Fog Collection in a Region of the Western Mediterranean Basin: Evaluation of the use of Fog Water for the Restoration of Wildfire Burnt Areas

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ABSTRACT

The Mediterranean Basin combines important problems in water resources due to its characteristic climatology. Urban development, irrigated-land expansion and aquifer stress are some activities among others that constrain water availability. Recently, the Meteorology-Climatology work group of the CEAM has been working in the analysis of fog formation factors and fog dynamics in Eastern Spain and also in the quantification of fog deposition and the measurement of other atmospheric variables at several mountain locations by means of passive fog collectors and meteorological instrumentation. This pioneer project in the western Mediterranean Basin is aimed to quantify and relate fog water collection to the meteorological and geographic conditions in order to evaluate this kind of resource. First results show that fog deposition may be comparable to precipitation amounts for a one-year period depending on location and exposure. During the summer period, when diurnal temperatures are high and rainfall amounts are small, fog collection can be as much as 100 l/m^2. The summer amount of collected fog water depends on the location of the experimental site, however it is above the summer precipitation amount in most of the cases. As a first application of the study, we have revised the possibility of using fog water for the restoration of areas that have been affected by forest fires in Eastern Spain.

1. INTRODUCTION

Due to its climate characteristics, the Mediterranean Basin is a region with important problems in water resources. Water supply is being strained all over the Eastern Spain because of the anthropic pressure, the expansion of irrigated land and the aquifer over-exploitation. Within this context, the Meteorology and Climatology work group has been determining the key factors for fog formation over coastal areas and also has been quantifying collected fog water as an input in the hydrological system (Millán et al., 1998). Some authors (Marzol, 2001; Marzol and Valladares, 1996) have also worked in other regions of Spain, not in the Iberian Peninsula but in Canary Islands, to evaluate the use of collected fogwater in rural areas for crop irrigation or population supply.

Coastal regions of Eastern Spain meet most of the geographical considerations for fog formation and potential collection as exposed by Schemenauer and Cereceda (1994). This region features some mountain ranges that rise to altitudes higher than 500 m and are close enough to the coast, no more than 10 km away from the coastline. Orientation of these mountain ranges is approximately perpendicular to the direction of the maritime east winds which bring clouds and moisture air to form coastal and advected fog. Two objectives have been proposed in this study. First, collected fog water must be quantified at several selected sites throughout different annual seasons with the aim of finding the most appropriate periods for collection and the final storage needs in a practical use. Second, a potential fog water use in the restoration of forest areas affected by wildland fires must be evaluated in the same selected sites in order to determine a number of vegetation units that may be restored.

2. METHODOLOGY

Three pilot sites were selected: Mount Bartolo, the northernmost site, Mount Mondúver and Mount Montgó, placed to the south of the region under study. These three sites represent different climatic areas and coastal wind exposures (see Figure 1).

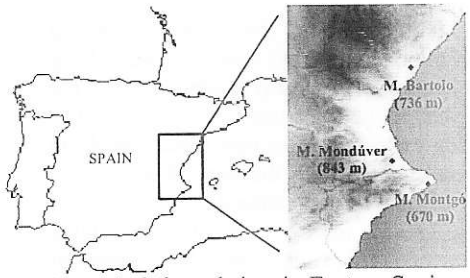

Figure 1. Selected sites in Eastern Spain

Instrumentation for fog collection measurements at each site is made up by a number of different sensors. The fog collector itself is handmade, being based on the ASRC (Atmospheric Science Research Center, State University of New York) string collector (Falconer and Falconer, 1980). It consists of a cylindrical polyamide frame to which 1000 vertically oriented and closely spaced (1.8°) nylon strings (0.8 mm in diameter) have been mounted in five concentric circles. This sensor acts as a passive continuous fogwater collector since it lacks from mobile parts or other mechanical devices. The collector is 46 cm high and 26 cm in diameter so it exhibits a cross-section exposure area of 46x26 cm^2 to the actual wind direction. Water drainage is made by means of several holes on the base frame and silicone tubing that leads into an enclosure containing a tipping bucket raingage (see Figure 2). A polypropylene cylindrical tray was attached to the top of the string collector to prevent contamination by rainfall as far as possible. The collected fog water volume per unit area (l/m^2) comes from dividing the collected volume by the cross-section area.

The string collector is set on top of a galvanized steel pole of 3-m height. Other meteorological instruments are also appended to the pole at different heights (Figure 2). From top to bottom, these sensors are: an integrated vane-anemometer, a tipping bucket raingage, four parallel-connected wetness sensing flat grids and a temperature and relative humidity probe. Finally, a Campbell CR510 data logger and a GMS communications modem are allocated into a watertight enclosure. Sensor sampling is made at 6-second intervals in the case of the wind sensor and tipping buckets, and 1-minute intervals for the other instruments. Data is recorded as 10-minute averages of the sampling measurements, and these are daily transmitted via GMS communications to the CEAM central station. A 12 V battery and a 10 W solar panel power the whole instrumentation so the system can work unattended.

