8	5,9	2,8	8,9	4,3	3,0	2,1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	2,5	4,9	0	0	0	0	0	1,6	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	1,5	3,0	1,0	0	0	0	0	0	0	0	0	0	0	0	6,1	10,2	6,4	4,1	2,8
31	4,3	1,8	4,8	4,3	7,4	2,1	1,2	1,3	0	0	0	0	0	0	0	0	12,8	21,6	32,8	31,3	28,0	10,7	8,6	5,3
Σx	25,6	24,2	26,9	48,8	54,6	66,9	74,4	86,5	74,8	104	179	142	179	188	86,5	70,5	69,2	103	130	185	180	157	79,5	52,7
n	8	8	8	10	10	13	14	15	14	15	13	13	13	8	7	7	8	8	10	13	11	12	9	9

Table 24 - Fog-graph recordings (1 x 10/m²/hr), El Tofo, IV Region - January 1985 (59)

Hr. Día	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	2,8	7,1	1,0	6,6	10,0	10,7	9,9	3,0	0,7	1,0	6,1	10,9	5,6	0	0	0	0	0	0	0	0	0	1,6	1,1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,4	3,6	0,3	0,5
3	0,5	0,5	5,1	16,3	16,5	12,8	3,8	2,0	11,0	4,6	5,3	4,4	1,3	5,9	0	0	0	0	0	0	4,3	6,8	17,5	6,1
4	1,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,1	16,5	11,2	2,6	0
5	0	0	0	0	0	5,6	5,3	6,3	2,0	0,8	11,5	2,0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	3,5	5,3	2,1	0	0	0	0	0	2,1	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,3	9,4	4,6	0	0	0
11	0	0	0	0	0	0	0	0	20,6	34,3	30,0	25,5	7,1	1,5	2,1	0	0	0	3,8	6,9	5,6	9,7	4,6	11,2
12	5,9	0,3	7,9	9,1	9,9	0,5	6,3	16,1	26,5	29,2	32,9	29,6	31,3	13,8	6,8	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,6	24,2	33,3	30,6	21,1	4,4	4,8
16	1,6	6,9	2,0	4,0	0,5	0,7	0,7	0,8	0,5	11,4	16,5	8,2	0	0	0	0	0	0	0	0	4,3	1,3	1,3	2,0
17	1,8	1,3	1,8	0,8	0,8	0,7	0,7	0,2	0	0	4,4	3,6	3,1	1,8	1,3	0	0	0	6,3	8,4	6,8	4,8	1,8	4,4
18	1,3	12,0	2,8	1,6	13,3	3,5	1,2	3,5	1,8	0,5	7,6	0,3	2,0	0	0	0	0	0	0	0	0	0	0	0,3
19	0,2	0,2	0,2	2,5	0,8	0,8	0,8	0,5	0	0	0	0	0	0	0	0	0	0	0	0	4,6	14,8	13,8	0,3
20	0,2	6,6	4,3	6,3	5,3	0	0	0	0	0	0	0	0	0,8	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,6	0,6
22	7,1	4,9	0	0	0	4,0	7,4	5,9	5,3	4,8	0	0	0	0	0	0	0	0	0	0	0	2,5	0	0
23	0	0	0	0	1,6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	1,8	7,2	2,6	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	1,6	21,7	24,2	4,1	0	0	0	0	6,1	23,9	11,7	0,5	2,3
27	1,5	0,7	0,2	0	0	0	0	6,9	7,1	4,9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0,8	0	0	0	0	0	0	0	0	0	0	-	-	-	-
29	-	-	-	-	-	-	15,3	6,1	4,8	2,0	0	0	0	0	3,6	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	2,0	2,0	0	0	0	2,3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Σx	24,7	40,5	27,3	49,2	58,7	42,8	56,7	55,8	80,3	96,1	121	88,7	72,1	50,1	17,9	0	0	1,6	38,6	71,2	106	87,5	49,0	33,8
n	11	10	10	9	9	10	11	13	10	12	9	10	7	7	5	0	0	1	4	6	10	10	11	11

FOG AND FOREIGN RELATIONS

10

The formation of droplets (50)

The formation of droplets in a cloud happens as soon as a relative humidity of 100% is obtained and condensation nuclei are available, which is normally the case, even too many. The number of cloud droplets is much smaller than the number of condensation nuclei; there may be thousands of such nuclei per cm^3. Very small drops, smaller than 1 to 2 μ diameter, with a solid nucleus, enhance the vapour pressure because of tension over a strongly curved surface and re-evaporate immediately. In case the nucleus consists of a salt particle, due to its hygroscopic action on water, it will dissolve at relative humidities even below 100%, which reduces the vapour pressure over the surface. So only those droplets are likely to survive with a soluble nucleus or with a sufficient large nucleus to allow the curvature effect to be small. The surviving droplets develop to diameters varying between 2 to 20 μ. This process reduces the vapour pressure in the surrounding of the drops, preventing their further growth.

The droplets begin to fall. If they reach levels below the cloud base they evaporate quickly, even under conditions of a high relative humidity. The air in a persisting cloud, however, must continue to rise (decreasing in temperature) in order to produce the saturation of more and more of its vapour content. The heat release during condensation makes the cloud-forming air buoyant, stimulating further upward motion.

Imagine a cloud mass containing many small droplets of uniform size which compete among each other for the available vapour. Because condensation of the limited amount of water vapour tends to make the droplets grow at the same rate, there is not enough water at their disposal to convert them to proper raindrops with diameter well over 100 μ or 0.1 mm if they want to reach the ground before being evaporated. A droplet of 10 μ diameter falling from a cloud base of let us say 1,100 m altitude would need 50 hours to reach the ground because of friction with the atmosphere, while a raindrop of 500 μ or 0.5 mm would arrive after less than 10 minutes fall. Of course, evaporation during the free fall would have taken its share, but it would still arrive as a rain drop.

In nature, however, droplets vary in size, especially when they have grown on giant nuclei of ± 10 μ, and therefore they have different falling velocities. The larger drops fall faster or, in an ascending cloud, rise more slowly than the smaller ones, collide with some of them and draw others into their wake. The collisions cause the number of droplets to decrease and allow the large ones to grow to real raindrops at the cost of the smaller ones.

Conclusively, a good rain cloud needs the following characteristics:

1. few nuclei should be available so that the competition for growth of the droplets is reduced and the droplets can increase their diameter (in this connection maritime air contains in the order of 100 nuclei per cm^3, against continental air 10 to 50 times more, especially if generated by upwhirling dust from drought stricken areas);
2. nuclei sizes should cover a wide range, producing droplets with different fall velocities;
3. liquid water content in the cloud should be sufficient to allow sufficient growth of the droplets;
4. a sufficient vertical dimension of the cloud to allow a long falling time for the droplets, followed by a long updraft etc., until the droplets become so heavy that the updraft cannot withhold them any more and they will continue falling down like mature raindrops.

Considering that the liquid content of a Pacific stratus cloud is around 0.5 gram per m^3, only one part per 2 million of the cloud volume contains water (as 1 gram water occupies 1 cm^3). This explains also that a cloud needs to have a considerable vertical dimension exceeding at least 500 m, to produce some rain. This thickness is never obtained by the Camanchaca clouds or any similar stratus clouds limited in thickness by a thermal inversion.

It will also be clear that raindrops have a dominating vertical fall direction, while fog droplets have a dominating horizontal component of movement (Fig.43).

Hawaii

It has always been one of UNESCO's fundamental tasks to transfer relevant information from other countries to its specific projects and vice versa. The International Conference on Rainwater Cistern Systems organized from 15 to 17 June 1982 in Honolulu, Hawaii, was one of these opportunities. In Hawaii watermen from mainly Pacific, Caribbean and Atlantic archipelagoes expressed their regained interest in cisterns and demonstrated their practical use. Cisterns had become unpopular due to the various water-borne diseases they had helped to spread. At least the cisterns in North Africa, as for instance in Algeria, were always remembered as a source of misery which should be avoided at all cost. However, as long as modern means guarantee the safeguard of the established hygiene criteria, there are no reasons to keep away from them. In areas without reliable groundwater or surface water resources, and where people depend exclusively on rainfall like in many small isles or areas with saline or contaminated groundwater, cisterns are a relief. As an example, the Mennonite colonies in the Paraguayan Chaco could have never reached their present state of well-being without their cisterns, adapted with great ingenuity to the particular combination of conditions, like horizontal terrain without drainage system, saline groundwater and very irregular scarce rainfall. Of course, precipitation should be free of any contamination, which makes its application on islands or in coastal areas generally feasible.

One of the main problems apart from construction and cost, is their dimensioning in dependence of changing supply and a more or less fixed demand. This dimensioning could of course immediately be applied for irregular Camanchaca water supply.

The fundamental design factors for a rain catchment cistern are: rainfall, catchment area (of roof), storage capacity and water demand. This, translated for Camanchaca conditions, is: specific Camanchaca interception, installed interception surface area, storage capacity and water demand.

Table 25 presents an example using inflow: I(t) and demand: D(t) to follow the net change of a theoretical storage if a sufficiently large tank were available, to calculate the minimum volume V which would satisfy the demand of 215000 liters per month or just over 50 m^3 per week for Chungungo. In the period from January 1984 to January 1985 this minimum storage volume was 173.320 m^3. A tank of 200 m^3 allowing a K value of 26.680 m^3 would have done. This situation was different in the period November 1987 to April 1989 (Table 26). To satisfy the same demand a reservoir of 621.600 m^3 would have been needed. In the case of a tank of 350 m^3, as was planned by CONAF in 1985, only the strict necessary demand of 172.500 m^3 a month or just over 40 m^3a week could have been provided a minimum volume V= 291.600 m^3 and a value K= 350.000 m^3 - 291.600 m^3 = 58.400 m^3. Of course recordings like Table 16 to Table 24 allow the calculation to be refined by choosing a smaller value for t, a week or even a day.

Table 25

Month	Spec yield l/month	Correction for new fogtrap m^2	Inst. area l/month	Inflow l/month	Demand l/month	Net change l/month	Acc. change l/month	Max amplitud of acc. curve
January 1984	75.9	1.5	2400	273240	215000	58240	58240	from high to low
February	56.2	1.5	2400	202320	215000	-12680	45560	with
March	95.5	1.5	2400	343800	215000	128800	174360	
April	81.2	1.5	2400	292320	215000	77320	251680	rel. maimum
May	32.8	1.5	2400	118080	215000	-96920	154760	minus
June	38.5	1.5	2400	138600	215000	-76400	78360	rel. minimum
July	63.8	1.5	2400	229680	215000	14680	93040	= V
August	97.3	1.5	2400	350280	215000	135280	228320	173320
September	128.2	1.5	2400	461520	215000	246520	474840	excess
October	110.6	1.5	2400	398160	215000	183160	658000	abs max -V =
November	57	1.5	2400	205200	215000	-9800	648200	677040
December	112.8	1.5	2400	406080	215000	191080	839280	
January 1985	62.8	1.5	2400	226080	215000	11080	850360	abs. maximum
SUM	1012.6	1.5	2400	3645360	2795000	850360	-excess = V = 173320	

Table 26

Month	Spec yield l/day	Multiplication for l/month	Inst. area m^2	Inflow = I(t) l/month	Demand 1 = D1(t) l/month
November 1987	6.1	30	2400	439200	172500
December	6.2	30	2400	446400	172500
January 1988	5.5	30	2400	396000	172500
February	4.4	30	2400	316800	172500
March	3.5	30	2400	252000	172500
April	3.4	30	2400	244800	172500
May		30	2400	108000	172500
June		30	2400	72000	172500
July	2.1	30	2400	151200	172500
August	1.7	30	2400	122400	172500
September	3.4	30	2400	244800	172500
October	2.7	30	2400	194400	172500
November	4.9	30	2400	352800	172500
December	2.4	30	2400	172800	172500
January 1989	2.5	30	2400	180000	172500
February	1.5	30	2400	108000	172500
March	1.6	30	2400	115200	172500
April	1.9	30	2400	136800	172500
SUM	56.3	30	2400	4053600	3105000

Net change accumulated Minimax			Demand 2 = D2	Net change accumulated Minimax		
l/month	change	Volume V1	l/month	l/month	change	Volume V2
266700	266700		215000	224200	224200	
273900	540600		215000	231400	455600	
223500	764100		215000	181000	636600	
144300	908400		215000	101800	738400	
79500	987900		215000	37000	775400	
72300	1060200 maximum		215000	29800	805200 maximum	
-64500	995700		215000	-107000	698200	
-100500	895200 V = max-min		215000	-143000	555200 V = max-min	
-21300	873900	291600	215000	-63800	491400	621600
-50100	823800		215000	-92600	398800	
72300	896100 Excess		215000	29800	428600 Excess	
21900	918000 max -V =		215000	-20600	408000 max - V =	
300	918300	768600	215000	137800	545800	183600
300	854100		215000	-42200	503600	
7500	926100		215000	-35000	468600	
-64500	861600		215000	-107000	361600	
-57300	804300		215000	-99800	261800	
-35700	768600 minimum		215000	-78200	183600 Minimum	
768600			3870000			

The minimum cistern volume can be calculated for a deterministic set of rainfall data. However, rainfall is stochastic and its impact on the cistern design varies with the available length of recordings and available statistics (compare Tables 25 and 26 covering respectively 1984 and 1988).

Considering that !988 and the beginning of 1989 was a bad Camanchaca period, storage capacity of 600 m³ is needed, or more interception capacity has to be installed in order to provide Chungungo with sufficient water. Excess waters can be used for drip irrigation systems, in this case with preference the cheap "porous pot" irrigation and for reforestation also with isolated porous pots, preventing that evaporation takes its share, except via evapotranspiration, and that the applied water does not percolate down to below the root zone.

The information from Hawaii was elaborated with great effort by the Water and Sanitation for Health Project (WASH) sponsored by USAID in "A workshop design for Rainwater Roof Catchment Systems", introducing an elegant graphic way to size a cistern as a function of a certain rainfall pattern and a given roof catchment area. UNESCO/ROSTLAC in collaboration with UNICEF supported the publication of a Spanish version, which is intensively used in Bolivia (15) (Fig.44).

Another stimulating input was the mountain fog investigation initiated in the Sixties. From 1974 onwards, this became a systematic study on the windward and leeward slopes of the Mauna Loa volcano carried out by Paul C.Ekern and James O.Juvik of the Water Resources Research Center of the University of Hawaii at Manoa, financed by the Office of Water Research and Technology of the U.S. Department of the Interior (36).

Almost every year one or more districts on the Hawaii Island suffer droughts especially in summer, resulting in water restrictions and government-subsidized hauling of domestic water. This is related to the extreme variability of the annual and seasonal rainfall pattern characteristic for the island. The area above the high precipitation belts from 1000 to 2000 m is generally used for grazing. As pumping well water to these altitudes is not economic, surface water harvesting, if possible, is the only way out. This is done as high as possible in order to use gravity for distribution, in spite of the fact that rainfall is decreasing with elevation above the tradewind inversion.

During the past two centuries man has caused serious destruction of the mountain forest which was well watered by the mountain fogs occurring with high frequency, either in association with or without rainfall. With the deforestation stopped also the influence of the fogs on the water balance. Powers and Wentworth commented as early as 1941 on the relation between ground level mist and abundant fog drip from trees.

These reasons motivated Ekern and Juvik to study fog regimes, to develop a standardized louvered-screen fog catchment gauge and to analyze in a methodical way rainfall and fog components in the overall atmospheric water supply on the basis of fog and rain-gauge geometry, droplet size, inclination angle and wind speed (Fig.43).

of Mauna Loa increases with elevation only up to 2000 m, with fog amounts equivalent to the rainfall, or about 250 mm.

At the trade-windward side the fog-to-rain ratio approaches zero under conditions of extreme high rainfall, and becomes infinite under conditions of very low rainfall. The relation is best described by the function Y = 1/X. *Fog is more likely than rain when the inversion height and the precipitable water content in the air are low.* Rainfall is negligible when the inversion is below 2000 m. On the wind side during measurements made in May, June, July and September 1975, daily rainfall was divided into two groups: days with rainfall less than (<) 2.54 mm and with rainfall more than (>) 2.54 mm. See Table 27 for correlative characteristics of the two categories.

