Water Harvesting Lab

UNIVERSITÀ DEGLI STUDI FIRENZE
DAGRI
DEPARTMENT OF AGRICULTURE, FOOD ENVIRONMENT AND FORESTRY

CASE STUDY: FOG NETS

PROF. ELENA BRESCI, PHD, GIULIO CASTELLI, PHD

WATER HARVESTING LAB
DEPARTMENT OF AGRICULTURE, FOOD, ENVIRONMENT AND FORESTRY (DAGRI) –
UNIVERSITÀ DEGLI STUDI DI FIRENZE

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ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

OUTLINE

- Introduction on fog collection
- Meteorology of advection fog
- Reforestation / land restoration with fog: UNIFI pilot project
- Potential for upscaling

INTRODUCTION

- Advection fog is the sole source of water for **many near-the-sea arid areas** worldwide, such as the lomas of Southern Peru
- These areas underwent **deforestation** since the XVI century, which implied **progressive and severe desertification** (Belknap and Sandweiss, 2014)
- **Desertification**, in turns, led to environmental degradation, including soil erosion and loss of **carbon sink** potential

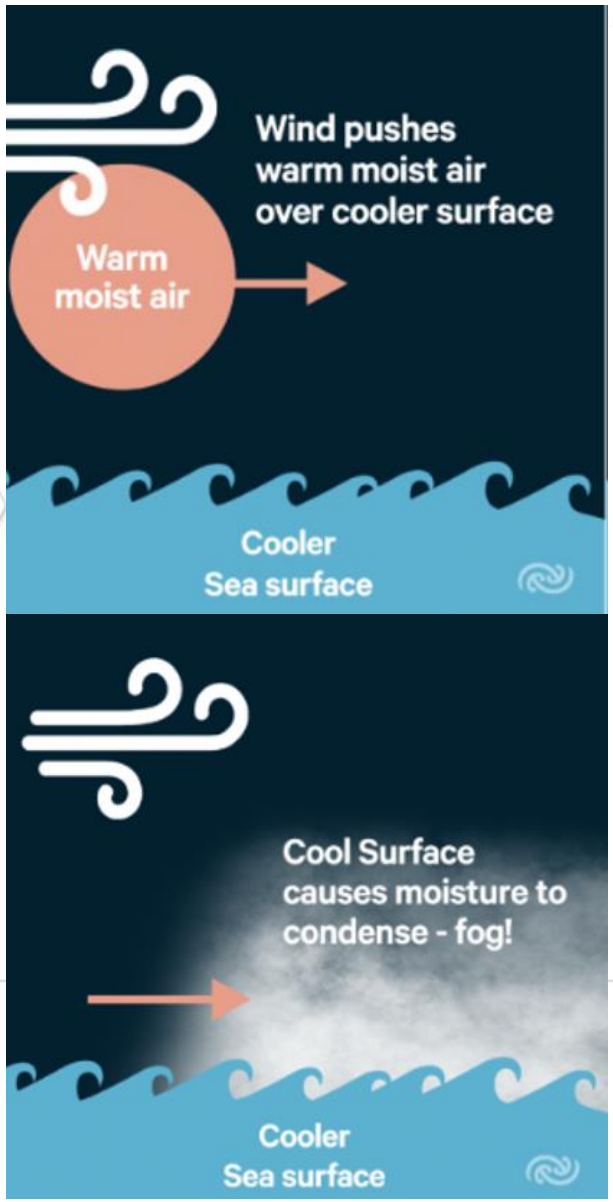
Belknap D.F., Sandweiss D.H., (2014). Effect of the Spanish Conquest on coastal change in Northwestern Peru. *PNAS*, 111: 7986-7989

INTRODUCTION

- **FOG:** a cloud of tiny **water droplets** suspended in the atmosphere at or near the earth's surface which obscures or restricts visibility

- **ADVECTION FOG:** Fog droplet diameters are of some 10s µm and an can be **easily moved by horizontal wind**

ADVECTION FOG



Conditions for generation of advection fog

- High evaporation
- Cool sea / oceanic surface / current

Conditions for advection fog stability

- High pressure

FOG COLLECTION BY VEGETATION

- Wind-blown fog droplets are collected by vegetation contributing substantially to the water cycle of forests and terrestrial ecosystems

- The interception of fog by the tree stems contributes to the areas re-greening

FOG COLLECTION BY VEGETATION

Using fog collectors denuded areas, once dependent on natural fog drip can

- be restored
- benefit local hydrology and
- benefit ecosystem recovery


Falciai, 1996

Domen J., et al., (2014). Fog water as an alternative and sustainable water resource. Clean Technologies and Environmental Policy, 16:235–249

