UNIVERSITÀ DEGLI STUDI FIRENZE

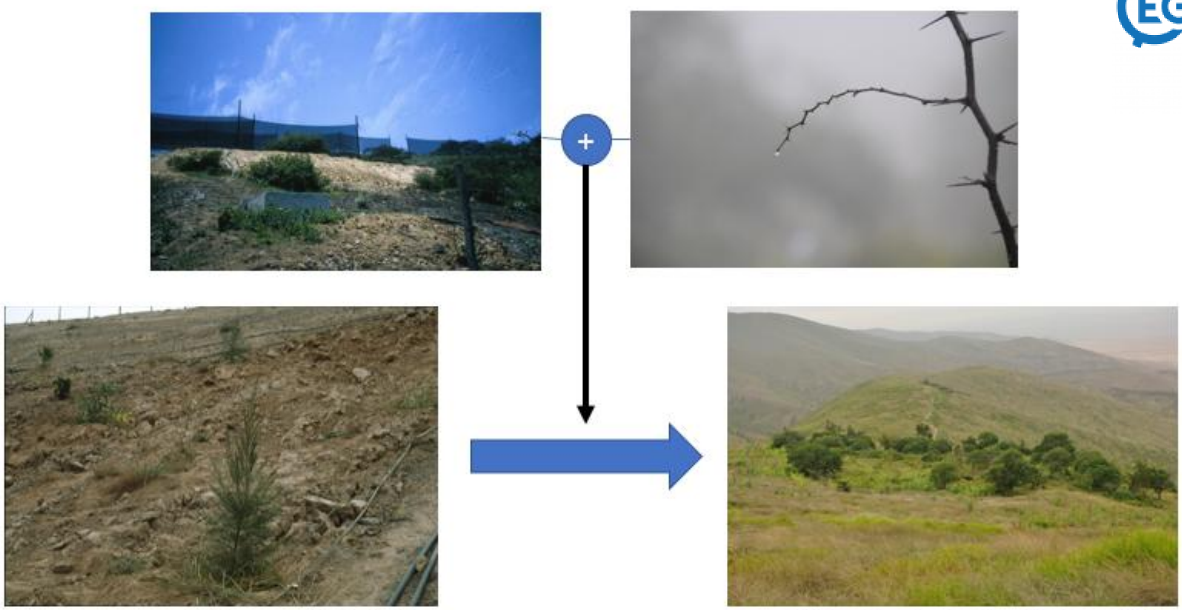
Photography encouraged

Fog collection as a strategy to sequester carbon in drylands

EGU General Assembly 2019

UNIVERSITÀ DEGLI STUDI FIRENZE DAGRI DIPARTIMENTO DI SCIENZE E TECNOLOGIE AGRARIE, ALIMENTARI, AMBIENTALI E FORESTALI

UNIVERSIDAD NACIONAL SAN AGUSTIN



1996, year of plantation

2010, after fog-induced reforestation

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#fogcollection
#headsintheclouds

giulio.castelli@unifi.it

Giacomo Certini (1), **Giulio Castelli** (1), Elena Bresci (1), Gianfranco Calamini (1), Alberto Pierguidi (1), Luis Norberto Villegas Paredes (2), and Fabio Salbitano (1)

(1) Department of Agriculture, Food, Environment and Forestry (DAGRI) - Università degli Studi di Firenze (Italy)
(2) Universidad Nacional de San Agustín, Arequipa (Peru)

Outline

- Introduction on fog collection
- Meteorology of advection fog
- The project
- Carbon stocks
- Experimental scheme
- Materials and methods
- Results
- Conclusion and further steps
- Reference