Table 27 - Summer 1975 precipitation and inversion height segregated by rainfall intensity, Kulani Camp (A-1) Station, Hawaii Island (35)

Month	Sample Size (days)	Rain	Fog	Fog: Rain Ratio	Inversion Height (m)
		mm/period (mm/day)			
		DAYS WITH RAINFALL INTENSITIES < 2.54 mm/day			
May	10	11.18 (1.12)	23.89 (2.39)	2.13	2.080
June	15	13.46 (0.89)	33.79 (2.25)	2.51	2.060
July	15	16.26 (1.08)	22.31 (1.49)	1.37	2.140
Sept.	10	12.19 (1.22)	12.71 (1.27)	1.04	2.180
TOTAL PERIOD	50	53.09 (1.08)	92.70 (1.85)	1.76	2.120
		DAYS WITH RAINFALL INTENSITIES > 2.54 mm/day			
May	9	72.89 (8.10)	43.47 (4.83)	0.59	2.530
June	6	30.73 (5.12)	28.29 (4.71)	0.92	2.330
July	5	54.10 (10.82)	21.52 (4.30)	0.39	2.900
Sept.	9	79.76 (8.86)	33.68 (3.74)	0.42	2.660
TOTAL PERIOD	29	237.48 (8.23)	126.96 (4.40)	0.58	2.610

Note: Averages in parentheses

At a leeside station at 1560 m altitude for a total of 20 days with precipitation during May, June and August 1974, there were 118 precipitation hours, of which 62 hours were classified as rain (57.40 mm), i.e., estimated droplet diameter > 100 μ, and 56 hours as fog, with a gauged 12.16 mm. Both *rainfall and fog were limited exclusively to the afternoon and evening hours with maximum frequency between 15 and 18 hr. Both are almost exclusively associated with the upslope daytime wind. In all but two cases the afternoon precipitation ended within one hour preceding the evening wind reversal. The lack of any distinctive temporal separation between rainfall and fog frequency, and the congruence with respect to prevailing wind direction*, dependent on localized differential heating and independent of trade wind, *confirm that the two precipitation forms simply represent different "magnitudes" of a single condensation process*. The frequency and altitude occurrence of fog at the leeside is lower in number and elevation respectively than on the wind side.

A missed opportunity

In March 1984 Carlos López Ocaña attended a meeting in Hawaii and MRP asked him to stay some days longer to inform himself about the state of the mountain fog investigation, and to invite one of the investigators to visit the Camanchaca sites in Chile and Peru in case one of them happened to be in the neighbourhood. Carlos returned with documentation which was quickly distributed among the interested parties.

Not long afterwards James Juvik on his way back from the Cape Verde Isles, where he also visited some fog exploitation activities, expressed his desire to pass by. Together with Carlos, Guido Soto and Jorge Marcos, professor in applied archaeology at the Escuela Superior Politécnica del Litoral (ESPOL) in Guayaquil, Ecuador, a programme was made for his visit in the month of June. People were informed about his arrival and, according to the comments, everything went fine. UNESCO never had any direct contact with Juvik, as at that very moment there were many other matters that required attention. López Ocaña found out that Juvik, like himself, would attend the Arid Land Research and Development Conference in Tucson, Arizona, USA, in the second half of October of that year. López Ocaña was invited to chair the group on *Conservation and Non-conventional Water Resources in Arid Zones*. Due to contacts obtained during the preparation of the meeting, he had received various suggestions to devote some special time to fog water harvesting. More and more countries seemed to be interested in the question. Dr. Silvia de Matteuci, of the Universidad Nacional Experimental Francisco de Miranda in the State of Falcón, Venezuela, wanted to exploit tradewind fogs on Isla Margarita. Antoine Swenne, FAO expert in silvo-pastoralisme, was involved in something similar in the Cape Verde Isles. Dr. Mahgoub G. Zarouf, Agricultural Officer of the FAO Crop and Grassland Service wished to become acquainted with fog harvesting for its application on the south coast of the Sultanate of Oman. Ing. Rómulo González of the Mexican Comisión Nacional de Zonas Aridas (CONAZA) showed interest with respect to fogs in Baja California. Even people of the Scripps Institution, La Jolla, California, USA, seemed not to be indifferent. Obviously, the Desert Ecological Research Unit in Walvis Bay, Namibia, was represented in this group.

The URH was unable to participate, after he had unsuccessfully explored the possibilities of going. Guido Soto was asked to go on behalf of MRP, but he could also not leave Chile at that time. Financial resources were short, at least around UNESCO/ROSTLAC, and so we had to be conspicuous by our absence. Moreover, the Conference programme was heavily booked, every moment was reserved for an important subject. At the end, even Carlos López Ocaña had only a few minutes to present the Camanchaca case. At that instant, because of the background noise in the conference hall, only some people nearby must have heard the funny word Camanchaca, which probably in its isolation did not make much sense. In the scientific world as well as in many other worlds, it needs a lot of lobbying to put something on the forefront. Normally during this type of occasions part of the gathered creative potential will stay untapped as it is not given the chance to be exposed.

Canary Isles (Fig 45)

A different story was the farmer Antonio González Ferrer, who after having read the article (34) in Nature and Resources wrote asking for advice on fog water harvesting for his farm on the northern point of Lanzarote, the driest north western island of the Canary Isles. The answer sent to Antonio contained as much advice as possible and after some time the message came that he had followed the indications and that he solved in this way the emergency watering for his cattle.

Some time later UNESCO ROSTLAC received a report from the "*Instituto Nacional para la Conservación de la Naturaleza* (ICONA) studying the impact of rainfall and fog drip on the water balance of the isle of La Gomera, Canary Isles (52). Here also a frequent tradewind inversion with temperatures at the lower level 10° C below those of the upper level, results in a regular strato-cumulus cloud cover, called "*Mar de Nubes*" which intersects the slopes of the high volcanoes, producing intensive fog drip in the forested areas. The regions of the isles which stay wrapped up in the *Mar de Nubes* have well-defined climatic characteristics: little insolation, relative humidity of the air above 80 %, very low daily temperature variations and a net radiation balance approaching zero. In these zones the cloud cover disappears during the night leaving behind on vegetation and soils the major part of the water content of the atmosphere in the form of light drizzle (*garúa*) and dew. Then usually it is cloudless until shortly before dawn. Only occasional intrusions of a polar depression from the north or the influence of the Inter-Tropical Convergency Zone from the south change this general weather pattern and produce heavy rainfall.

From the Izaña observatory situated on the isle of Tenerife above the strato-cumuli deck, the *Mar de Nubes* has been watched systematically. The following Table 28 shows its physical characteristics as a result of observations during the period 1939-1950.

Table 28

Month	A	B	C	D	E	F	G
January	9	18	5	1570 m	15	8	7
February	10	16	4	1600 m	13	7	7
March	13	18	4	1650 m	12	7	6
April	18	21	2	1540 m	7	4	4
May	22	25	1	1660 m	7	3	2
June	25	29	0	1400 m	4	3	2
July	28	29	2	1240 m	3	3	2
August	22	28	3	1230 m	8	3	3
September	18	25	2	1470 m	10	4	3
October	15	19	3	1590 m	12	6	6
November	9	16	4	1620 m	14	8	8
December	10	17	5	1670 m	14	7	6
				mean altitude			
Annual total	199	261	35	1520 m	119	63	56

A: Days with *Mar de Nubes* during three daily observations: 6, 12, 17 hr.

B: Days with *Mar de Nubes* at least during one observation.

C: Days without *Mar de Nubes* .

D: Mean altitude a.s.l. of top cloud deck.

E: Days without *Mar de Nubes* at 6 hr.

F: Days without *Mar de Nubes* at 12 hr.

G: Days without *Mar de Nubes* at 17 hr.

Figure 47 shows the adaptation of the vegetation to the climate on the isle of La Gomera with maximum altitude of 1487 m, generally covered by the *Mar de Nubes*. The fog is a colloidal system composed of water droplets condensed around hygroscopic nuclei and has a liquid water content varying over a wide range from 0.0001 to 2 gram/m^3 with an average of about 0.2 gram/m^3.

The cloud cover produces abundant springs above 1000 m a.s.l. near the mountain crests and the water flows down in small brooks through the dense forest. These springs are fed mainly by *horizontal precipitation* or by sea fog. Of course these springs are the main suppliers of drinking water for the population on the island. The yield of the springs, however, exceeds to a great extent the estimated yield on the basis of precipitation in the open terrain alone. This excess yield is attributed to the forest interception of the frequent fog occurrence above 900 m altitude, covering the entire central elevated part of La Gomera (see Figures 48 and 49). Figure 50 shows the isohyets of the normal (vertical) precipitation (in the open field) while Figure 47 shows the extra effect of the mountain fogs expressed in terms of the fog over rainfall ratio. The interception at the mountain crests with maximum wind speed can be up to 10 X and more the normal precipitation. There even exists an observation of 50 X the normal precipitation The white area around the mountain crests are the densely forested areas which intercept up to twice the normal precipitation. Consequently, the most probable ratio between *horizontal precipitation* (or fog interception) and precipitation in the open field is 2 to 3.

Kämmer (1974) studied the effect of humectation of different tree species with reference to the quantity of *horizontal precipitation*. Some twigs of yew tree (*Erica scoparia* subspecies *platycodon*) and some branches with laurel leaves (*Laurus azorica*) are kept during some time in dense mist with appreciable velocity. The result is as follows: the twigs of the yew tree start to drip copiously after some minutes, while the equally large branch of the laurel hardly produces one drip after even a longer exposure to the fog. Under the same conditions the laurel leaves are positioned perpendicular to the wind and the humectation can be observed only along the sides of the leaf stalk. The behaviour of the laurel leaves is different from the one of the yew tree needles. In the first case the wide leaf produces turbulence in its proximity, the droplets are rebounded and the adherence contact between drops and leaf are made difficult. In the second case yew tree needles, or heather, or pinus canariensis needles, all of the same category, present more favourable aerodynamic conditions for the fixation of the droplets on the needles because of a relative absence of whirlwinds around the needles.

Various other scientists became interested in measuring fog drip under different tree species on the Canary Isles. On the island of Tenerife many pluviometers were placed under various types of vegetation during a long period and the results were compared with pluviometers located nearby in the open field (Fig 46). The best known experiments were realized by F. Kämmer (1974) and L. Ceballos and F. Ortuño (1952). The latter carried out his measurements with 50 pluviometers on a mountain crest at 1590 m altitude, strongly hit by the wind. The drip collected during the period of one year under Pinus canariensis was 3222 mm/m^2, being the average of the 50 rain gauges, while the pluviometer in the open field collected only 666 mm/m^2. He also measured drip inside the pine forest and on the windward forest edge. The first case produced less than the second, but always considerably more than in the open terrain.

In Cruz de Carmen, Tenerife, under a close group of 20 twisted and inclined laurel trees covered with epiphytic vegetation at 915 m a.s.l., as an average of 50 pluviometers 1074 mm/m^2 was collected during one year compared with 888 mm/m^2 in open terrain. Here the forest is dense and not exposed to strong winds.

The normally mixed Canarian forest of laurel and pine trees with height of 20 to 30 meters with humid and rich organic material on the forest floor, receives fog invasions only occasionally because the cloud base is normally above the tree tops. This is also the type of forest that occurs in the narrow ravines where the temperature is stable and where the sky is almost continuously covered by a cloud deck. However, if the sky becomes clear during the night these trees receive their portion of dew.

Other measurements of the same type at 1300 m a.s.l. on Gran Canaria, delivered inside a pineforest 2724 mm against 865 mm in the open terrain, and on an mountain crest, inside a forest, again on Tenerife at 1490 m altitude, 3038 mm compared with 956 mm in the open.

In March 1983 ICONA measured fog drip within the forest at different altitudes and in nearby open terrain. The horizontal precipitation is defined as the ratio of precipitation collected under the trees and in the open field. For Pinus canariensis at 1260 m, Pinus canariensis at 1350 m, Pinus insigne at 1090 m, laurel at 1000 m, heather at 940 m, successively values of 1.5, 2.1, 1.8, 2.5, and 0.7 were found. These values are slightly lower than those of Ceballos and Ortuño. The ICONA experiment was executed inside well-developed forest in more representative locations, while the earlier investigators selected more favourable sites near the edge of a forests or on an exposed mountain crests.

Of course, these punctual fog drip observations, which vary from site to site, represent only approximations, but enough to demonstrate the importance of the vegetation for the water balance of the Canary Isles and La Gomera in particular. On La Gomera it has been proved that the vegetation is fundamental for the feeding of the numerous springs.

The Galapagos Islands

This coolest tropical archipelago also needs water. Often fresh water is transported by boat from Guayaquil, while it must be possible to collect Camanchaca or other type of fog water from the mountain and volcano tops frequently hidden in the clouds. According to the Ecuadorians, fog harvesting would be an interesting enterprise.

Camanchaca on the peninsula of Santa Elena and Manabi

Having shown on several opportunities a keen interest in the matter, in 1984 MRP invited Dr Jorge Marcos, an applied archaeologist residing in Guayaquil, Ecuador, and some of his collaborators to visit the Camanchaca sites in Chile and Peru, and to make personal contact with the MRP investigators working on Camanchaca.

Marcos and anthropologist Silvia Alvarez, with private funding from a U.S. university, are looking for archaeological evidence of rational Camanchaca exploitation in the valley of Chanduy in the west of the Santa Elena peninsula. On the basis of their findings they are establishing an eco-museum, demonstrating how the old pre-Columbian inhabitants lived in wise symbiosis with the resources of their environment. It seems that Marcos has found small irrigation canals which start in (previously) forested lomas and used to conduct the drip water to small agricultural plots and terraces.

Less than 100 km to the north a few km from the coast, there is the small settlement of Suspira, housing 56 families. The hamlet lies in an open valley permitting the free access of the fog-laden sea breeze during some months of the year, and is surrounded from the inland by hills which hide their tops in the overcast. A small, practically dry water course fed by fog drip on the once tree-covered hills must have provided abundant water for the cultivation of the fields. Because of the good price offered for the wood of the effectively capturing trees, the villagers were tempted to sacrifice their natural inheritance. The result is a tragedy: the disappearance of the trees (some are still visible on the hill slopes and some remaining logs are lying on the ground) made the springs dry up. They have cut off their water supply and the village chief asked MRP's advice to solve their present water problem. Questioned if he had any notion of the causes of their sad destiny, he nodded:

"By felling the trees, especially on the hilltops", where the trees were best developed due to the fog. You killed your hen of the golden eggs and from now onwards your people will be thirsty and doomed to be hold the sterile barren hill slopes. Were you not aware of your crime ?

The poor man admitted that he had had some doubtful presentiments, but he was seduced by the influential businessmen and their technicians from the capital. Their convincing self-assured arguments and the short-term bright prospects for the village had wiped his last intuitive resistance. And now he was left alone with his remorse. Even the answer to our question had evaporated his idle hope that his presentiment might be wrong. By his interference in God's creation he had prevented God to do His blessing work.

This was a very obvious case. But how many more hidden cases do there exist? And if one includes the forest areas which do not depend in the first place on fog water, practically all forests in the world, with the exclusion of especially protected areas, are involved in this mass destruction either by motor-saw, forest fire or water or atmospheric contamination.

It is sad that the slowly progressing quality of life-and-environmental problems only receive the general attention when they have become immediately perceptible problems for the large human masses normally living in the large urban centres. By then those problems cannot often be checked any more and the only remaining solution is genetic adaptation to the polluting effects.