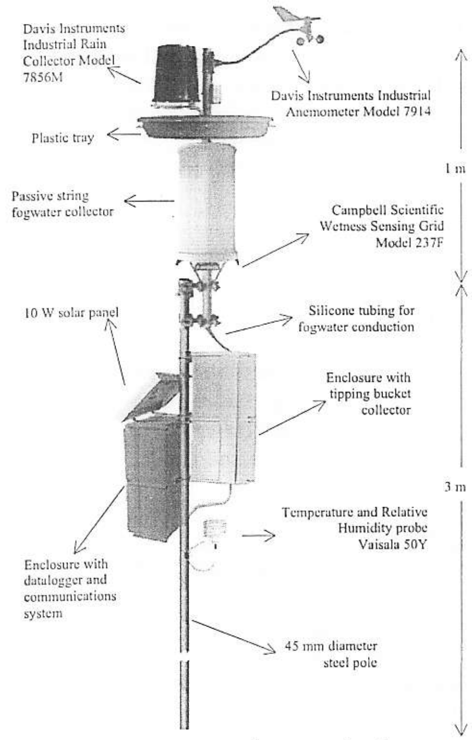

Figure 2. Integrated system for fog water collection and meteorological measurements

These added sensors to the string fog collector have allowed to achieved quality measurements of several meteorological parameters that appropriately complete fog water volume data.

The above integrated system for fog water collection has been set up for last year (2003) at the three selected sites. Data collected during periods when wind velocity was greater than 10 m/s were discarded. This practice was useful to remove strong gales or storms that are not the actual interest of the study and also produce data of difficult interpretation. Data recorded for periods of wetness sensing grid response not close to one were also rejected because it was considered they could not represent wet conditions that prove either rainfall or fog episodes. Rainfall was then computed from the reduced data set at 10-minute intervals, and daily and seasonal total values were calculated. From this reduced data set, a fog collection 10-minute sample was also discarded if precipitation greater than 0.5 mm occurred in the previous one hour period. This practice tried to prevent fog measurements from contamination due to rainfall in combination with wind episodes. Finally, fog collection volumes were computed, and daily and seasonal total values were also calculated.

Although the study has a clear purpose towards the design of a method for obtaining and storing fog water to be used in the restoration of degraded forest areas, we only present first results of the experimental part with regard to the quantification and frequency of fog collection.

3. RESULTS

1.1 Collected water volumes

Table 1 shows the total seasonal values of rainfall and collected fog water that were measured after the application of the methodology that has been exposed above.

	Mount Bartolo		Mount Mondúver		Mount Montgó	
	Rain (mm)	Fog (l/m^2)	Rain (mm)	Fog (l/m^2)	Rain (mm)	Fog (l/m^2)
Summer	57	55	141	114	75	173
Autumn	161	145	425	19	338	348
Winter	66	77	321	234	71	369
Spring	290	32	178	148	209	180
Total	574	309	1065	515	693	1070

Table 1. Total seasonal values for collected rainfall and fog water.

Mount Bartolo presented a total annual precipitation of 574 mm and a total annual fog water collection of 309 l/m^2. Fog collection is not equally distributed along the study year. Autumn and beginning of winter are the periods when greater volumes of fog water can be registered. It can be observed how fog collected volumes are similar in value to precipitation volumes during the length of a season, except for spring. Having in mind that summer is a quite dry and hot season, collecting fog water during this period for irrigation of degraded forest areas may be an important practice for the restoration of such areas. The predominant wind direction for the development of fog is south-southeast with mean wind velocities under 15 km/h.

Mount Mondúver presented the highest total annual precipitation of the three sites with a volume of 1065 mm, while the associated total annual fog water collection was around 515 l/m^2. Maximum values took place in winter and spring, and the low values in autumn were due to a technical problem. During spring, the seasonal collected fog water volume is of the same order as the precipitation volume. Winds during fog episodes are predominantly from the East and Southeast directions with speeds below 15 km/h, reaching values around 25 km/h for some intervals during winter.

Mount Montgó shows the most interesting results of the three selected sites. The annual fog water collection (1070 mm) is almost twice the annual precipitation volume (693 l/m^2). The highest fog collection rates take place mainly in autumn and winter alike the two other sites. In this part of Spain characterized by hot and dry summers, it stands out how the collected volume for fog water is more than twice the volume of precipitation during this seasonal period. Winds are predominantly from East and Southeast directions with mean speeds around 15 km/h, reaching occasionally values around 25 km/h.