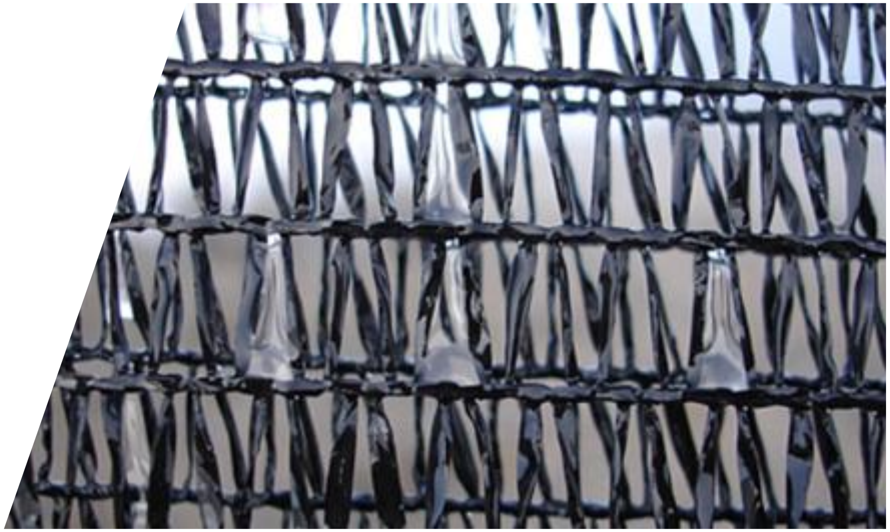
Introduction (1)

- 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 (2)

- **Fog:** a thick cloud of tiny **water droplets** suspended in the atmosphere at or near the earth's surface which obscures or restricts visibility
- Wind-blown fog droplets are collected by vegetation contributing substantially to the water cycle of **forests** and **terrestrial ecosystems**
- Fog can be collected on artificial **fog-collection structures** and used for multiple purposes

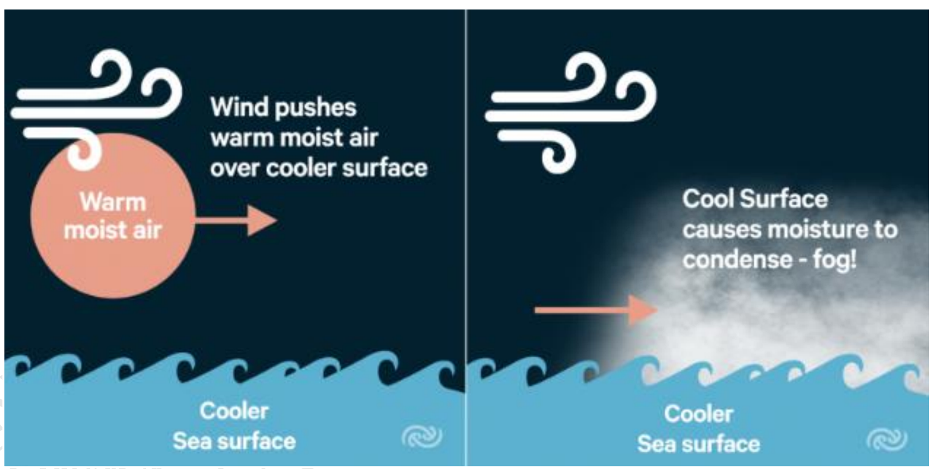


ADVECTION fog

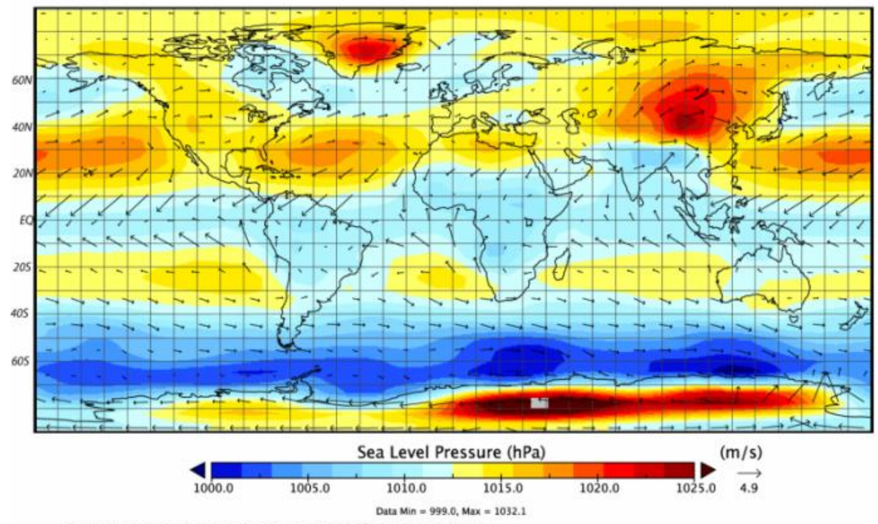
fog induced by **moist air passing over a cool surface**