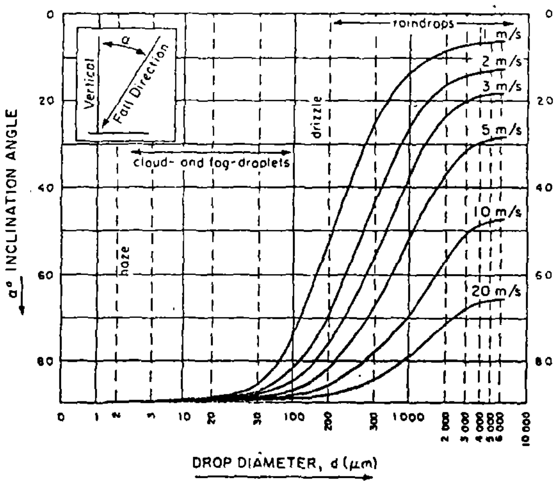


Figure 43 - Relationship between drop diameter, inclination angle and wind velocity (35)

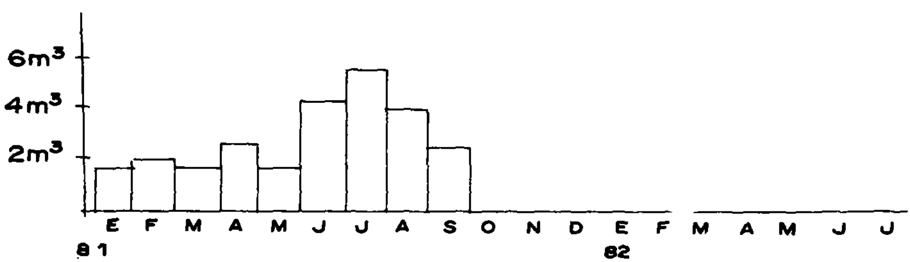


Fig. 44

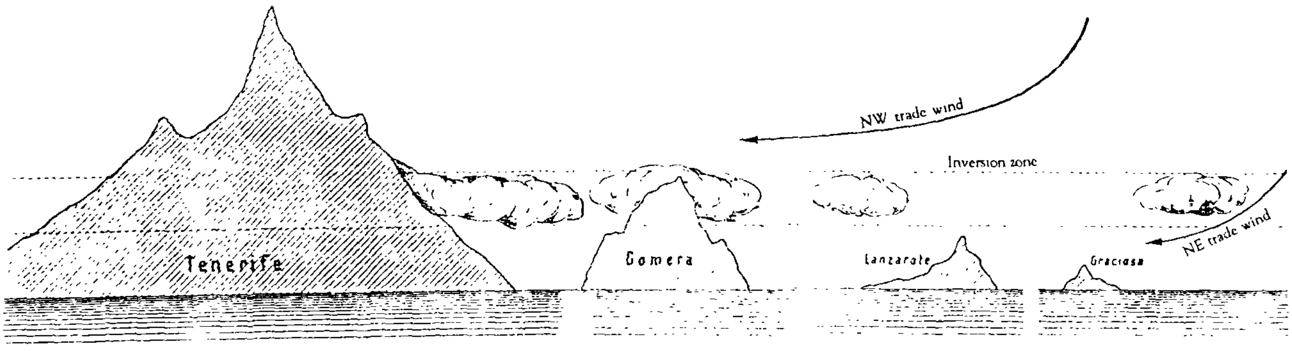

NW trade wind
Inversion zone
Tenerife
Gomera
Lanzarote
Graciosa
NE trade wind

Fig. 45

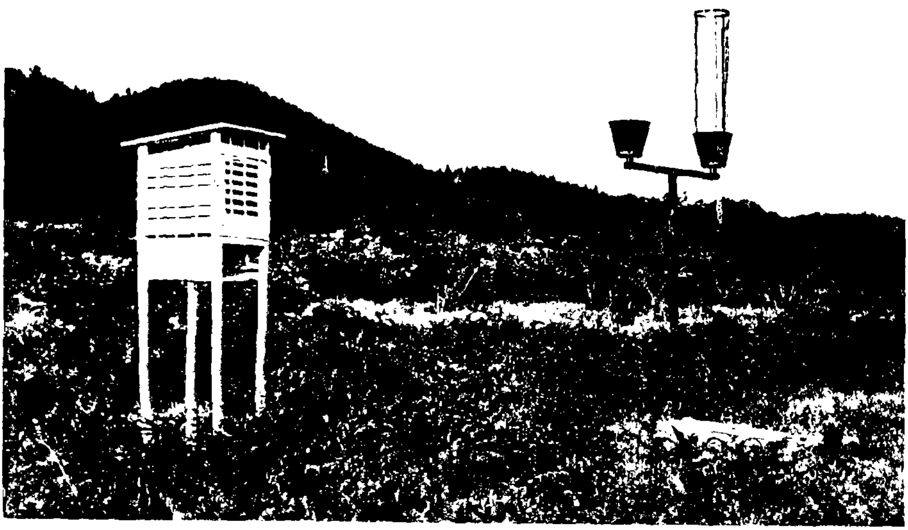


Fig. 46 - Cylindircal fogtrap designed by ICONA. The fogtrap has been installed at several sites in our wooded zones at various altitudes with different geographical characteristics.

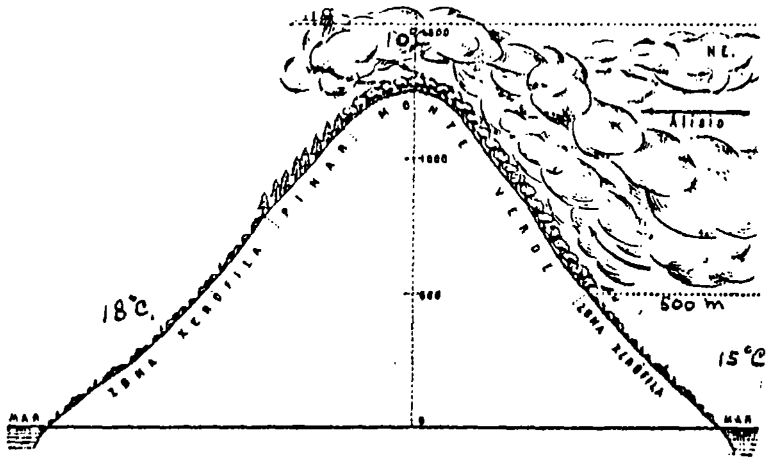


Fig. 47 - Formation of the "Mar de Nubes" above La Gomera and the distribution of the vegetation depending on it. (51)

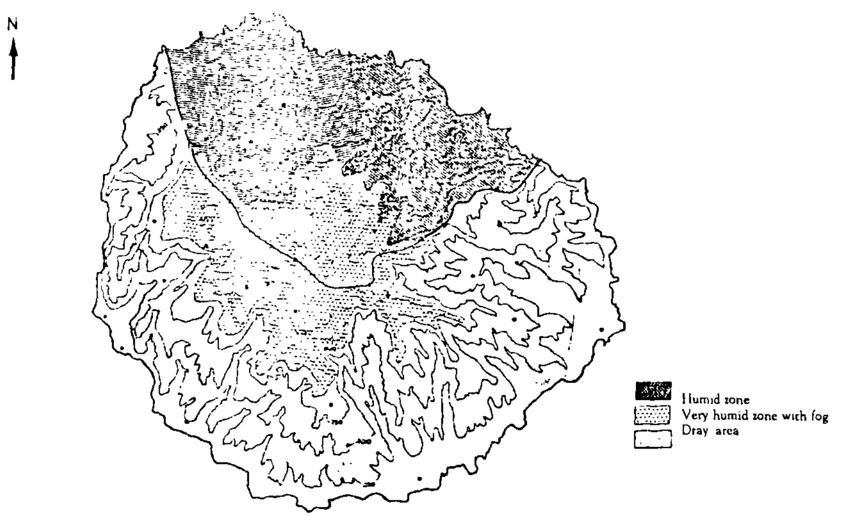


Fig. 48 - Climatic zones of La Gomera island : The windward or humid side, the central meseta or fog zone and the leeside or arid zone (51)

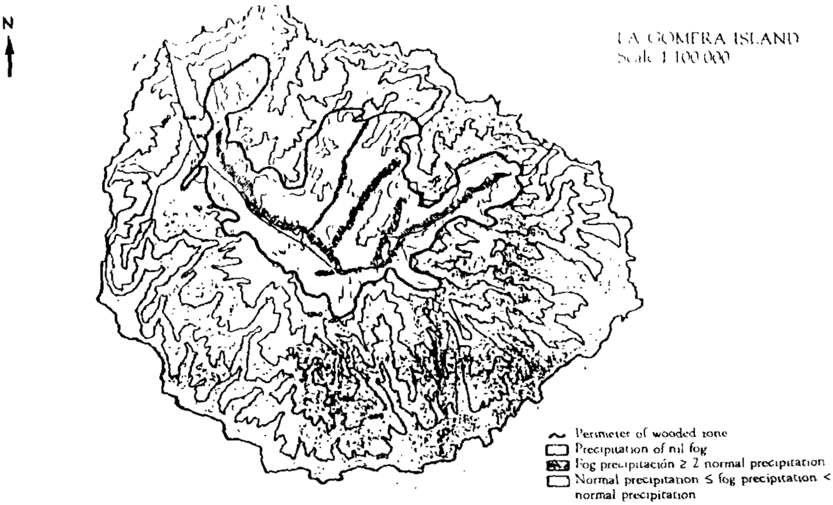


Fig. 49 - Distribution of "horizontal precipitation" on La Gomera island (51)

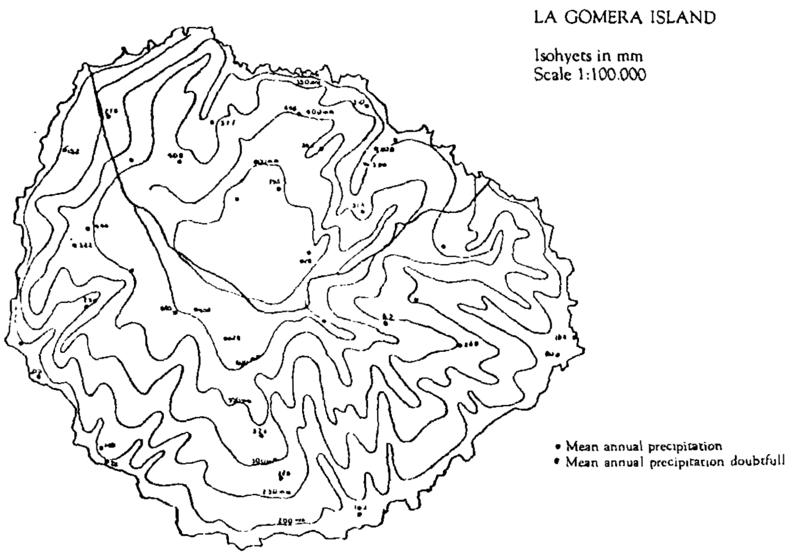


Fig. 50 - Isohyets in mm/year on La Gomera (51)

SEEKING IDRC INVOLVEMENT

11

Since 1971 India had studied its snow and ice problems in the Snow and Avalanche Study Establishment in Manali in the Himachal Pradesh, in a straight line 250 km southeast of Srinagar. The Indian National Committee for the IHP had applied for UNESCO support for a *Workshop and Training Course* in this field. The best month for a course would be April when the winter snow has reached its greatest thickness and the melting process is starting. UNESCO conceded the request and reserved funds for the 1977/1978 period. The workshop was planned for April 1977 with 3 top international consultants from Canada, Europe and Japan and about 8 Indian specialists to come to clear directives for a regional course after an extensive exchange of the accumulated knowledge in the last five years. Both the workshop and the course with participants from the Himalaya and Karakorum region were highly valued.

This was the schedule elaborated on the basis of a satisfying experience end 1971 when the first Regional Training Course on the Hydrology of Snow and Ice was held in Santiago, sponsored by UNESCO, with excursions in the Chilean and Argentine Andes.

Since that time competitive requests for funding and assistance to workshops and courses on the subject have been received from both regions.

UNESCO had to divide its financial resources carefully as only one event of this kind could be executed per budgetary period. Finally, from 3 to 8 December 1984 it was again the turn for South America. During the Sixth Session of the Intergovernmental Council of the IHP, Dr. Gordon J. Young of the Department of Geography, Wilfrid Laurier University, Waterloo, Ontario, Canada, had promised to contact IDRC for supporting the participation of a group of Canadian specialists in snow and ice in the *Jornadas de Hidrología de Nieves y Hielos en America del Sur*, as they were called. The regional meeting was a great success. Both Argentina and Chile had progressed a lot since 1971. Apart from a Japanese and a Swiss consultant, the Canadian group was headed by Gordon Young and guided by Raúl Vicencio, a Chilean geologist working at that moment with IDRC as Associate Director for Earth Sciences of the Cooperative Programme Division. Raúl Vicencio performed an impressive task as simultaneous translator. After the meeting the URH succeeded to persuade Vicencio to visit La Serena in order to become acquainted with the Camanchaca project. Vicencio could spend only one day in La Serena and conditioned the presence of Humberto Fuenzalida, Director of Department of Geophysics of the Universidad de Chile, as a consultant in meteorology. IDRC had been contacted already several times to assist the project and always they had showed interest in the subject, but never had any of them visited the experimental sites. ROSTLAC, with the help of Guido Soto, improvised a return flight to La Serena by private plane for the following group: Raúl Vicencio (IDRC), Humberto Fuenzalida (Universidad de Chile), Francisco Díaz who had recently left IREN, and his successor Raúl Campillo, also taking over as secretary of the Chilean IHP committee, Carlos López Ocaña from Peru (UNA and CIZA), Ramón Aravena (Nuclear Centre of the Comisión Chilena de Energía Nuclear) presently working at the University of Waterloo (Canada).

In La Serena the visitors were cordially welcomed by representatives of CONAF, SERPLAC and the University of La Serena including Luis Garin, Regional Secretary of the Ministry of Agriculture, Eduardo Rozas, professor in geology and mineralogy, Universidad de La Serena. Carlos Espinosa, arriving by bus from Antofagasta together with two volunteers of his *Los Nidos* project and Victor Denham, writing his engineer's thesis about the intercepting efficiency in El Tofo of 12 small fogtraps of 2-dimensional and cylindrical design with different geometry (chapter 9). During the presentation of the present state of the project the participants informed about their respective subprojects in Lachay (Peru) and Los Nidos (Antofagasta). El Tofo disposed at that time of two complete years of recorded meteorological data (in the process of being printed, 60) apart from one year recorded platform data which was never retrieved.

The large bi-dimensional fogtrap of 3 m X 30 m = 90 m^2 had captured water during 224 days in 1984 or during 62 % of the days. In 1984 the total annual yield was 85.4 m^3 varying from 38.2 l/m^2 per month to 128.2 l/m^2 per month or 947.8 l/m^2 or as an average 2.6 l/m^2 per day. The square one of 0.50 m X 0.50 m = 0.25 m^2, the most efficient of the series of twelve installed and controlled by Victor Denham, had produced as a daily average 3.8 l/m^2. (See also the data in chapter 9 extracted in detail from *Evaluation of the coastal fogs Camanchaca in the sector El Tofo* (60), published by CONAF in May 1985).

The fundamental idea of the establishment of the experimental station in El Tofo was always the proximity of Chungungo with its urgent need of drinking water.

During the following excursion to the experimental sites and Chungungo, the recently nominated burgomaster Carlos Fara Frederic of the Higueras community composed of ten more hamlets, mentioned that fuel expenditures amounted to 40.000 pesos per month to truck water to the widely extended community and the same amount for maintenance of the tankers and wages for the drivers.

Aravena reported on the activity of the Nuclear Centre through an agreement with the Catholic University, investigating to what degree Camanchaca water contributes to recharge on the basis of stable isotope analyses of Camanchaca, rainfall, and groundwater samples (2) (see also chapter 6)

The macro-diamond fogtrap in El Tofo, made by Carlos Espinosa, had produced one third less than the 90 m^2 2-dimensional one. (The inclination of the pyramid shaped macro-diamond followed approximately the angle of slope of the terrain. A macro-diamond structure in a more protruding position, would certainly have given more satisfaction.).

Also the new site Brillador of Eduardo Rozas was visited, but the visitors did not experience cloud interception as time ran short (Photo 35).

