# RESEARCH BY ROBERT KOURIK

*Although the following was accepted as a keynote address at an international water-use conference held in Beijing, China in July, 1995, it has not appeared in any U.S. gardening magazine; this is primarily because editorial space in such magazines is geared toward the statistically-average reader, not to sub-groups like people living in coastal-fog areas with dry summers. While this article doesn't apply directly readers who live outside the California coastal zone, it is a model for the importance of understanding very local environmental nuances. This is a condenstaion of the longer, original paper about condensation!*

## Capturing the Clouds: Fog Drip & Cisterns

Did you know that many Californians overlook 32 to 123 inches of "rain" each year? Although actual summer rain is scarce-to-nonexistent in the Northern California Mediterranean coastal zone where I live, another type of "rain," consisting of droplets of condensed fog, is a frequent occurrence. Moist summer (and winter) fog condenses on the leaves of plants and forms droplets like the hot-weather "sweat" on a bottle of cold soda.

My house is at an elevation of 1200 feet. It’s located on a wooded ridge which divides a hotter, dryer inland plain from the more temperate, wetter Pacific-Ocean climate; the average winter rainfall on this cloud-scraping ridge is about 58 inches per year. Summer or winter, the collective needles of Douglas fir trees near my house offer an immense surface area for condensation. Shortly after moving to my ridge, I noticed that a foggy summer evening produced the sound of steady rain beneath the tallest trees, while the meadow 20 feet away remained dry.

Curious, I decided to document the amount of usable "rainfall" generated by this phenomenon. The resulting paper, "Fog Drip in California and its Implications for Cisterns,” addressed four important omissions in scientific literature with regards to fog drip and using cisterns to capture it:
1- No studies had measured fog drip under the same tree(s) for more than one year.
2- There was no documentation of the different rates of fog precipitation under one tree at various intervals out from the trunk.
3- The implication of harvesting fog drip for cistern catchment and recharge was noticeably ignored.
4- No one had studied the possible impact on native flora from harvesting fog drip .

**Abstract**
The author compares ten years of fog-drip measurements with measurements from a control rain-gauge set in a nearby open meadow. During the ten-year study, the fog-drip harvest under a 200-foot Douglas fir ranged from 155% to 312% of the year-round rainfall on the adjacent meadow.

For two years, rain-gauges were placed every five feet out from the trunk of a shorter (85-foot) tree and every five feet from the trunk of the original tree. The water collected under the taller tree ranged from 12% less to 44% more than from under the shorter tree.

This paper summarizes the quantity of fog drip under two trees of different heights as well as at various distances from their trunks. The paper also examines the potential for recharging a properly located cistern with a collecting roof built beneath trees in areas with seasonal fog.

The vegetation around my house is composed of open grazing grasslands and mixed oak/Douglas fir/Coastal redwood forests containing virgin Douglas firs over 200 feet tall. The climate is Mediterranean and most of the rainfall occurs in the winter between October and April. Summer rainfall is *very* infrequent.

The tallest tree near my home is a Douglas fir which is approximately 00 feet tall, with a 56-foot-wide canopy, and, at 10'-75' above all other adjacent trees, is well-positioned to intercept fog and clouds from the southwest.

Tree #2 in the study is on the northeast (leeward) side of the taller tree and, at 85 feet tall, is about 67% shorter than Tree #1.

**Methods**

The intent of this study was to set up a monitoring program that could be easily and inexpensively replicated by the average homeowner. No expensive or complicated meteorological equipment was used.

Two primary conical rain-gauges, each with a capacity of 5.5 inches, were installed in 1985, one located arbitrarily 19 feet from the trunk of Tree #1 and the other in an adjacent meadow.

For the second study of fog drip at various intervals beneath the canopy, eight simple and inexpensive ($3) tube-type gauges, each with a five-inch capacity (in 1/10-inch intervals), were used (provided by my folks). During the second phase, beginning in 1992, these simple cylindrical gauges were placed every five feet from the trunks of both trees.