Key elements for advection fog

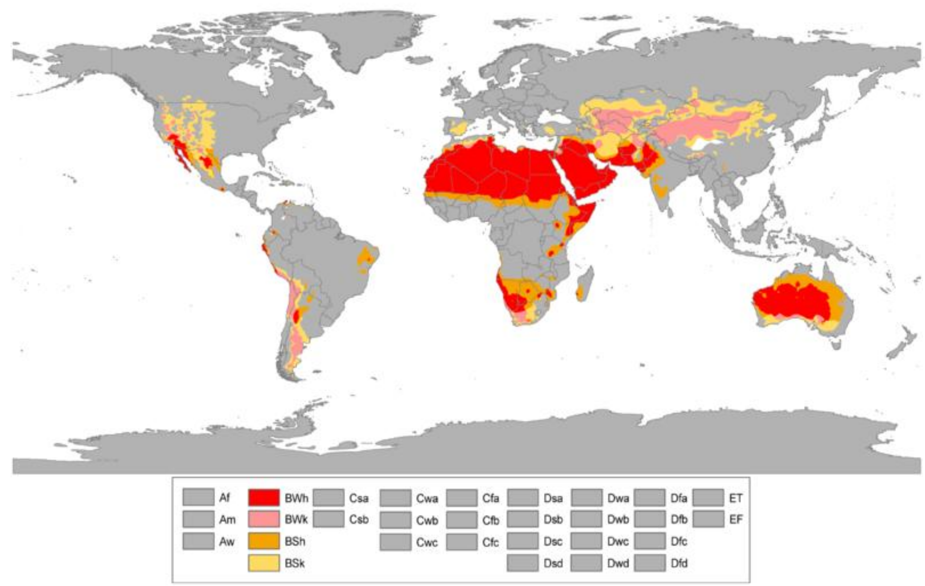
- **cold oceanic current** – cool surface
- **high pressure** – avoid precipitation formation and stabilise fog clouds
- **wind** – moves fog



High pressure areas



Arid climates at global scale



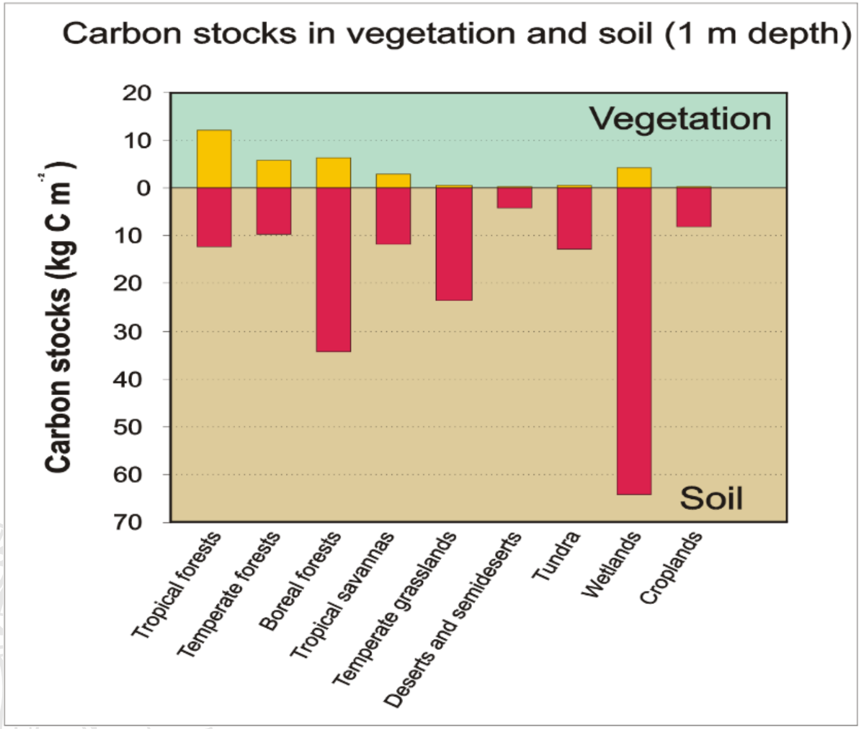
The EU project "*Fog as a new water resource for a sustainable development of the Peruvian and Chilean Coastal Desert*"