Humberto Fuenzalida focused on the need to study the cloud physics of the Camanchaca phenomenon by thoroughly examining the underlying meteorological parameters such as stability of the altitude of the temperature inversion, frequency of the occurrence, liquid water content of the clouds, percentage that can be captured with the available types of netting, wind influence, etc.

The physical aspect was not forgotten but it was expensive as it required sophisticated equipment. In this connection, first the recordings of the NASA meteorological platform should be analyzed.

Fuenzalida suggested a synoptical aerial survey in the area of El Tofo along profiles perpendicular to the coastline from the interior across the coastal range 50 km into the Pacific, with adequate ground control. A suitable fourteen days should be selected to carry out such an intensive survey.

Raúl Vicencio responded that in Canada he would recommend the support of the cloud physics study and that within three months after the meeting a letter from IDRC regarding the subject could be expected. However, to complete the survey by providing Chungungo with water seemed to him too simple and certainly not the task of IDRC. The URH disagreed with this last argument, reasoning that since Camanchaca had not yet been recognized by the general public as an economic water resource in specific cases, it is part of the scientific study to prove the economic productivity of the resource by introducing a first experimental exploitation and studying its overall efficiency.

Further discussions and arguments could not eliminate this difference of opinion. Without doubt the fact that the excursion had not come face to face with even a few minutes of active cloud-water interception had a psychological impact on the IDRC recommendation, by giving priority to the meteorology question: how often and how intensive are the coastal fogs?

On the other hand, the question of storage and adequate distribution becomes prominent once the cloud water interception, together with the jet stream (Photo 29) evacuating the captured waters into a container, has been observed. In the latter case the observer has been convinced that the phenomenon really occurs and does not need to prove its existence. Even educated Chileans and Peruvians are not aware of the potential productivity of the phenomenon. For instance, the Director General of the *Dirección General de Aguas* of the Public Works Ministry had doubts about its exploitability. When he had once visited El Tofo, the clouds did not appear. The reason is that 1) the arid north is very thinly populated and 2) if people live over there, they live or stay either on the coast as fishermen or tourists or in the valleys where the chance of finding water is always greater. Certainly people will avoid the narrow zone of frequent fogs unless economic interests (mining) or a single road crossing of the fog zone obliges them to do so. That is why only a few mineral prospectors and/or botanists may have some notion about the potential of Camanchaca.

Flying back to Santiago while the sun was setting above the hazy Pacific, Vicencio repeated his point of view and confirmed his compromise with respect to a letter within three months.

Time passed and no reaction came from IDRC. As in 1984 USA withdrew from UNESCO to which it contributed normally up to 23% of its budget, in the following period the ROSTLAC office suffered reductions in its originally approved budget. Funds allocated to the various IHP and MRP programme points agreed upon were subject to sudden cuts in the budget and it required a lot of financial acrobatics to follow up the established agreements. However, it is obvious that UNESCO was urgently in need of extra-budgetary technical assistance and/or funding that could take over part of ROSTLAC's responsibilities in promising subjects like Camanchaca development. The extra cost of flying the IDRC people to La Serena, neglectable for a funding organization but extravagant for the MRP budget, was compensated by the agreement with CONAF that IDRC financial contribution would mean the end of UNESCO's financial support. Of course, UNESCO would continue the technical support and cooperation contacts with other countries interested in the subject and relevant MRP projects for rational Camanchaca exploitation.

Time went by without any news. After a year or so an IDRC mission visited the ROSTLAC office in Montevideo in search of attractive projects. This was an opportunity to raise the subject again. Why had the IDRC reaction with respect to the Peruvian and Chilean request for assistance never come? Why had no reaction come from Canada after the oral statements made by Raúl Vicencio in La Serena? In the meantime he had left IDRC and had moved to the United Kingdom or was on the verge of doing so.

Anyhow, the IDRC mission was not aware of these commitments but assured us that this time they would certainly do something about it. After the explanation of the cuts in ROSTLAC's budget and the UNESCO responsibility to hand over the technical assistance of this project to a competent organization, the parties came to an agreement that IDRC would take over. Guido Soto was duly informed. ROSTLAC would make an effort to keep the project afloat until the takeover and would then stop funding Camanchaca research.

In the meantime letters had arrived in ROSTLAC from Headquarters, expressing HQ's doubts about the value of the project. What had seemed exciting at the beginning appeared in the long run to be a flop. So why not give up?

Of course, the fractioned handling and financing of the project with a regional coordinator far away in Montevideo, was not really beneficial to the project. Moreover this coordinator was occupied with the management of the entire MRP and IHP in Latin America and Caribbean, two extremely active and constructive programmes covering subjects from micro hydro-electric plants and restoration of pre-Columbian terraces and waterworks, to even the more social aspects of rural development like editing manuals, as for instance "*Agua, vida y desarrollo*" (Water, life and development) and execution of water balances.

In Chile there were the NASA group and the group of Humberto Fuenzalida of the Universidad de Chile, the group of Physical Geography of the Universidad Católica headed by Profesora Pilar Cereceda, the Comisión Chilena de Energía Nuclear, the Universidad of La Serena, SERPLAC II Región, SERPLAC IV Región, CONAF IV Región who fortunately had some influence on CONAF II Región and CONAF III Región due to the fact that Guido Soto adequately coordinated the internal distribution of UNESCO funds, also including after a while support to Espinosa. The latter, in the course of time, had ever-increasing difficulties with his University and also the contacts with his colleagues were in decline.

In Peru the UNDP Resident Representative Dr. Ramírez Boettner, acquainted with the Camanchaca phenomenon since 1971 through the author, offered to spend US$ 50.000 on it, but with a condition. Support could only be given in the form of an amendment to the ongoing WMO/UNDP project on the meteorology and climatology of Peru in which Vega Cedano, now retired from SENAHMI, was working. The possible participation of the associate organizations such as ONERN, INFOR, UNA, CIZA and the Universidad Nacional Federico Villareal was discussed un vain. Since the WMO/UNDP project had its established structure, participation could only take place on the basis of goodwill and communication among the groups in Peru. However, what could be expected with a lot of new faces in this project? UNDP, according to the rules, would provide transport and equipment but no money for fuel or operation of cars. In this connection, CONCYTEC reminded of the possible support suggested by IDRC during negotiations which had been broken off for unknown reasons.

With the original groups the contact had been sufficiently close to make the collaborators work according to certain criteria agreed upon, concerning communication, exchange of information and respect for the intellectual contributions of the other participants.

MRP had always been careful to mention the efforts of each of its collaborators. Because of this policy people had more confidence and communicated their new inventions and creations more freely to MRP. One must not forget that many scientists from developing countries have seen their work published under other names in western magazines (sometimes they are not even aware of the originality of their ideas), and also UN officials may not always have a clear conscience in this respect.

It was agreed upon that all new ideas and devices developed within MRP should be treated as the intellectual property of UNESCO, in the sense that they could be given free of charge to interested outsiders, but outsiders were not allowed to patent or sell this information.

In Antofagasta the situation was different. The scientists had always worked in an individual way, without coordinating or comparing their scientific observations. This resulted for instance, in the unexplained discrepancy of research observations and measurements of Espinosa and Zuleta.

In Peru the new air force heads of SENAHMI, forming the integral part of the WMO project, ordered strict secrecy from their civil employees among which the young meteorologist Cristóbal Pinche. At the start of his involvement Pinche had been invited by UNESCO to visit the various sites in Chile and to take up contact with his Chilean colleagues. Therefore, when he later wrote his *Tesis de grado* at the Universidad Nacional Agraria, La Molina (UNA) under the guidance of Professor Carlos López Ocaña (later forwarded to ROSTLAC), this lack of contact inside Peru and also with the Chilean teams could be compensated to a certain extent.

All these small problems could have been handled better with a more permanent presence of UNESCO in the region. Although HQ in Paris had been duly informed, UNESCO's critical circumstances did not allow an alternative. Transfers were frozen due to the economic difficulties.

After the *Jornadas de hidrología de nieve y hielo* at the end of 1984, Humberto Peña of the Dirección General de Aguas of the Chilean Public Works Ministry and member of the National IHP Committee, had taken up contact with the Argentine IHP group on an advanced course on snow and ice hydrology of one month duration to be held in Mendoza in end 1986. On both sides of the Andes scientists were busy with the preparation of the curriculum. ROSTLAC's budget of US$ 18.000 for the course was reduced by 50%. Gordon Young's group in Canada had again obtained support from IDRC to cover all the expenses of three lecturing Canadians. But who would pay the scholars? Trying to solve this question ROSTLAC contacted Peña. In spite of his efforts, he did not see a way out nor could his Argentine brothers, and so the course had to be cancelled for that year, but he had some positive news about the Camanchaca.

Before leaving, Vicencio had initiated the contact between Dr. Humberto Fuenzalida of the Universidad de Chile and Dr. Robert Schemenauer, researcher at the Division of Cloud Physics in the Atmospheric Environmental Service of Canada.

This information led to a visit of the URH to the Departamento de Geología y Geofísica of the Universidad de Chile, Blanco Encalada 2085, Santiago.

Fuenzalida told how after the meeting in La Serena in December 1984, and stimulated by Raúl Vicencio, he started to obtain the NASA meteorological platform data consisting of recorded weather information from El Tofo from September 1982 to August 1983. This covered just the important period of the "El Niño" phenomenon, which had been active to an extent never observed and recorded before. It caused not only weather disturbances in South America (drought in the Altiplano and in Northeast Brazil, excessive precipitation and floods in the Paraná basin) but also seriously affected the climate in other parts of the world.

The platform measured the following parameters: temperature, air-humidity, atmospheric pressure, solar radiation, wind velocity and direction, the water captured by a neblinometer (small fogtrap) mounted on top of a pluviograph of the "tipping bucket" type. The sampling time interval was one hour, obtaining in this way 24 sets of measurements a day, all collected on magnetic tape and finally processed by a computer.

The first four parameters provide the most reliable information, as instantaneous measurements of varying parameters like wind speed and even more so wind direction, do not represent correct average values.

The only corrected conclusion of Fuenzalida's report ((24) end 1985) is that the absence of the intercepted cloud water during the exceptional long period of 15th December 1982 to 14th February 1983 is a consequence of the stabilization of the inversion layer higher than usual (for this reason the F90 fogtrap was moved to a ± 200 m higher site). This was related to the higher ocean temperature.

Fuenzalida was not aware of this change of location and therefore interpreted the lengthy absence of fog in a different way. Again ongoing studies should better be discussed with all people involved and give each testimony the attention it merits after careful investigation.

Fuenzalida also showed a research proposal submitted to the IDRC Cooperative Programme by his department of the Universidad de Chile, the Instituto de Geografía of the Universidad Católica and CONAF, Ministry of Agriculture. This was made in consultation with Schemenauer in Canada.

While on mission in Bogotá Colombia, on 6th November 1986, the URH contacted the IDRC Regional Office for South America and had a long conversation with Mr.Robert Thornberry, deputy director for South America. The entire story of the IDRC- UNESCO relationship with respect to the Camanchaca project had to be told as Thornberry was not acquainted with the facts touching upon the following details: the initial IDRC interest in the Camanchaca project shown on various occasions, the meeting with Fuenzalida and Vicencio in La Serena to become acquainted with the work carried out, Vicencio's unfulfilled promise to react within three months, the agreement in Montevideo between IDRC and ROSTLAC to take over because UNESCO's budget reductions did not enable its continuation, the contact between Humberto Fuenzalida and Robert Schemenauer established by IDRC, and finally Fuenzalida's project proposal with the Universidad Católica forwarded to Canada at the beginning of 1986 and still awaiting reply.

Almost five years had gone by. UNESCO had extended its modest contribution in order to prevent the project from collapsing completely before IDRC could take over. Thornberry firmly denied that this behaviour of IDRC had something to do with the political situation in Chile, of which UNESCO and IDRC were obviously aware. And what about Peru?

Thornberry, expressing his sincere regret on behalf of IDRC with respect to this unhappy development, had not been aware of all this and reacted immediately by offering to call one of his men, who just happened to be on mission in Chile and was supposed to travel the next day from Concepción to Santiago. By phone the man was instructed to contact Humberto Fuenzalida or Guido Soto to reach some kind of agreement on the lingering affair.

It must be said, in fairness, that due to Thornberry's rectifying action the question finally reached a settlement. IDRC blew new life into the practically dead project when the UNESCO regional hydrologist (URH) and programme specialist in environmental sciences had retired and his successor had not yet been appointed. Therefore, since the project management had never been taken over officially, the project's strategy and responsibilities in the way UNESCO/MRP had created them were lost and the project took a new course.

PRELIMINARY CONCLUSIONS

12

II MRP Meeting

From 16th to 24th January 1987, after several delays, the II Meeting of the MRP took place in La Serena. The objectives of the meeting were:

- To examine the results of the ongoing 35 projects, among which "Use of coastal fogs: Camanchacas".
- To evaluate the technological exchange.
- To analyze the role UNESCO plays as a catalyst.
- To define the future course of MRP.

The meeting was organized by UNESCO/ROSTLAC in collaboration with the University of La Serena, SERPLAC IV Region and CONAF. Some 100 specialists from Latin American countries, with a majority of 60 from Chile, attended the meeting, while 12 active collaborators of the Camanchaca project were present, among whom one Peruvian and one Ecuadorian.

The working group on Camanchaca, after an introduction on the project's history, reached the following conclusions:

- *A large volume of information has been accumulated on different practical aspects such as: fogtrap design, water production, materials, related natural resources and historical background on the use of this resource in the past.*
- *Renewable natural resources in Camanchaca sites known as "fog oases" are highly degraded. In order to ensure a sustained production of the ecosystems it is necessary to restore the environment through the introduction of techniques for improvement such as reforestation, management of existing vegetation and soil conservation. The use of artificial fogtraps would constitute a first step in this operation.*
- *Camanchaca projects should be located where water is needed and a potential exploitation capacity exists, and for this purpose water collection yields should be studied and obtained on the basis of structures at the scale of practical use and suitable materials that will later allow for mass production.*
- *Along the Pacific coast there are places that are crucial from the point of view of the rational use of the Camanchaca resource, as for example: the Chanduy valley (Santa*

Elena Peninsula) and Galapagos Islands National Park in Ecuador, the National Reserve of Lachay and Atiquipa (16° Latitude S) in Peru, Fray Jorge National Park and Los Nidos and Chungungo in Chile.

— *Although Camanchaca constitutes a resource with economic potential for arid zones, the multidisciplinary and experimental character of its use makes it difficult to obtain funding at sectorial level, be it national or international.*

— *There is lack of basic information on aspects relating to cloud physics, dynamics of the phenomenon, the appropriate location of fogtraps in local topography and wind conditions.*

— *There is lack of additional information on appropriate technologies used for the exploitation of fogs in local communities, past and present.*

— *There are no common measuring standards for comparative purposes in the countries involved in Camanchaca research.*

— *There is no formal and systematic information mechanism between researchers that allows for its effective and timely use.*

Taking the above conclusions into consideration, the meeting recommended the following to the countries involved in the exploitation of Camanchaca:

a) *Undertake and rationalize studies on the methods used by existing traditional societies and by others long disappeared for the collection, conservation and use of cloud water, through interdisciplinary efforts that take archaeological and social anthropology aspects into consideration, in order to recover their technologies.*

b) *Elaborate a document with information on the fog phenomenon and its social and economic potential, to be disseminated among governmental and private institutions at national and international levels in order to obtain the funding needed for the execution of projects on Camanchaca exploitation.*

c) *Improve the exchange of information and adoption of equivalent technologies, especially concerning measuring units and instruments, in order to guarantee and ensure that the information obtained is comparable and usable by researchers of MRP-network countries.*

d) *Concentrate technical and financial efforts in places where the fog phenomenon has considerable social and ecological importance, such as: sites mentioned in the fourth conclusion.*

e) *Foresee the implementation of basic studies on the Camanchaca phenomenon in universities and research centres.*

Especially to Chile:

f) *Request SENDOS to take the appropriate steps to obtain the complementary funding required for the execution of the project on drinking water supply for Chungungo, as soon as the IDRC-Canada grant to this project is confirmed.*

The following criteria were adopted for the programming in 1987-1989:

— UNESCO/MRP *will promote projects that improve the quality of life in rural areas of Latin America and the Caribbean.*

— UNESCO/MRP *will fundamentally act as a catalyst in sponsoring and promoting activities.*

— UNESCO/MRP *will sponsor initial research (seed money) to encourage financial independence of the projects.*

— UNESCO/MRP, *in coordination with a given project, will collaborate in seeking funding for its conclusion and/or implementation and will remain as co-sponsor.*

— UNESCO/MRP *considers that all pilot projects should necessarily include demonstration, educational and extension activities.*

IDRC CAMANCHACA PROJECT, CHILE

On 23rd January the IDRC Executive Committee approved the **Project Camanchacas Chile**, which started on 1st of June 1987 on the same date of the retirement of the UNESCO regional hydrologist and general MRP coordinator.