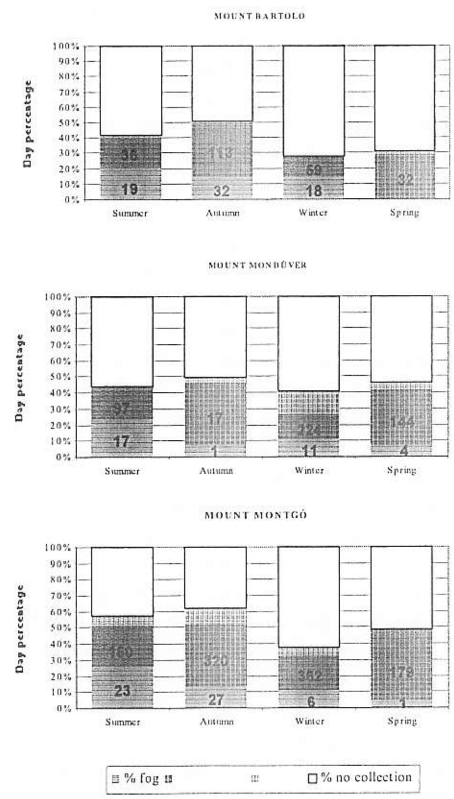

Figure 3. Seasonal percentage of days with only fog, fog and rainfall, and only rainfall collection.

Figure 3 shows the number of days in percentage for which fog only, rain only or both were collected. It is clear that when only one element is collected, there is not contamination from the other. For days with both rain and fog collection, contamination is also minimal after data reduction as explained in Section 2. As stated there, fog data were considered valid if the previous 1-hour rainfall was less than a threshold of 0.5 mm. Therefore, days with both rain and fog collection contain episodes of these two elements at least one hour apart. For these days it was verified that reducing the threshold to zero, obtained volumes for fog water were similar or a bit smaller; while setting this threshold to a greater limit, fog water volumes were almost twice the earliest values.

The figures that appear on the bars of Figure 3 represent the seasonal fog water volumes collected for days with presence of fog alone and days with presence of both rain and fog. The sum of each pair of figures equals seasonal values of fog water that appear in Table 1. As seen, fog episodes alone bring less water volumes than episodes accompanied by rainfall, even though the percentage of days with presence of fog only is bigger.

1.2 Geographic variability

The three selected sites show different annual collected fog water volumes even though they share geographic conditions as altitude and proximity to the coastline. The least volumes were registered at the northernmost site (M. Bartolo). This finding may be explained because of the orientation of the mountain ranges. In the case of the northernmost site, wind directions for the development of fog episodes must be South and Southeast which in fact do not correspond to prevailing winds in this area of the Mediterranean. However, the other two sites are perfectly exposed to the east winds, which are more common in Eastern Spain. With regard to wind speed, collection of fog water is maximum when values are around 15 km/h. There have been no fog episodes when wind speed has reached values above 28 km/h. The differences in water collection of the three sites cannot be due to the small differences in altitude nor to differences in fog thickness which are unreasonable.

Having in mind that some technical problems occurred at M. Mondúver that could deplete the measured volumes, there seems to exist a North to South gradient of collected fog water. Fog episodes are more frequent at M. Montgó rather than at M. Bartolo.

4. CONCLUSIONS

- During summer, fog water collection volumes can be as high as 100 l/m^2. This value may be considered an important water input for areas with hot and dry summers since it may even exceed the precipitation amount for those periods.
- This preliminary study has shown very promising results in Eastern Spain in order to obtain a new water resource as an input for the restoration of the degraded vegetation canopy after a forest fire. The fogwater collected volumes meet the irrigation-required quantities of 10 to 20 litres per pine plant for a standard forest plantation of 800 to 1000 trees. The small trees need only one or two waterings in their first year after planting (Pemán and Navarro, 1998).
- Forest restoration is critical during summer because of the lack of available water. An important water contribution for this period could be obtained from fog water collection as demonstrated in the study.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Falconer, R.E. and Falconer, P.D. (1980) Determination of cloud water acidity at a mountain observatory in the Adirondack Mountains of New York State. *J. Geophys. Res.*, **85**, 7465-7470.

Marzol, M.V. (2001) Fog: drinking water for rural zones. *Second International Conference on Fog and Fog Collection*, 247-250.

Marzol, M.V. and Valladares, P. (1996) Evaluation of fog water collection in Anaga (Tenerife, Canary Islands). *First International Conference on Fog and Fog Collection*, 449-452.

Millán, M., Estrela, M. and Vallejo, R. (1998) Evaluation of the hydrological inputs in the Mediterranean basin. *First International Conference on Fog and Fog Collection*, 281-284.

Pemán, J. and Navarro R. (1998) Repoblaciones forestales. *Edicions de la Universitat de Lleida*, 400 pp.

Schemenauer, R.S. and Cereceda, P. (1994) Fog collection's role in water planning for developing countries. *Natural Resources Forum*, **18**(2), 91-100.