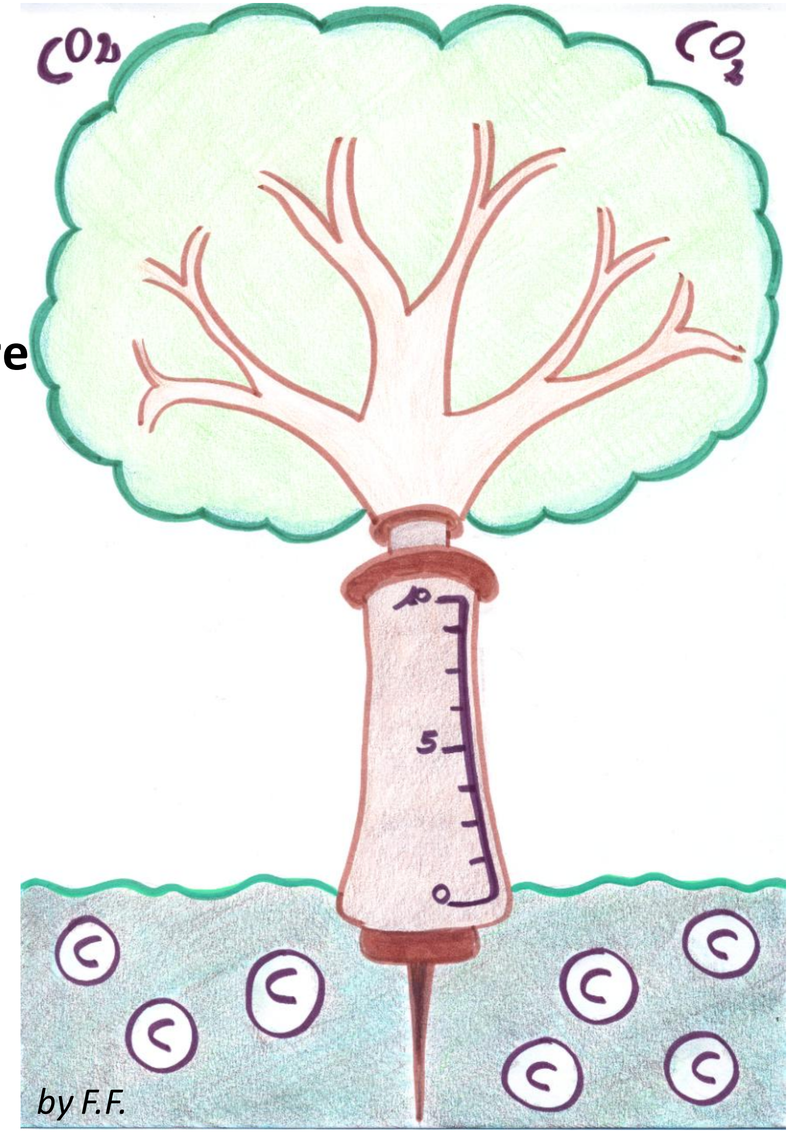
- **Running** from 1995-1998
- Case study of Lomas de Meija, Peru (*BWn Desert climate*)
- Exploration of **fog collection-based irrigation for reforestation**
- Analysis of the fog collection capacity of the **vegetation** itself
- Analysis of reforestation effect on soil carbon storage in a semi-desertic area