The project was financed by IDRC and executed by the following entities: "Departamento de Geología y Geofísica" of the Universidad de Chile (DGG), "Instituto de Geografía" of the Pontificia Universidad Católica de Chile (IG), CONAF, and "Atmospheric Environment Services" of Environment Canada (AES).

Unfortunately, neither an IDRC representative nor Humberto Fuenzalida (DGG), Pilar Cereceda (IG) or Robert Schemenauer (AES) were present during the II MRP meeting, which explains the break in the project's strategy, although the new project focused just on some of the points that had been widely recognized as the existing gaps in the knowledge of Camanchaca.

The general scientific and practical objectives were to provide better understanding of the behaviour and micro-physics of the strato-cumuli along the coast of Chile and to alleviate the shortage of drinking water in one small isolated community: Chungungo. The two years' programme was centred at the El Tofo site. The main action was carried out during two periods of intensive field observations of 15 days each in the springtime, when according to observations the best conditions for water collection occurs. These periods were from 31st October to 14th November 1987 and from 31st October to 14th November 1988.

The specific objectives were:

To identify the optimum fogtrap location and optimum height at El Tofo surroundings, and to define site selection criteria for other coastal regions and make a preliminary study of other sites in northern Chile.

This task was given to IG and covered an expansion of the work carried out around the year 1982 in the IV Region by Larraín and Cereceda with the help of Carvajal.

To elucidate physical processes operating in the atmospheric boundary layer, particularly those related with the strato-cumulus variations, through the relationship between inversion base height and cloudiness, with synoptic and meso-scale conditions.

To correlate water volumes collected at El Tofo with the height of the trade wind inversion base, the sea surface temperature, wind speed, wind direction, and meso- and large-scale meteorological conditions.

To assess the quantity and quality of the water produced to be used potentially for potable water supply purposes.

The task of the last three points was carried out by DGG.

To estimate the efficiency of the water collectors (or fogtraps) was the task of AES.

During the concentrated investigation periods a small aircraft made two daily observation flights at ± 9 and ± 15 hrs local time, and meteorological data was obtained continuously at two fixed locations in El Tofo and Chungungo and occasionally at other sites. A large series of pilot balloons were released and followed by optical theodolites to obtain vertical wind profiles.

CONAF with some additional financial support from SERPLAC was responsible for the construction and maintenance of the fogtraps and for provision of drinking water to Chungungo.

Installation of a 2,400 m² intercepting capacity

CONAF started its work on 20th October 1987 and installed an intercepting surface of 2.400 m^2, consisting of 12 single fogtraps of 48 m^2 each, 19 double fogtraps of 96 m^2 each, and a 24.000 liter accumulation tank (Photos 33 and 34). The model of the fogtraps was based on the 40 m^2 fogtrap according to the design of Carvajal and financed by UNESCO, with the Rashell netting covering the fogtrap suspension cables (replacing the earlier rigid frames) at both sides, The construction and installation work was completed in a period of 4 months with a group of 8 labourers, a foreman, and "constructor civil"/project chief, at a total cost of US$ 28,000.

The criteria used for the orientation of the fogtraps were:

1. perpendicular to the predominant western wind, and
2. related to the so-called "pass" effect, caused by the local topographic relief near a depression in a mountain chain, locally deviating the general wind direction. In this connection, a long series of fogtraps were installed at about 780 m a.s.l., at the site of the old fogtraps and its lateral continuation, and a smaller series at 600 m a.s.l., slightly higher than Larraín originally built the 90 m^2 fogtrap.

Considering the pioneering character of this work, certain technical problems rose during the construction which were solved afterwards: e.g. the damage of the installed fogtraps, equipment and measuring instruments caused by animals attracted to the site by the presence of water. This was solved by surrounding the entire area of fogtraps and cistern connected by PVC tube with a solid fence.

Strong winds that sometimes accompany Camanchaca provoked rupture of the upper suspension cable that fixes the netting. This happened in the lower sector with the "pass" effect, where the wind is always stronger. This was solved by adding a pulley-wheel to the hook that keeps the cable up, and conducting the cable over a larger circumference to alleviate the friction which caused its rupture during periods of strong wind. Do not forget that the aerodynamic fogtrap abandoned the rigid frame structure. Moreover, the angle of flexion of the suspension cable towards the ground was decreased.

Originally the 4 m high netting was suspended by a cable at the top, one at the base with the plastic water collection gutter, and a third horizontal cable in the middle, at 2 m from the upper and lower ones. If the wind makes the netting bulge, captured droplets may easily fall behind the collection gutter, causing losses. These losses (15%) could be decreased by adding two more horizontal cables and diminishing the vertical distance between the cables to 1 meter, decreasing in this way the outward curving. It was also tried to reduce the losses by introducing a fiberglass collector with slightly lifted backflap of about 25 cm. at the base of the netting. This collector was rather expensive and so the first solution was by far the more practical one.

For the same reason, the collector at the base of the netting, originally made by cutting a PVC tube of 110 mm diameter in two equal parts or by taking away 50%, was later made by eliminating only 25% and by fixing the lower cable at the base of the netting in the central axis of the collector, in this way surrounded by the collector.

In order to fix the collector to the lower cable, galvanized wire was used. This wire suffered an accelerated oxidation process which also caused a reduction of the water quality. To avoid this the galvanized wire was replaced by plastic-lined wire.

Apart from Guido Soto, director CONAF IV region, it is important to mention the members of his competent team: Waldo Canto, forestry engineer, since 1983 in charge of activities in El Tofo; Juan Osandón, foreman, who has lived during the same period as the only resident in El Tofo; and Clemente Mendieta, his aide, who knows the Camanchaca and the fogtraps as a farmer knows his land and his equipment; further, Luis R.Elicer, CONAF engineering consultant ; and Juan Blanco, in charge of the administrative part of the Camanchaca project. These are the people who know the practical aspects of Camanchaca exploitation in El Tofo. Others who paved the road to the point presently reached are Zuleta, Espinosa, Carvajal, Cardich and others mentioned in the previous and following pages.

The theoretical meteorological and microphysical part absorbed a budget 10 times higher, with the following results:

Fogtrap efficiency

With respect to the intercepting capacity of a large-scale fogtrap, Robert S. Schemenauer and Paul I.Joe studied the efficiency of a 48 m^2 fogtrap with a double layer of Rashell netting, a triangular weave of flat fiber, 1 mm wide and 0.1 mm thick. As one layer of netting occupies 35% of the surface area of the fogtrap, a double layer depending on the overlap of the fibers can occupy up to ± 62% of the surface area of the fogtrap.

By locating two Particle Measuring Systems Forward Scattering Spectrometer Probes (FSSPs), both equipped with aspirators to suck the droplets through the measuring section at a constant speed of 25 m/sec., at 0.5 m in front and 0.5 m behind the centre of the intercepting surface (in this case at 3.5 m above ground level, as the netting had its base at 1.5 m above ground level, depending on the irregular terrain), the difference in liquid water content of the fog measured by the two FSSPs indicates the efficiency. The equipment was properly checked and calibrated. Normally the probes were operated with a nominal channel width 0.2 µm for each of the 15 channels. Occasionally this was changed to nominal channel width of 0.5, 1 or 3 µm to measure parts of the droplet spectrum in more detail.

During all measurements of liquid water content, droplet diameter, number of droplets and wind speeds were measured 6 m in front of the netting.

Table 29 shows the measurement results.

Table 29 - The collection efficiency of the netting for 10 sets of measurements near the center of the collector.The sample duration (t), liquid water content (LWC), efficiency (Em), droplet mean volume diameter (MVD), droplet concentration per cm^3, and wind speed are given.

Date	Position	t	LWC(g/m³)		Em	Front spectrum		Wind
	#	(sec)	front	back	%	MVD(µm)	Conc/cm³	m/sec
12 Nov 87	3	20	0.31	0.098	69	12	231	6.5
4 Nov 88	3	100	0.31	0.099	68	11.5	383	3.5
4 Nov 88	3	100	0.22	0.071	67	10.8	301	3.5
4 Nov 88	3	100	0.32	0.10	68	11.1	406	3.5
9 Nov 88	4	300	0.68	0.50	27	14.4	477	1.9
9 Nov 88	4	300	0.72	0.45	37	14.6	435	2.6
9 Nov 88	4	300	0.73	0.46	36	14.9	419	2.6
9 Nov 88	5	300	0.66	0.38	43	14.6	408	3.2
9 Nov.88	5	300	0.73	0.36	51	15.3	384	3.1
9 Nov 88	5	300	0.68	0.31	55	15.2	366	3.4

Table 30 shows a comparison of the calculated and measured flow rates from the 48 m^2 fogtrap on the basis of Table 27 data. Measured liquid water contents (LWC) were between 0.22 and 0.73 gram/m^3.

Table 30 - A comparison of the calculated and the measured fow rates from the 48 m^2 fogtrap

Date	LWC Removed g/m3	W s m/sec	Flow rate Calc cm3/sec	Meas. cm3/sec
12 Nov 87	0.21	6.5	65.5	18.5
9 Nov 88	0.18	1.9	16.4	5.1
9 Nov 88	0.27	2.6	33.7	12.1
9 Nov 88	0.27	2.6	33.7	17.1
9 Nov 88	0.28	3.2	43.0	24.2
9 Nov 88	0.37	3.1	55.1	14.7
9 Nov 88	0.37	3.4	60.4	20.7

These values are typical of the lower or mid-levels of cumulus (Schemenauer and Isaac, 1984) and are considerable above what Jiusto (1981) reports for marine or continental surface-based fogs. This is reasonable, given that the LWC in the Camanchaca can be of 0.7 g/m³ or higher, is of major importance in establishing the water availability on the mountain. LWC values this high or higher are supported by adiabatic LWC calculations on days with low pressure (1000 mb) and warm (20° C) cloud bases.

Droplet concentrations were between 231 and 477 droplets/cm^3 with an average of around 400 droplets/cm^3. The mean volume diameter (MVD) of the Camanchaca droplets ranged in the ten cases studied from 10.8 to 15.3 µm. Maximum droplet size rarely exceeded 30 µm (Fig 53).

The collection efficiency at the center of a 48 m^2 fogtrap is strongly dependent on both wind speed and MVD of droplets.

The efficiency varied from 27% to 69%. Values as high as 65% to 69% were measured for 11 MVD droplets when the wind speeds were between 3.5 and 6.5 m/sec.

Use of the measured centreline collection efficiency and the wind speed measured 6 m upstream results in a calculated large collector output that is as an average 2.9 times higher than the measured output. This implies that the actual average wind speed at the netting surface may be lower by a factor of 3 due to blockage effects of the large collector, or that the collection efficiencies across the netting are lower than at the centreline.. The implied efficiency of the collector as a whole is about 20%, i.e. it removes about 20% of the fog liquid water approaching it.

Schemenauer's conclusion is that fogtraps such as being used in El Tofo may be applicable at most of the locations with similar meteorological conditions; however, operations in extreme conditions such as very high or low wind speeds may require modification of the netting.

N.B. Comparing Schemenauer's punctual measurements of Table 29, which immediately produce efficiency values varying from 27% to 69% (mean value 52%) with the indirectly deduced values found on small screens by Zuleta in Antofagasta (1969) of 40 %, and by Waldo Canto and Victor Denham in El Tofo (1984) of an order of 30%, the latter averages, although lower, fall within the range of Schemenauer's observations.

However, observing Schemenauer's values more in detail, one notes the different probe durations of respectively 20 seconds, 100 seconds and 300 seconds. In Table 30 the measurements of the 3 sets of measurements of 4 November 1988 of 100 seconds each have not been taken into consideration because the fog event had just started and the output flow had not yet stabilized (according to Schemenauer). Eliminating also the first 20 seconds measurement of 12 November 1987, the 10 measurements of Table 29 are reduced with 4 of the unfortunately highest efficiencies to only 6 more representative ones. The latter ones measured on 9 November 1988, vary from 27% to 55% with a average of 41.5 %, fitting much better with the earlier Chilean observations.

For the 48 m^2 fogtrap the measured flow rate was 2.9 times lower than the calculated one on the basis of the centre point efficiency measurements (Figures 51 and 52). If one classifies the efficiencies in function of their areas of interception on which basis they were calculated or estimated, then one obtains the following succession:

1. The punctual measurements with the FSSP's with average 52% or the corrected value of 41.5%.
2. Zuleta obtaining from 1967 to 1969 at Miramar de los Morros with his battery of 0.10 m^2 surface area an average of 34% and corrected 40% if the 6% of large droplets that are blown off at the leeside are included. Of course small corrections should be made for the netting used by Zuleta, the altitude (Fig 54) (slightly higher) and temperature (about the same as El Tofo) at which interception takes place in Miramar.

3. Denham & Canto calculating as an average 30% over the period of one year of observations with their fogtrap F1 of 0.25 m^2 surface area.
4. The overall efficiency estimated by Schemenauer of a large (48 m^2) fogtrap of approximately 20%, or using his figures:

   52/2,9 = 18% Leaving out the first 4 measurements even

   41.5/2.9 = 14.5%.
5. Fuenzalida estimated the total output of the 12 single and 19 double fogtraps with a total surface area of 2400 m^2 in El Tofo to be of the order of 10%.

In spite of the sophisticated centrepoint measurements of Schemenauer, the rough extrapolation for large intercepting surfaces makes the overall results certainly not better than those covering long periods of observation made by Zuleta in 1969 or Canto and Denham in 1984.

By measuring entire horizontal and vertical efficiency profiles and the same at other sites, like for instance Fray Jorge and Antofagasta, the FSSP measurements would have allowed perhaps more reliable calculations of overall efficiency of large-scale fogtraps.

Of course MVD values or size (and mass) of the droplets and wind speed have a predominating influence on capturing as the product of the two, determining the momentum of the droplets, indicate to what extent turbulences in front of the netting, or airflows, which go around the obstacle, can deviate the droplets from their original course perpendicular to the netting.

Once a netting exposed to a dense fog gives a stabilized production, the netting is saturated and gradually approaches an effect on the wind equal to an impermeable barrier of the same dimensions as the fogtrap with respect to the wind.

In this way also the high efficiencies of the sets of measurements made on 4th November 1988 (from 67% to 69%) can be explained. They were high because they were made during the beginning of an interception event and the output flow of water had not yet been stabilized. The maximum permeability of dry netting for wind decreases gradually with the onset of the interception process until a stabilized flow of the captured waters is produced and the long-term efficiency decreases reaching an asymptotic value. Although the blockage factor of the wind by the fogtraps is recognized by Schemenauer, the factor of increasing blockage of the wind due to the gradual saturation of the netting was not considered.

Camanchacas Chile - IDRC project No 3-P-86-1008-02

Humberto Fuenzalida, José Rutllant, José Vergara and Patricio Aceituna of the Department of Geology and Geophysics of the Universidad de Chile wrote the results of their research financed by IDRC in two reports treating respectively the first and the second intensive investigation periods in the spring of 1987 and 1988. The work was carried out following the outline given by Fuenzalida during the meeting with Raúl Vicencio at the end of 1984 in La Serena, and the most relevant details of the Final Report presented in June 1989 are given in the next summary.