COLLECTION BY FOG COLLECTORS

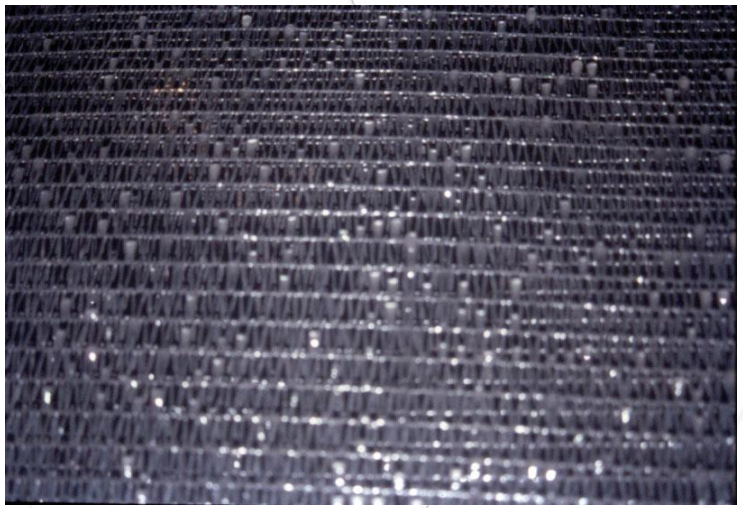
- Starting from **NATURE observations,** it has been proposed the collection of advection fog through **man made collectors** (Schemenauer and Cereceda, 1991)

- Fog can be collected on fog collectors and, then, water used for multiple purposes (reforestation, drinking water)

Schemenauer R.S., Cereceda P., (1991). Fog-water collection in arid coastal locations. Ambio 20: 303–308

FOG COLLECTION

- A **mesh** is exposed to the atmosphere and fog is pushed through the mesh by the wind.
- A fraction of the fog droplets deposits on the mesh material by impaction.
- When more and more fog droplets deposit, they combine to form larger droplets, **run down the mesh material into gutters and tanks** for storaging.



HOW MUCH WATER FROM FOG?

Table 1 A summary of fog water harvesting potential for select locations

Location	Average yield[a] ($L\ m^{-2}\ day^{-1}$)	Fog events per year	40 m^2 Collector average yield[a] ($L\ day^{-1}$)	No. of people supplied per 40 m^2 collector[b]	Source
South Africa	4.6	80	184	24.5	Olivier and de Rautenbach (2002)
Nepal	6.8	192	272	36.3	Karkee (2005)
Chile	3	365	120	48	Schemenauer and Cereceda (1994b)
Peru	9	210	360	48	Schemenauer and Cereceda (1994b)
Oman	20	77	800	106.7	Abdul-Wahab et al. (2007a)
Canary Islands	9.5	230	380	50.6	Marzol (2008)
Namibia	2.4	120	96	12.8	Shanyengana et al. (2002)
Saudi Arabia	4.0	45	160	21.3	Gandhidasan and Abualhamayel (2012)
Morocco	7.1	141	284	37.8	Marzol and Megía (2008)

[a] Average yield during fog events

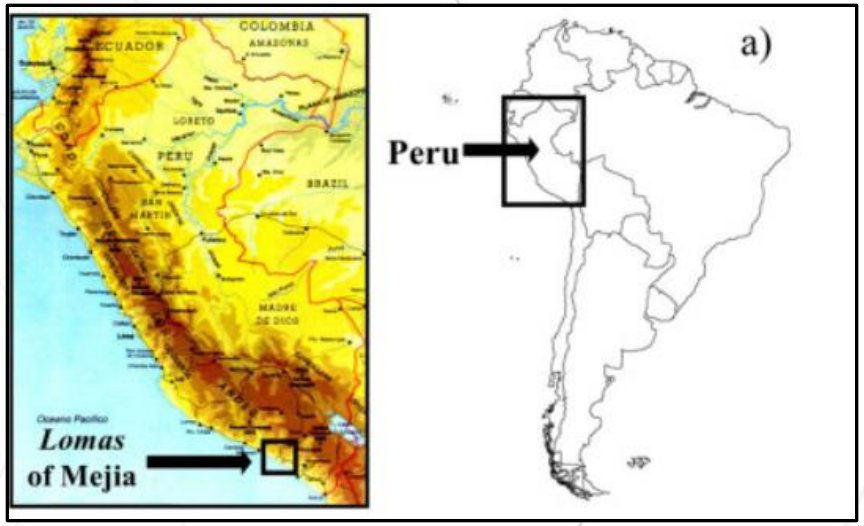
[b] Calculated using a minimum drinking water usage of 7.5 L $capita^{-1}\ day^{-1}$ (WHO 2011)

Domen J., et al., (2014). Fog water as an alternative and sustainable water resource. Clean Technologies and Environmental Policy, 16:235–249