**Results**

For the ten years of fog drip and rain measurements during that time, under Tree #1 there were 19 summer months with no measurable rain in the open-sky (OS) rain-gauge, but measurable fog drip beneath the Douglas fir tree (DF). In general, the DF captured more water than the OS gauge, even during actual rainfall in the winter rainy season. The lowest ratios between the DF and OS gauges for a month were a negative 22% in December 1990 and a positive 1% in January 1985.

The highest measurable rain harvest beneath the DF tree was 29.55 inches in November 1988—during a protracted six-year drought. The lowest recorded monthly summer-fog harvest for the DF gauge was .8 inches in May 1985. Under Tree #1, the position of greatest fog drip was approximately 68% of the canopy's distance from the trunk.

Measurements under Tree #2 show a similar pattern of fog drip relative to distance from the trunk. Tree #2 showed a 12.2% increase in water at a gauge located five feet from the trunk compared to the one at the edge of the canopy. During the 1993/1994 season, the gauge at a 10-foot distance from the trunk of Tree #2 gathered 13.5% more water than any other gauge, although no gauge located beneath Tree #2 in that year captured more water than the OS raingauge.

The annual ratio between the DF and OS gauges varied from a low of 167% in the 1992/1993 rain season to the highest recorded amount of 312% more precipitation under the DF for the 1989/1990 season. During the ten-year study, the arithmetic mean of DF-precipitated water was 225% greater than the OS gauge.

Comparing Tree #1 to Tree #2, the taller tree harvested 36-44% more water than the smaller tree.

**Discussion**

An inverted conical roof, screened to keep out debris and animals, can cover a cistern and simultaneously act as a catchment area (See Figure #4). This combination rain and fog-drip cistern is especially useful in much of the California coastal zone because the rainless summers are so long that few people can afford to build a cistern big enough to store enough winter rain to last the entire summer.

According to other cistern researchers (#1, #2, #3) the gross amount of water collected should be adjusted by .56 to .72, or a 44-28% loss, for the practical net harvest of a sheet-metal catchment area.

During my study, the total summer fog-harvest during the 19 months in which only fog drip was collected averaged 3.91 inches per month. For every 100 square feet of conical cistern roof the net would be a total of 242 gallons per month-or 873 gallons per five-month summer (1212 total gross gallons, with a 28% loss).

In order to determine theoretically how much harvested fog-water could be collected without harming native plants, it is necessary to compare the amount of fog drip to the plants' evapotranspiration rate ($ET_O$). For April through September of the original ten-year study, the average harvested fog-drip water, in inches, is less than the $ET_O$ rate for adequate plant growth, and ranges from .63 to 2.97 inches per month less water than the $ET_O$. (The $ET_O$ is based on the $ET_O$ of cool-season lawn grasses; many drought-resistant plants can readily exist on an $ET_O$ considerably less than 1.0). During the rainy season, the amount of fog or cloud drip and rain harvested far exceeds that of the $ET_O$—from .41 inches more in October to as much as 2.79 inches more in December. On a yearly basis, the fog-drip alone falls 4.22 inches short of satisfying the $ET_O$ rate.

**Summary**
In this Mediterranean location, the native plants in the forest could not be maintained at an optimum moisture level with just the amount of water that condenses as fog drip. Thus, one must look at the combined fog drip and rainfall amounts to assess whether there is surplus water for cistern storage. In this study, the total precipitation equaled 58.3 inches per year. (This occurred during a protracted drought, when the average rainfall in the open meadow alone averaged only 27.47 inches per year.) If the yearly $ET_O$ rate of 35.05 is subtracted from the total rainfall of 58.3, the "surplus" precipitation is 23.25 inches per year. Therefore, each 100 square feet of a catchment roof can collect 1457 gallons of water per year without impacting the native flora. Based on the fog-drip rain-gauges in this study, the monthly rate will vary from a low of 42.78 gallons/100 sq. ft. (based on the historical May average of .69 inches) to 246.76 gallons/100 sq. ft. for the month of October.

These conclusions are entirely preliminary. The impact on native plants of a fog-drip-catchment cistern system requires further research.

**Fog Drip Bibliography**

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