Since November 1987 records for at least one single 48 m^2 fogtrap are available. Monthly averages for this fogtrap vary substantially from 6.3 l/m^2/day in December 1977 to ± 2.0 l/m^2/day in August 1988 (Fig 55). The recording was not reliable during April, May and June and the latter two with extremely low values are most improbable. The mean annual value should be around 4 l/m^2/day.

Figs. 56 a and b show the average daily cycles for summer and winter. The recorded fogtrap is representative for the interception of the other 30 ones, as correlation trials demonstrated. Although at a particular moment the differences are considerable the mean values correspond fairly well.

Two adjacent fogtraps with different netting (one Rashell and the other an expensive netting made in USA with finer mesh) were furnished with flow meters. Sometimes the finer mesh performs better that the Rashell netting and at other times the Rashell is better. The size of the droplets may be significant in this connection. Anyhow, in the long run the Rashell one is not only much cheaper but also more efficient.

The base and top of the cloud deck were measured from an aircraft 50 km offshore at 9 and 15 hrs local time. Fig 57 shows that cloud top follows very closely the height of the base of the trade wind inversion . The cloud base does not follow the cloud top variations and although in most days it rises from the morning to the afternoon there are days when this does not happen.

In general, significant water collection seems to take place after a jump in the inversion base, following a transition associated to the pass of the coastal depression. The amount of water collected increases with the height of the inversion above El Tofo, especially in association to frontal lifting and weakening of the subsidence inversion (Fig 58 a and b). The relative position of the cloud top and base with respect to the altitude of capturing affects also the droplet size and liquid water content of the interceptable cloud stratum.

The automatic station at the summit of Cerro Carmelitas (1000 m) directly south west of El Tofo proved to be very useful in tracking the inversion on a continuous basis at El Tofo.

The small amounts of water collected when the inversion base descends beyond the El Tofo altitude seem to be connected with easterly orographic ascents, advecting lower level cloudiness, or through in-situ cloud formation if the lifting condensation level is attained before reaching the fogtraps during the westerly wind regime.

The wind regime in El Tofo shows pronounced daily cycles: western winds in the late morning, afternoon and evening, from midnight to 9 a.m. weak variable winds coming from the east. The diurnal cycle indicates that the evening maximum of water collection is associated with the strongest west winds, during night and at dawn small volumes of water are frequently collected with eastern winds, while the minimum at midnight is related to the change from western to eastern winds and the reverse in the early afternoon related to the diurnal warming that occurs just before the sea breeze starts (Fig 59).

The correlation between wind speed and water flow is demonstrated in Figs. 60 and 61. The scatter plots of the two variables show an increase of water collection points with windspeeds in the interval from 0 to 5 m/sec (Fig 62). Beyond this speed the growth stops and the points spread over a large range of water flow. Selecting several days with strong winds it was found that the break in the proportional relation is not of dynamic origin but rather due to solar radiation. In fact, turbulent transfer is increased by radiative or mechanical processes and this probably diminishes the size of the droplets by partial evaporation, lowering the efficiency in water trapping by the netting (see Fig. 63).

The sea surface temperature does not seem related to the cloud presence but its influence on the cloud base height deserves further investigation.

The quality of the water was determined on the basis of three water samples: the first one directly from the netting after several days without fog so that the sample was heavily loaded with the dust deposit, the second one was taken from the tank at the moment it was full of water from previous collection episodes, the third one was taken from the collector during the last days of the second field experiment. The results are listed in Table 31.

Bacteriological analysis have been performed on six samples. Samples 1 and 3 were taken directly from the netting, samples 2 and 6 from the tank and samples 4 and 5 from the pipe outlet from two collectors. Results are presented in Table 32 and show that the water collected is of very good quality, although the tank was contaminated.

From 20 to 22 April 1989 a Camanchaca Workshop was organized in La Serena by IDRC. Fortunately contact was taken up again with old Camanchaca collaborators like Carlos Espinosa and Ricardo Zuleta from Antofagasta, Pinche from SENAMHI, Peru and José Marcos from ESPOL, Guayaquil, Ecuador. Fuenzalida, Pilar Cereceda and Schemenauer presented their recent results, and a representation of the Sultanate of Oman headed by R. Whitcombe showed the characteristics of the Camanchaca phenomenon on their south coast of the Dhofar province.

The slow process of learning from mistakes

Returning to the II MRP meeting, when the technical secretariat gave an overview of the history of MRP it was reminded that its operation started with the compilation of the information presented by the members of the working groups set up for the I MRP meeting in Mexico.

The first exchange of experiences and techniques was carried out between regions of Latin America with comparable physiographic and sociological conditions, like Mexico around the Tropic of Cancer and the Andean region around the Tropic of Capricorn with populations of autochthonous and European descent, in an environment of dry altiplanos with garlands of volcanoes.

With respect to Camanchaca, exchange was sought in vain between Baja California and the Camanchaca project area, although it was known that the missing element in both cases is fresh water. (According to physiographic conditions in Baja California exploitation of coastal fogs may be feasible.) Other comparable fields of interests or activities followed.

Originally, MRP projects were classified in the following categories:

A. water management (with "use of coastal fogs" as A.3),

B. irrigation and drainage,

C. integrated development,

D. education and dissemination, and

E. drinking water and sanitation.

Later, when integrated development became more important, two more categories were added:

E. rural energy (generation and conservation) and

F. rural economy.

The crucial point was to help rural communities to attain "creditworthiness", the fundamental condition to gain access to credit and reach self-sufficiency. Therefore MRP/ ROSTLAC had recommended CONAF to involve the beneficiaries of a (new) technology as soon as possible with obligations and responsibilities they have to assume with respect to the later routine exploitation, like for instance the Camanchaca water supply, because to ensure that a water supply plant as isolated as El Tofo is functioning well, the local people should be in charge of its routine maintenance. And in order to prepare them for this task the technology should be assimilated by them as a new cultural acquisition so that they feel it is theirs, developed in their area of which they know the climatic conditions better than anybody else.

The pretentious western idea to give sophisticated tools with which more primitive people have to attain self-sufficiency, has proved to be one of the greatest historical mistakes. If a sophisticated or simply a new tool is not assimilated culturally, it will not be maintained and it will disintegrate with time, or become a status symbol not devoid of hypocrisy. This happened often in the Sixties with glorious donations like powerful deep-well pumping stations for the nomads and their cattle in the Sahel zone in the southern fringe of the Sahara. In quite a few poor developing countries the first gigantic and very expensive Inovac computers became in the early Seventies for any technical mission that passed by the show of paralyzed pieces. Do not forget the national remote sensing retrieval centres (mentioned already) introduced a little later in the same decade. Even the import of Frisian cattle in Africa, for instance, was a failure as the poor animals produced milk on the basis of self-service lush meadows surrounded by well watered ditches. But looking for their raw material in Africa they trampled down the scarce grasses in the savannah as they had not learned, like their African sisters, to walk in long rows on the endless cattle tracks to preserve the few palatable herbs that would be carefully relished in due time, to be converted to precious milk droplets. Fortunately the later hybrids, culturally more assimilated, fared better.

The MRP projects were divided into two groups:

1) Projects needing an initial research phase before being introduced as projects to be executed jointly with rural communities.
2) Pilot projects that could be introduced directly in activities executed jointly with rural communities.

The Camanchaca project belonged typically to the first category, but after the report written by CONAF in May 1985 called : *Evaluation of the coastal fogs (Camanchaca) in the sector of El Tofo*, quoted in this document, the knowledge acquired was sufficient to recommend the method as an original though realistic way to solve the water supply of Chungungo with the active collaboration of its inhabitants. The financing and perfecting of such an experimental plant was obviously beyond the capacity of UNESCO. So the IDRC project *Camanchacas Chile* was most welcome. But what must the Chungungo inhabitants have thought after groups of experts had been visiting their village since 1981 raising high hopes of a better future on the basis of Camanchaca water supply? In spite of these prosperous prospects, their poor water supply went down from 18 liters per person in February 1985 to 7 liters per person in 1987, while an average of 10.000 liters per day of clean water was flowing away at 6 km distance since the beginning of 1988.

UNESCO/ROSTLAC recommended the following with much emphasis during the II MRP meeting in January 1987.

Although the technology can be improved, it is possible today to intercept clean water from Camanchaca and it is known how to increase the interception by augmenting the quantity of fogtraps. Moreover, sufficient economic estimations have been made to make sure that water can be provided in the new way for less than the present costs per volume of water. However, before installing a large interception capacity, it is of first importance to construct a (small diameter) pipeline from El Tofo to Chungungo with storage capacity on the coast calculated for the most essential needs. Both water storage and piped water transport capacity can be expanded with time. Essential is that the precious water in this environment reaches its destination from the first moment of massive water production.

Negotiations should start with the inhabitants, through the existing community assembly of Chungungo, to provide labour and more skilled assistance with respect to the available know-how. Do not forget that fishermen have certain technical abilities certainly with regard to the construction of fogtraps. This capacity should be used to lower the construction costs and to make the new water supply plant the cultural property of Chungungo with guarantees of a well-maintained production in the future and with the possibility that the inhabitants themselves will provide later on the skilled labour required for installation of fogtraps elsewhere.

As the Camanchaca plant will be an experimental water supply which will undoubtedly attract attention, it should be operational as soon as possible. Afterwards there will be time to improve the system. For creditworthiness the first requirement is that something can be shown that works and justifies a credit for expansion and improvement.

MRP has had excellent experiences with integrated development projects in which the local population is providing all the labour and MRP professional collaborators provide technical advice and show alternative options which are presented to the local people so that they can express their preferences and select their most convenient solution, as they will have to live with it.

In Huaraco, at 4000 m altitude in the Bolivian Altiplano, the inhabitants are presently growing their vegetables in their own greenhouses, not only for themselves but also for marketing purposes. Solar water heaters, mud stoves, water management improvements, cattle raising practices, windmills for electricity generation and pumping, have improved their quality of life. The most important point was that they were included in the creative thinking process. After a relatively short time they took over, showing their ideas in the form of graphs and sketches on the blackboard of their new community house and discussing all aspects in detail with the community.

Until 1972 the majority of people in Peru lived in the Andean zone but since 1981 this has changed. Deterioration of the rural areas and unemployment drove the native people to the growing towns on the coast in search of work and food. Under the pressure of the emptying rural areas and the need of food supply in the crowded cities, the government had started to contract (with external financing) foreign consultants and contractors to reclaim new agricultural lands on the coast at an average cost of about US$ 6,000 per hectare. To introduce the costly irrigation and drainage systems on the coast (the latter ones not needed in the Andes) produced labour problems, as the coast has no rural population outside the 53 cultivable river valleys. Because of the high production costs on the coast its destination became more for export and to obtain foreign currency than to feed the population.

An ONERN study executed by Luis Masson Meiss, present director general of ONERN, showed that Peru has about 1,000,000 ha of terraced but often unused lands in the Andes mountains.

In contrast with the general trends in Peru however, life is changing in San Pedro de Casta, 90 km from Lima at 3.200 m altitude, situated in the upper part of the valley of the Rio

Santa Eulalia, a tributary of the Rio Rimac which traverses Lima on its short course to the Pacific.

In this mountain basin there exists an extension of 6.382 ha of terraces, of which 1.213 ha are still in use, 1.646 ha are lying fallow and are in a reasonable state of conservation, while 3.523 ha correspond to abandoned terraces in a far-reaching state of deterioration. Their recovery was considered unlikely but not impossible, depending on the availabitily of irrigation water.

After some orientation visits to the area, Luis Masson Meiss with the collaboration of professionals, most of them in their spare time and within the frame of a non-profit NGO: Naturaleza, Ciencia y Tecnología Local para el Servicio Social (NCTL), obtained at the end of 1983 a receptive response from local farmers to start recuperation of terraces in Casagayan, an eroded area belonging to the community, with slopes from 60% to 90%. In the course of several years the original distrust faded away and more and more farmers became involved in the activities until the MRP-supported NCTL assistance stimulated an integrated environmental development in which the entire community of 1000 inhabitants, including women and children, took part.

Masson Meiss' approach, which was an excellent example for MRP, was to execute the project in the following stages: evaluation, motivation of the beneficiaries, reconstruction, cultivation, and environmental integration. As Masson Meiss expressed clearly: *development of this type should never be imposed but should always be motivated; that means that one tries to motivate a development that starts from inside before coming out*". It should be understood that after long periods of moral repression, as happened with autochthonic and/or poor populations like the one of San Pedro de Casta, Huaraco and to a slightly less extent Chungungo (as it has a more creole composition), a certain amount of motivation is needed to overcome their internal doubts of own initiatives and capacities and re-establish self-confidence. Of course this procedure requires initially a lot of patience from the side of the motivators (which certainly in dictatorial Chile State organisms such as CONAF were not allowed to have), as well-defined goals should be obtained with time.

In San Pedro de Casta, the following results were obtained:

- Reconstruction of 5 ha of terraced lands in Casagayan in association with an important private multiplier effect of restored terraces in other parts of the basin.
- For several consecutive years harvests of 40 tons of potatoes/ha were obtained with improved potato seeds. In Peru a production of 7 tons/ha is normal and 15 tons/ha is considered a good harvest. The production of garden beans was also doubled.
- Reforestation with various species of trees was carried out along horizontal infiltration ditches to eliminate surface runoff and for the stabilization of slopes

like those above the cultivated terraces in Casagayan, and of course for firewood. Also a nursery was established in the village for additional private plantations and was run by the women, but reforestation did not take place at a large scale as the returns of this investment were considered too slow by the population and other more immediate useful items obtained preference.

— More than 6 km of irrigation canals were recuperated to bring water to Casagayan. Sections of maximum declivity were overcome successfully. This was to connect two previously deteriorated pre-Columbian storage reservoirs that were made operational again, with the respective areas to be irrigated.

The repair activities of the highest dam, 12 km distant, started in August 1985, in spite of the recommendation to start first with an easier case of more potential. This first work required the construction of a dam of 140 m long, 3.50 m high, with foundations 2 m depth, and an effective storage capacity of 11,750 m^3 at 4,500 m altitude, for complementary irrigation of 1,175 ha in the growing season, and the second easier one from a labour and access point of view, which needed heightening from 4 m to 5,8 m and waterproofing of an existing dam 22.5 m long, with expansion of 7.5 m to a total of 30 m length, with an effective capacity of 33,250 m^3 at 3920 m. altitude, started in 1987. Both rock-fill dams, designed by hydraulic engineer Andrés Gallarday F. of NCTL, were made with local material (except the cement) by the community members, in the form of unpaid labour contribution to the community during a certain amount of days per year, applying local technology.

As explosives for a quarry and excavations could not be allocated officially in this country severely suffering from terrorism, the local wizard produced explosives in his traditional way. The work could be realized in a series of task forces of twelve days each, during a number of years, in which three hundred community members participated in three shifts of 100 men at a time. They went up by foot with mules and donkeys, loaded with cement bags, their food rations and simple working tools, to defy the hardship of heavy work at those altitudes, and of camping with very low night temperatures. The financing of tubes valves and cement was covered partly by donations, partly with the profits of the extra agricultural production of Casagayan, but always in quantities which could be assimilated by the community's administration and proportional to what could be handled by the community in a foreseeable future. Each great accomplishment was duly celebrated according to their own ritual traditions, which meant cultural integration of the new acquisitions, like fish ponds, use of compost, introduction of new vegetables, inauguration of irrigation canals, and even a small fogtrap which produced some drinking water on the spot several weeks before the seasonal rains set in.

What kept the men moving was: "If our ancestors could make it, why should we not be able to do so?" At the same time the women took over at home the men's daily tasks.

The rainy season 1989-1990 was almost dry, but they collected the melting water of the high altitude precipitation in the form of snow and will have no problems this year. Due to this process the waterworks are unmistakably theirs and they will not let it deteriorate at least during this generation; therefore the effort has not been too great. Its description will stay as an epic in their assembly minutes.