FOG COLLECTION FOR REFORESTATION

Lomas de Meija: Southern Western Peru

- 17°2’36.31” S -17°2’35.44” S and 71°50’38.60” W – 17°50’34.05” W
- Heigth of 823 m a.s.l.
- Department of Arequipa
- It is one of the driest areas in the world (**rainfall 150 mm per year**, mostly in summer).
- **Fog period lasts about 6 months, from June to December.**



- **2 experimental plots** (pruebas) + **untreated control plot**
- **1996-1998**: tree planting and irrigation with fog water (960 m^2 of mesh).
- **1999 – now**: trees can directly collect water from advection fog

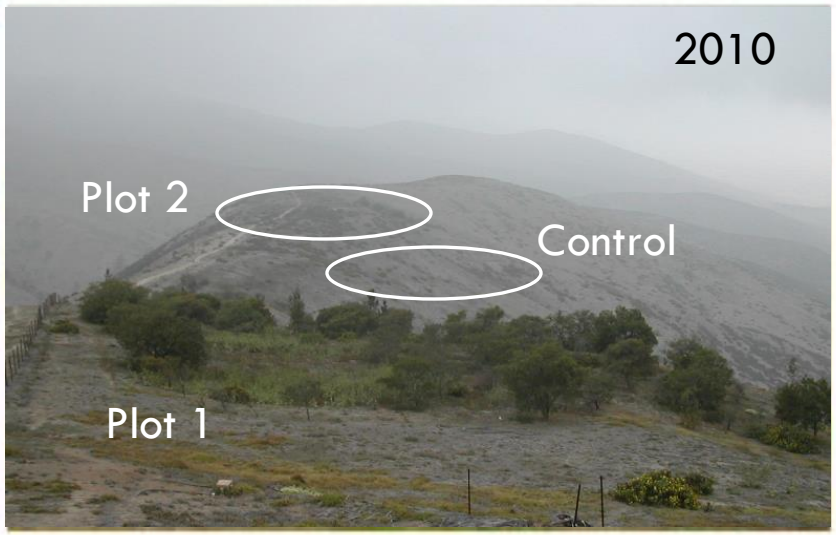
FOG COLLECTION FOR REFORESTATION

Experiment data:

- 864 trees planted (different species)
- Monitoring from 1996 until 2010
- Analysis of tree growth
- Analysis of C stock in soil

FOG COLLECTION FOR REFORESTATION

RESULTS AFTER 15 YEARS OF MONITORING



RESULTS AFTER 15 YEARS OF MONITORING

RESULTS AFTER 15 YEARS

December 2002)

RESULTS AFTER 15 YEARS OF MONITORING

- After 15 years from planting, **about 65% of trees were still alive and growing**
- Trees of *Acacia* Saligna (Allochthonous) up to 4 m tall
- Trees of *Caesalpinia spinosa* (Autochthons) showed a survival rate of 85% with no irrigation needed - **"natural fog collectors"**
- Carbon stock: **3-4 times higher** then non treated areas **on average**, and **17 times higher** in Acacia-covered areas – **carbon sink in a desertic area**

	C in the organic horizon [kg/m^2]	C in the top 10 cm of mineral soil [kg/m^2]
T1 1 (n = 52)	1.690 (0.435)^{a}	2.108 (0.052)
Control plot (n = 52)	0.390 (0.223)^{b}	1.743 (0.059)
T2 (n = 52)	1.178 (0.535)^{abc}	2.240 (0.052)
Acacia-covered area in plots T1 + T2 (n = 21)	6.637 (1.092)^{c}	2.364 (0.089)

Certini G., Capturing fog as a strategy to sequester carbon in drylands: the experience at Las Cuchillas, southern Peru. Science of the total environment, 657: 391-400

AND NOW?