On the basis of those examples it can be concluded that the Camanchaca project is from a MRP point of view, socially a failure. The beneficiaries were not involved to the extent they should have been. The investments in the form of work and installations made so far must have made little sense to them as they did not lead to a clearcut goal with respect to their needs. Even if one day the installation becomes operational, they will never consider its good functioning as something for which they can be made responsible, or else a radically different project strategy should be introduced.

Scientific conclusions and suggestions

Considering the extreme variability of precipitation in Chile as a whole, comparing for example the extraordinarily abundant rains of 1987, ± 900 mm in Santiago, with the dry year 1988, with only ± 100 mm., and an average annual precipitation of ±350 mm, always in Santiago, the Camanchaca is a much more reliable water source, although it varies also over the years (compare 1984 with 1988).

Camanchaca water can be used as long as the airflow carrying the droplets is not contaminated. In this connection Camanchaca exploitation should only be considered in areas free from any air pollution from towns, industrial plants, mining, etc.

Global warming will enhance the importance of the phenomenon. The rise of the ocean temperature will have its influence on the height of the temperature inversion, as was proved during the year of the period 1982-1983 of the extreme El Niño phenomenon in El Tofo, Chile and Pasamayo and Lachay, Peru. In the first case, the 90 m^2 fogtrap did not capture in the period of January and February for 60 consecutive days at its original site ±200 m lower than its later location. Also, the liquid water content will increase with higher temperature. It seems logical that with global warming, the Humboldt current will remain relatively cold, always provoking a thermal inversion if one takes into consideration the peculiar geographical setting of the west coast of South America. Also, an eventual rise of the inversion layer will not exceed for the time being the height of the coastal range.

The question raised, if an increase of the frequency of the El Niño occurrence is sufficient to explain the Holocene climatic history, or by extrapolation towards the future, a large scale change in the atmospheric circulation pattern and as a consequence could be the fundamental cause of climatic change, is likely to be answered negatively. For the resurgence of cold water along the west coast is a hydrostatic compensation of a slight imbalance produced by the tradewinds dragging the Pacific Ocean waters towards the Asiatic and Australian coasts. The predominant eastern component of the tradewinds is a consequence of the earth's rotation in the first place. Indeed, a stagnation in the resurgence of cold water producing a sudden rise of the ocean temperature along the west coast, as occurs during the El Niño phenomenon, would probably reduce or practically eliminate the continuous temperature inversion.

The correct scaling of conventional waterworks has to be based on statistics of long series of precipitation recordings and runoff figures. For fog water supply systems the wind regime, the frequency, thickness and altitude of the overcast, defining, as a function of the characteristic temperature profile, the liquid water content, have to be known for its scaling. It should not be forgotten that only some clouds produce precipitation, while every cloud contains droplets which can be intercepted. So a study of satellite images of the meteo-satellite (and others), a detailed study of the morphology of the interception site in a wider sense and its local impact on the regional meteorology are needed to start the design of a fog water supply system.

Considering all experiments carried out with fogtraps oriented perpendicular to the wind direction the following can be stated:

Although so far all investigators (except probably Carlos Espinosa) unanimously agree that fogtraps oriented perpendicular to the ruling wind direction provide the highest interception efficiency, it is the author's opinion that this question is not yet settled. For the time being this rule is valid for small fogtraps (with dimensions up to some square meters). Systems like the macro-diamond, in spite of its present disadvantage, should not be forgotten (Fig. 13 and Photo 37). The macro-diamond may work better if constructed in more protruding form with longer and stronger bars which can hold the weight of a man (Photo 39) to facilitate coverage with netting and repair works, on the condition that the water collection and evacuation can be solved properly.

The perpendicular position of the fogtrap optimizes the interception capacity when the fogtrap approaches minimum dimensions. With increasing dimensions the efficiency in this position decreases.

The balanced functioning of a fogtrap is reached when the intercepted water yield is equal to the evacuated yield and the mesh has reached its maximum saturation. In this case the fogtrap gradually approaches the characteristics of a closed barrier. The airflow towards the netting will produce with decreasing permeability of the mesh, an increasingly expanded turbulent air cushion, reaching its maximum expansion when the fogtrap is working at its maximum capacity.

A fogtrap placed perpendicular to the wind will, apart from the fraction that passes through, deviate the airflow in all directions parallel to the fogtrap. From the previous reasoning it can be concluded that the fogtrap efficiency will decrease with its surface area, and also with the increase of the wind velocity.

It is well known that a sailing boat goes faster in directions off the wind (half-wind) (when the projected surface area of the sail in the wind direction is smaller) than exactly down the wind (when the projected surface area of the sail comes closest to its real surface area). This is caused by the blocking effect of the sail on the wind in the latter case, which does not happen in the off-wind position of the sailing boat. In association herewith, for each wind force there must be a non-perpendicular orientation of a not yet defined angle, which will cause a better relation between efficiency and surface area of the fogtrap, especially for large to very large intercepting surface areas (of a size not yet made). A non perpendicular orientation of the fogtrap will produce a more guided deviation of the airflow, diminishing the disturbing influence of the air cushion and producing higher yields.

In this case one can again think of an angle with the horizontal or the vertical line of a plane perpendicular to the ruling wind direction, or an angle with any other line of that plane according to the topography and environmental situation of the fog harvesting site.

As a rule, a declined position of a fogtrap in the direction of the wind, will deviate airflow towards the earth surface, which for water capturing is likely to prevail over an inclined position, deviating the airflow to higher atmospheric levels.

One could imagine an intercepting (semi) rigid mesh hanging loose on a horizontal axis perpendicular to the ruling wind direction, and a heavy collector system attached to the basis, which allows the system to obtain an inclined position varying with the wind force. With a soft breeze the system should be in a practically vertical position. In a more sophisticated (and more expensive) way, a composite shape could be chosen according to a Venetian blind system, with netting strips not wider than one meter.

For instance, two protruding hilltops or rock outcrops of about the same altitude, flanking a pass or narrow opening in a mountain chain, well oriented on the ruling wind direction, might serve as the anchorage for a strongly tightened cable on which hangs the large intercepting structure. The larger the intercepting capacity and water production the more sophistication of the capturing interface and collecting/ evacuation system is justified.

Scale models of fogtraps should be tried out in wind tunnels conducting condensed vapour with different velocities.

Fog water harvesting should be studied and carried out in an integrated, interdisciplinary, inventive way, avoiding hampering conventionalism. Rational water production for man should be combined with practical ways to use the excess yields which make the installed storage capacity overflow, for trees, crops, etc. via efficient water distribution and application systems (and for animals, if they are not a danger for vegetation development). More improvised systems of fogtraps stretched between existing trees standing slightly apart, filling up watering troughs, will do for cattle in combination with vegetation. We are only at the very beginning of the exploitation of the fog water resource. Firewood collection should also be reduced by introducing solar cookers. With all respect for the work carried out by IDRC, the Universities and CONAF, it is the author's feeling that as soon as this exploitation comes into the hands of private enterprise to solve specific watering problems the method may gain in popularity. Ingenuity arising from necessity will certainly increase efficiency, if not in liters/ m^2, in liters per invested dollars.

Experience gathered on the west coast of South America, the Canary Isles, the peninsula of Santa Elena in Ecuador, Hawaii and many other places, has pointed out that, with priority, protruding vegetation on the windward slopes of mountains and hill tops which are frequently hidden in the clouds is not only beneficial for the water balance of these areas but even essential.

This vegetation should be preserved at all cost. In case such sites have been already deforested it is worthwhile to re-establish the vegetation. At the earliest government policies via eco-legislative measures are needed to protect such areas, while recuperation or re-establishment of the vegetation on such sites should be stimulated by incentives like subsidies or other encouraging steps.

In general, trees need to be preserved as much as possible, being essential for the beauty of the landscape. They should only be cut for good reasons. Their interception of droplets from fog always contributes to a great extent to the precipitation, apart from regulating the climate and the water flow on the earth surface, converting solar energy efficiently while filtering dust and contaminants from the air and producing oxygen for human and animal life, stimulating brain activity. Due to their disappearance they could become more and more the missing link in the production chain.

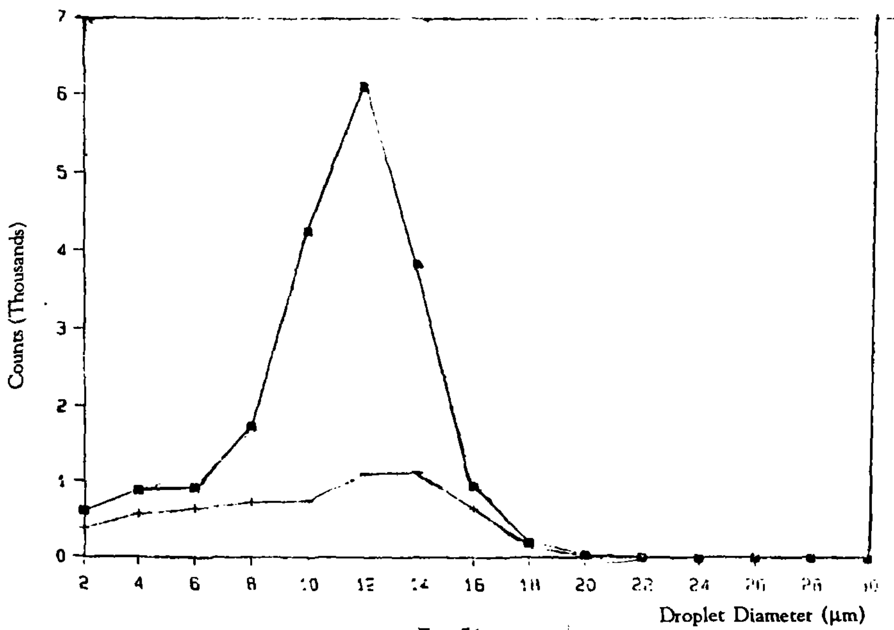
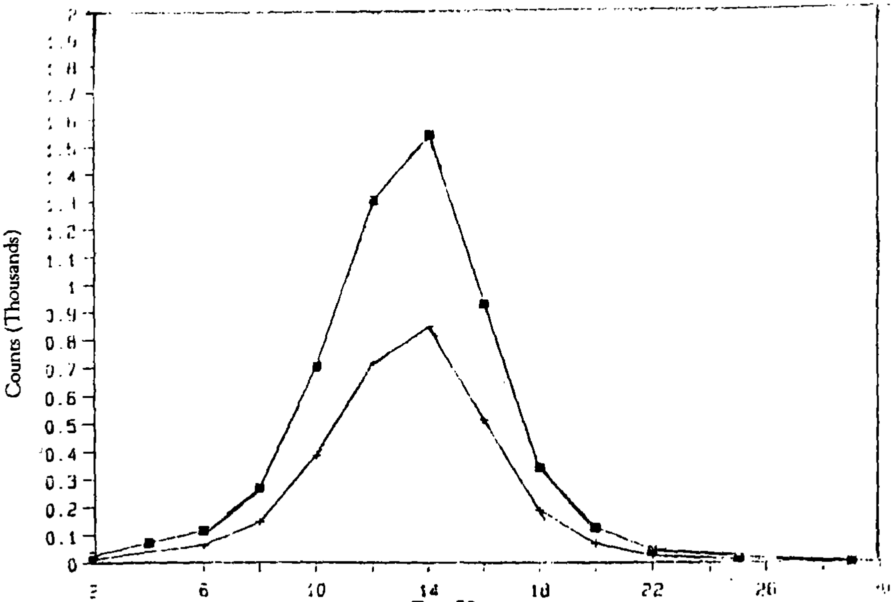


Fig. 51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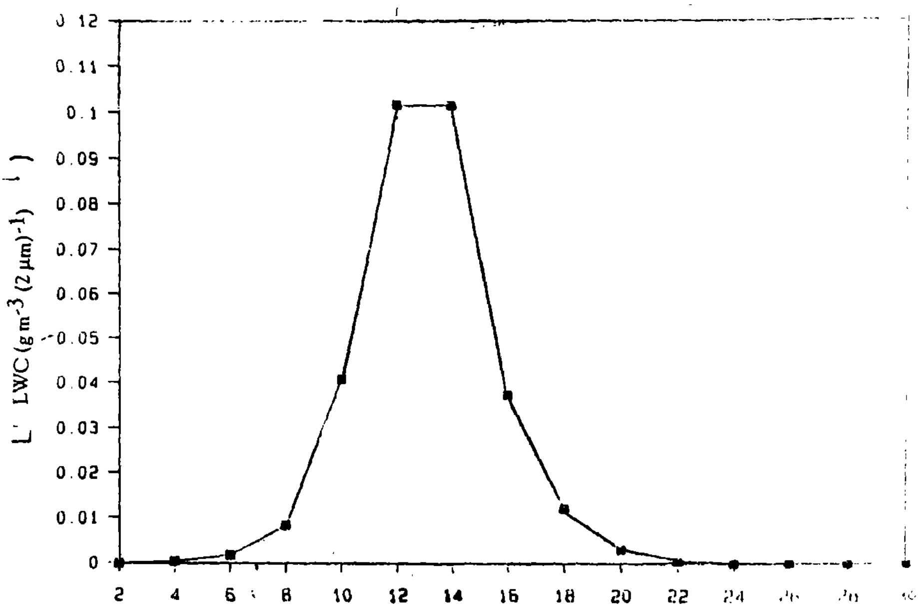
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6
10
14
22
Droplet Diameter (µm)

Fig. 52


LWC (g m-3 (2 µm)-1)
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0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2
4
6
8
10
12
14
16
18
20
22
Droplet Diameter (µm)

Fig. 53

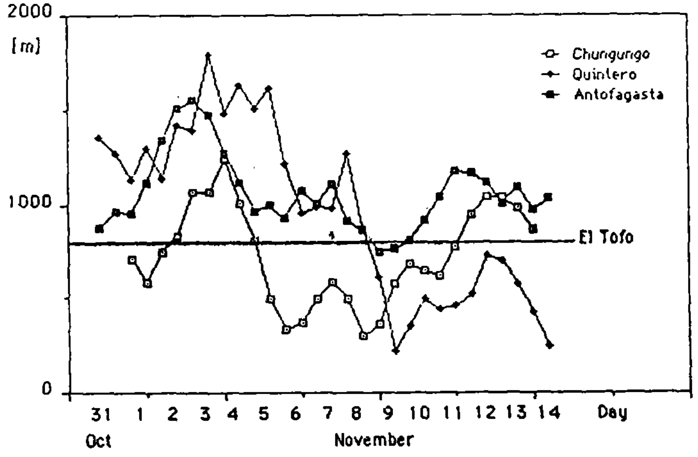


Fig. 54 - Smoothed variations of the inversion height at Antofagasta, Chungungo and Quintero

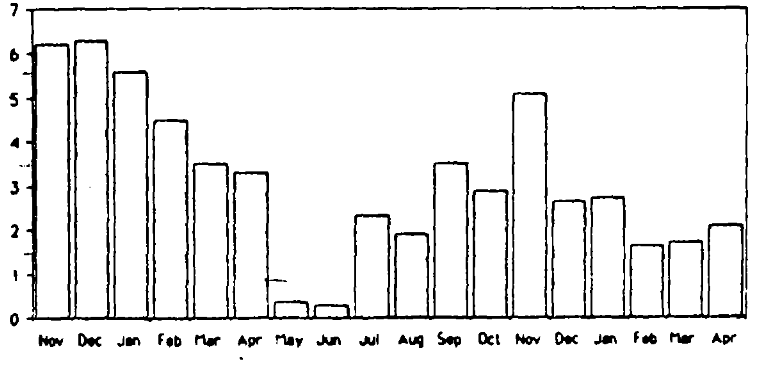


Fig. 55 - Monthly mean water collection (lts/day) per square meter of mesh (Rashell type)

Fig. 56a

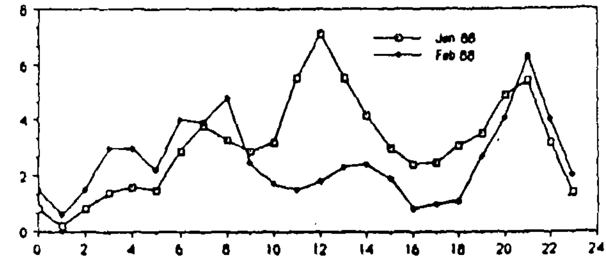
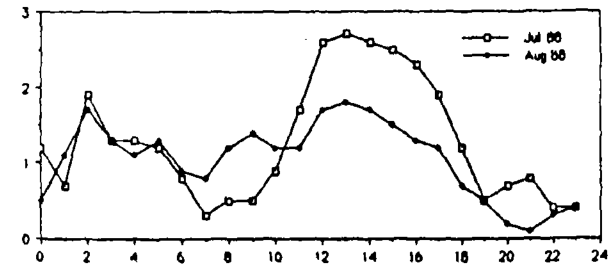


Fig. 56b



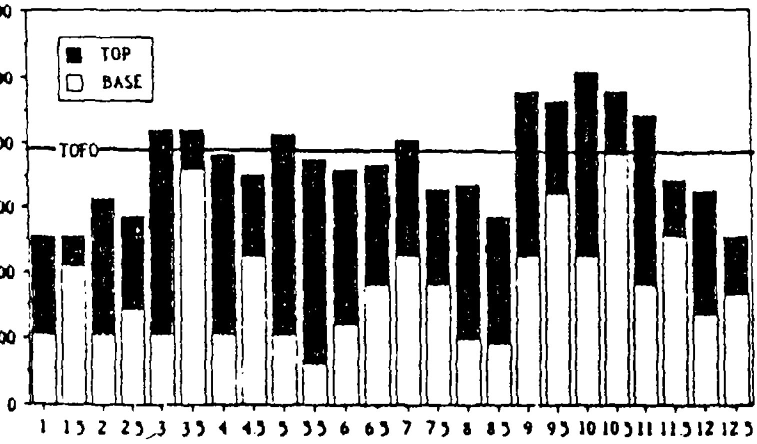


Fig. 57 - Base and top (m), of the stratocumulus deck 50 km offshore of Chungungo, determined at 9 and 15 local time. In abscissa the integer indicate the day of Nov. 1988.