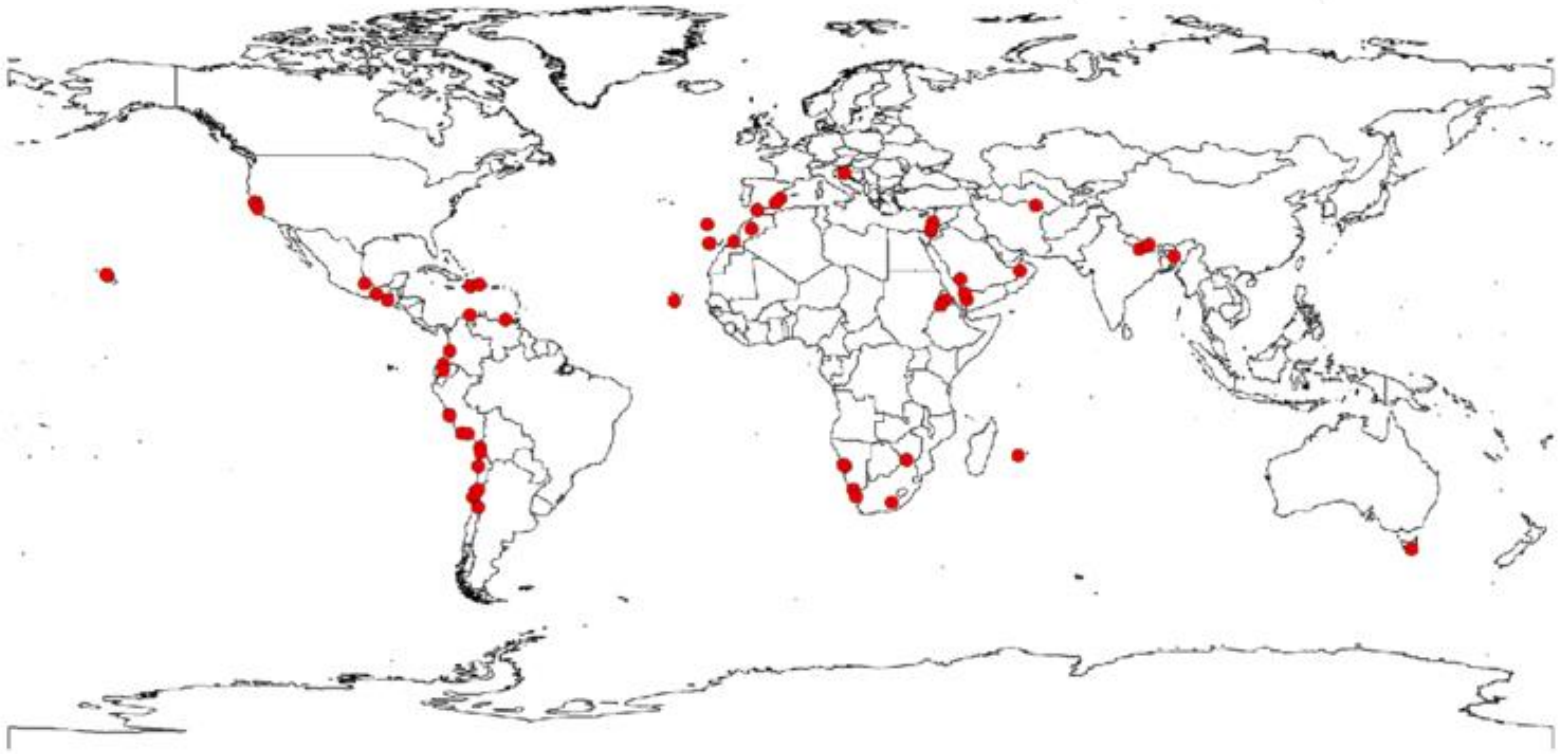
Trees still present and growing in 2018

Table 7
Evolution of forest cover (%) in the study area for the selected image dates. Averages of the values in the selected sampling points, with standard deviations in parentheses.

Image date	23/4/2003	31/3/2013	3/9/2018
T1	52.6 (5.65)	57.0 (5.57)	62.8 (5.47)
T2	57.1 (5.91)	64.3 (5.73)	70.0 (5.48)
WA	4.3 (2.61)	4.6 (2.47)	4.9 (2.24)
p-value on T1 and T2 difference	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$

Certini G., Capturing fog as a strategy to sequester carbon in drylands: the experience at Las Cuchillas, southern Peru. Science of the total environment, 657: 391-400

POTENTIAL UPSCALING



Considering the many locations where fog collection has a high potential for success according to Klemm et al. (2012), such an approach can make a significant contribution to carbon sequestration in drylands and, therefore, to global climate change mitigation.

FULL RESEARCH TEAM

The results showed in the present work have been originated by a **team effort** including:
Elena Bresci, Gianfranco Calamini, Giulio Castelli, Giacomo Certini, Alberto Giacomin, Luis Norberto Villegas Paredes, Alberto Pierguidi, Fabio Salbitano

This work is dedicated to the memory of Professor Mario Falciai, passed away in 2015, who firstly conceived the experiment and attended all the work since 1996, bringing in our University the idea of Fog Collection for sustainable water management.

For more information:

ELSEVIER

Science of The Total Environment
Volume 657, 20 March 2019, Pages 391-400

Fog collection as a strategy to sequester carbon in drylands

Giacomo Certini [a] ✉, Giulio Castelli [b] ✉, Elena Bresci [b] ✉, Gianfranco Calamini [b], Alberto Pierguidi [b] ✉, Luis Norberto Villegas Paredes [c], Fabio Salbitano [b] ✉

THANKS FOR YOUR ATTENTION

elena.bresci@unifi.it
giulio.castelli@unifi.it

Water Harvesting Lab
Department of Agriculture, Food, Environment and Forestry (DAGRI)
Università degli Studi di Firenze