Fig. 58a

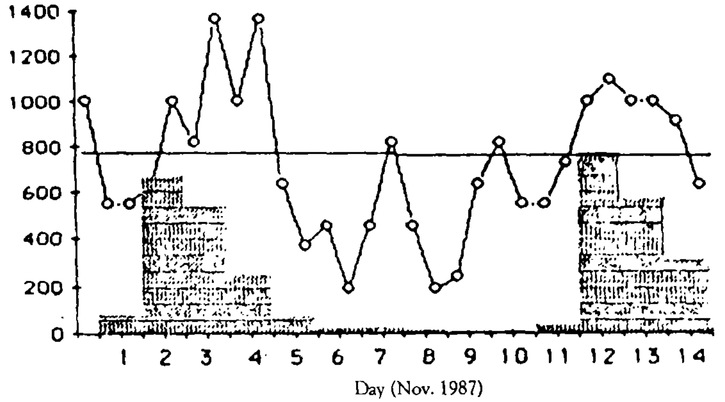


Fig. 58b

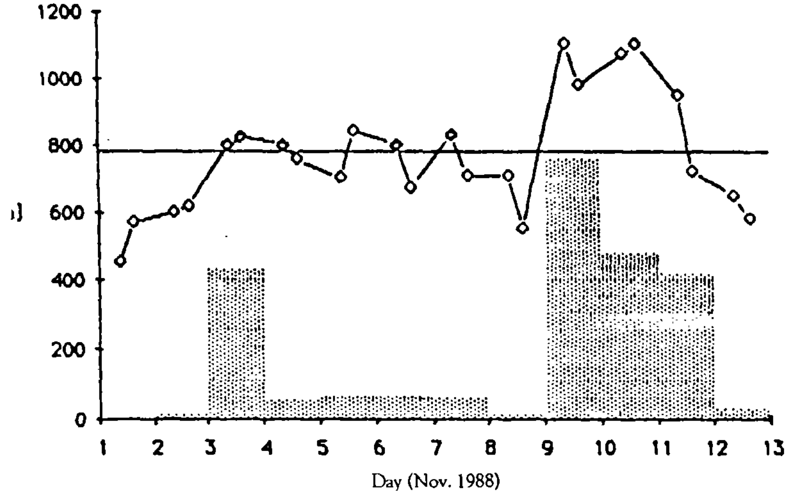


Fig. 58 - Inversion base height (m) (line) at 50 km offshore of Chungungo and daily water flow from a single 48 sq m. Rashell collector (lt/d). Horizontal line indicates the collector altitude. Upper part for Nov. 1987 and lower part for Nov. 1988.

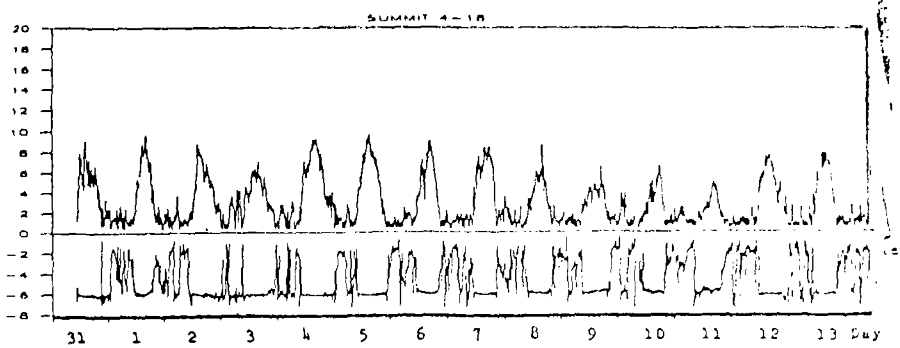


Fig. 59 - Wind variations at El Tofo. Wind speed (m/s) (upper) and wind direction (lower), north indicated by 0 and 8, east by 2, south by 4 and west by 6.

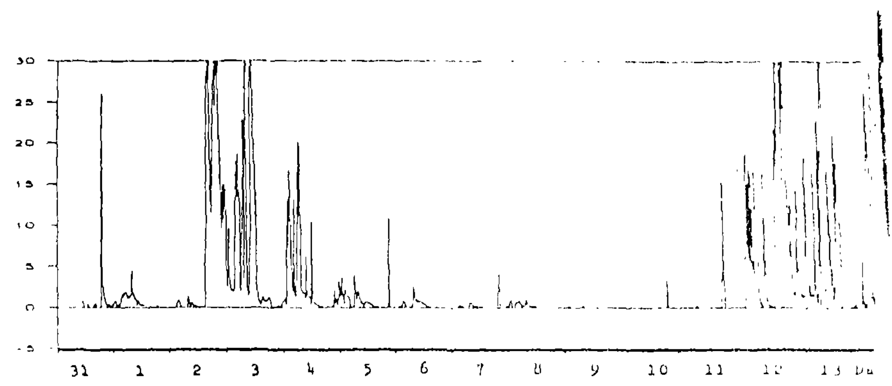


Fig. 60 - Water obtained from a 48 m^2 mesh collector (cm^3/s) for the field experiment. Abscissas are days from Oct. 31 to Nov. 14.

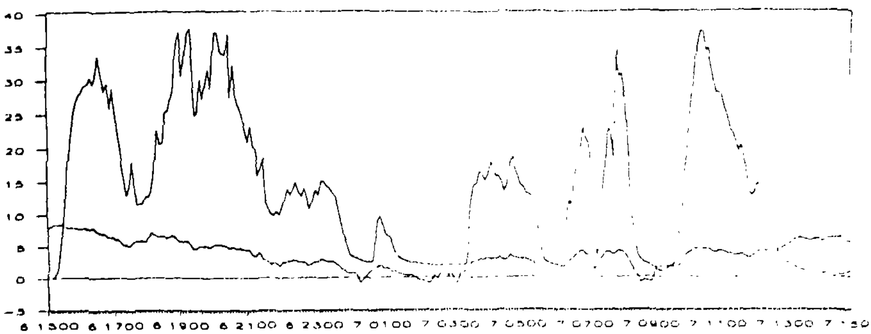


Fig. 61 - Zonal wind (m/s) (lower curve) and water flow (cm³/s) for a 24 hour time interval starting on Nov. 6 at 3 pm.

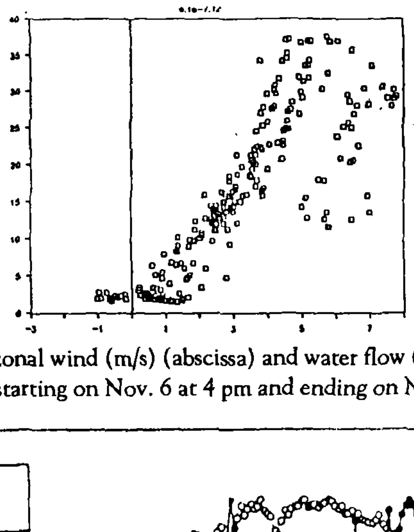


Fig. 62 - Scatter plot for zonal wind (m/s) (abscissa) and water flow (cm³/s) (ordinate) for a time interval starting on Nov. 6 at 4 pm and ending on Nov. 7 at 12.

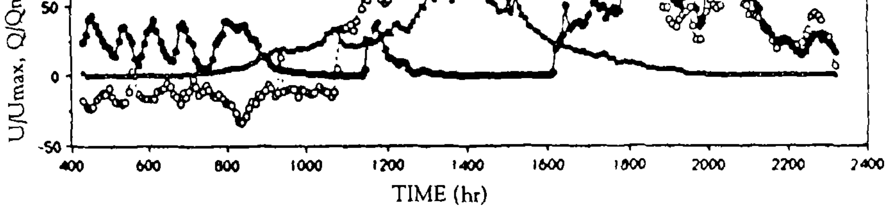


Fig. 63 - Wind speed, U, water flow, Q, and solar radiation, R, normalized to maximum values for Dec. 26, 1987 at the indicated local time.

Table 31 - Water bacteriological analysis

Sample estreptococcus	Date bacterial count colonies per ml	Sampling Place	Heterotrophic NMP/100 ml	Total coliforms NMP/100 ml	Fecal coliforms NMP/100 ml	Fecal
1	18-19/9/1989	Mesh	100	2.0	< 2.0	-
2	18-19/9/1989	Storage tank	700	79.0	7.8	-
3	30/9/1989	Mesh	30	< 2.0	< 2.0	< 2.0
4	30/9/1989	Collector outlet	30	< 2.0	< 2.0	< 2.0
5	01/10/1988	Collector outlet	100	< 2.0	< 2.0	< 2.0
6	01/10/1988	Storage tank	11200	26.0	< 2.0	< 2.0

Table 32 - Chemical water analysis

Sampling Date 18-19/SEP./1988 14/DEC./ 1988				
		First water	Storage tank	Collector #13
pH at 20°C		5.36	5.10	5.65*
Conductivity	(mhos at 20°C)	2819.00	337.00	-
Total hardness	(mg/L $CaCO_3$)	296.20	41.60	5.30
Calcium	(mg/L Ca)	83.00	7.70	1.20
Magnesium	(mg/L Mg)	21.60	5.40	0.50
Sodium	(mg/L Na)	340.00	32.00	1.50
Iron	(mg/L Fe)	8.00	0.60	0.00
Chlorine	(mg/L CL)	629.40	54.90	5.80
Sulphates	(mg/L SO_4)	224.00	36.00	6.20
Nitrogen (ammonia)	(mg/L NH_3-H)	11.20	2.10	-

Note: pH measure at 26°C

Photo 33 - New fogtraps built with IDRC support

Photo 34 - New fogtraps with detail of collector at the base of netting

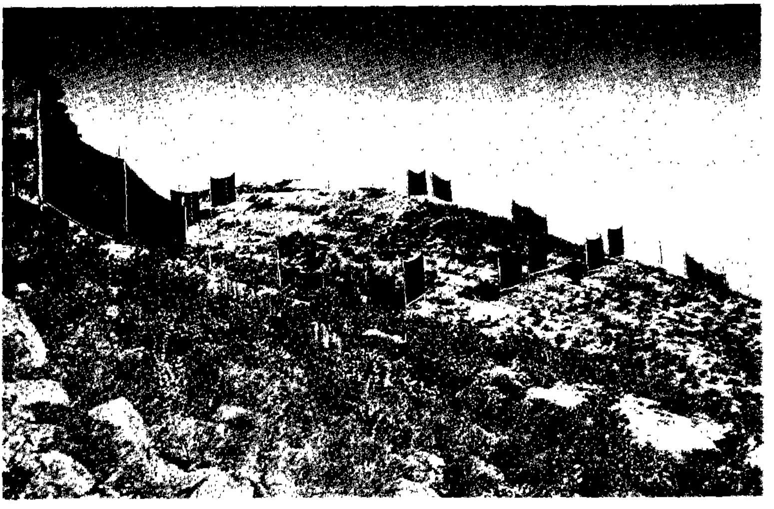


Photo 35 - New fogtraps

Photo 36 - Detail of tubing for evacuation of captured waters

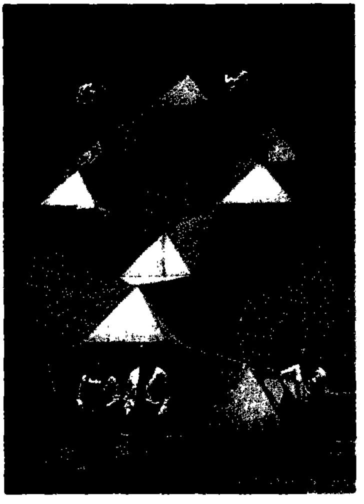


Photo 37 - General overview of largest part of 2400 m^2 netting

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The captions under photos 14 to 37 have been displaced by two places, i.e.: caption 16 corresponds to Photo 14; caption 17 to Photo 15; and so on.

On page 155 second line for "photo 35" read "photo 28".

Christiaan Gischler was born in Rotterdam (The Netherlands) in 1927. In 1953 he graduated as a geologist from the University of Leiden and in 1959 obtained a degree in hydrology in Grenoble (France).
He obtained his doctorate in hydrogeology from the University of Leiden in 1967.
The author has worked from 1972 to 1987 as UNESCO regional hydrologist and programme specialist in environmental sciences for the International Hydrological Programme, first in the Arab Countries and afterwards in Latin America and the Caribbean, where he coordinated the Major Regional Project on use and conservation of water resources in rural areas.
Being interest in H_2O in the widest sense, because of its indispensability for any form of life, he includes consequently its social implications. The earth sciences taught him that thanks to the occurrence of H_2O in the three phases: gas, liquid and solid, the solar energy keeps the hydrological cycle going, shaping the earth surface while regulating the climate and allowing man to interfere in the natural process by rerouting the water and use the surplus for its benefit. Spending his professional life either on the hydrology of semi-arid and arid zones like the Sahel, North Africa, the Middle East and the Atacama desert and Altiplano in the New World, or in areas with excess water like his home country, he realized that wisely rerouting sectors of the hydrological cycle where this is technically possible, profitable and harmless, requires a full understanding of the process and therefore an interdiscipilnary approach. Capturing fogwater from the Camanchaca clouds is such a case. It skips the usually needed precipitation and is useful where clouds which do not produce rain hit the earth surface.
He is the author of the following publications in the field of hydrology and water resources:

- A semi-qualitative study of the hydrogeology of the North Netherlands, Proceeding KNMG, The Netherlands, 1967.
- Outline of "Hydrology of the Sahara", in *Can desertification be stopped*, Swedish Ecological Society, 1977.
- Water resources in the Arab Middle East and North Africa, MENAS, United Kingdom, 1979.
- Low-cost techniques for water conservation and management in Latin America (with Carlos Fernández-Jáuregui), *Nature and Resources*, UNESCO, Vol. XX, N° 3, July-September, 1984.
- Different articles in World Water magazine, United Kingdom.

Since 1987 he lives in Chile.

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