Carbon stocks

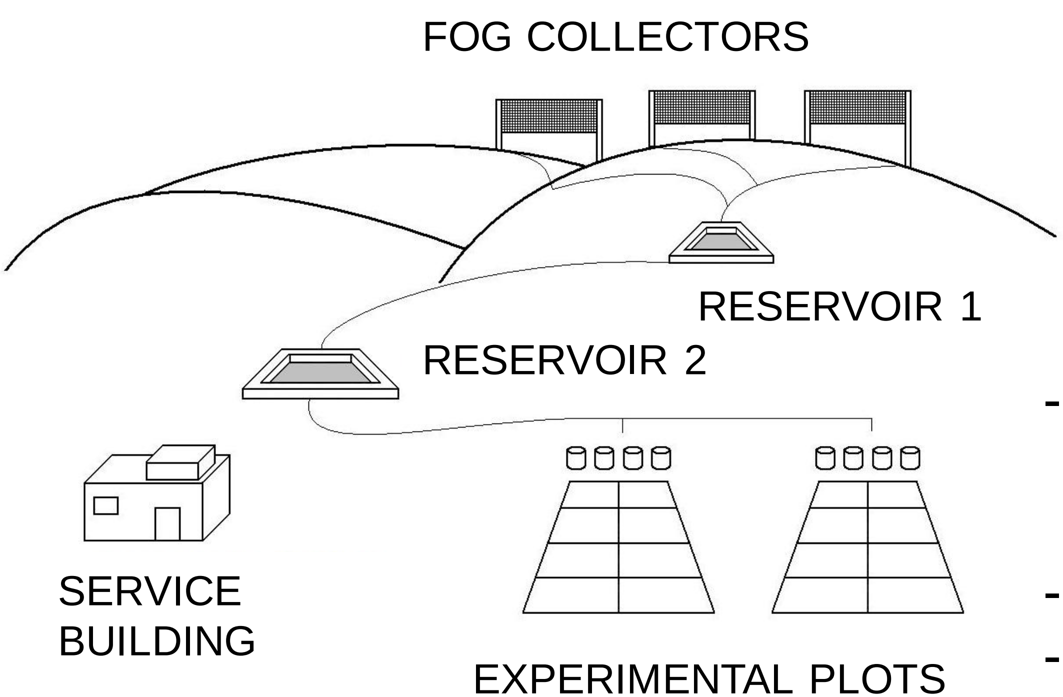
Trees are tremendous C sinks, because they transform the carbon dioxide of the atmosphere into organic carbon to increase their biomass. More importantly, however, they are a sort of “phyto-syringes” that inject organic C in soil

In most terrestrial ecosystems, carbon is more abundant belowground than aboveground



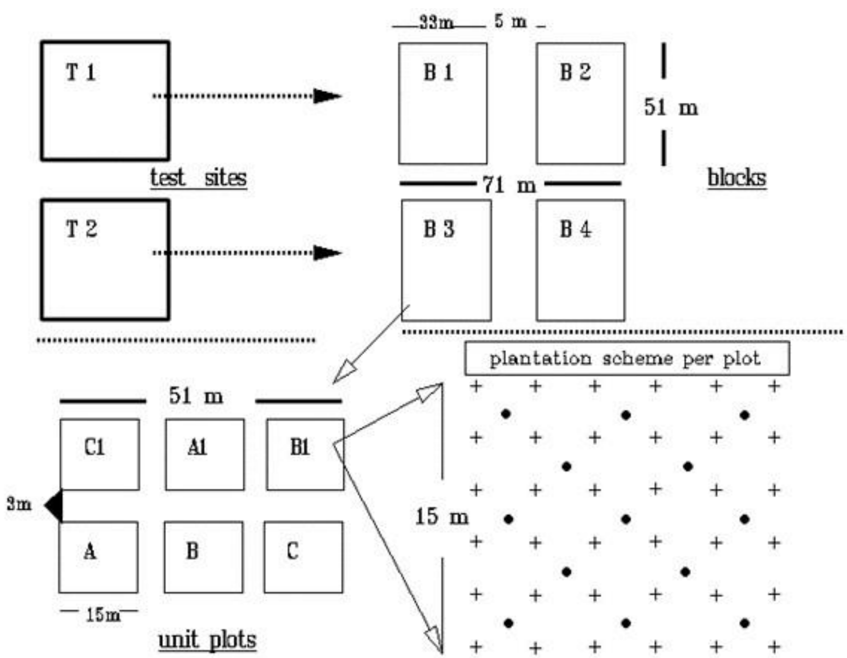


Project installation



- 20 **Large Fog Collectors** used for fog collection for irrigation (12 x 4 m)
- 2 tanks for water accumulation
- Drip irrigation system

Experiment design



- **864 trees** were planted with random-block design in **1996**.
- Blocks located in two different **test sites** (T1 and T2) with a difference in altitude of about 50 m.
- **Four blocks** (B), then divided in 6 plots.
- In each plot, 36 trees were planted 3 m from each other.
- Tree species (144 x 6 cohorts)

  Exotic and **Introduced**
  - *Acacia saligna* (AS)
  - *Causarina equisetifolia* (CE)
  - *Parkinsonia aculeata* (PA)

  Native
  - *Prosopis Pallida* (PP)
  - *Caesalpinia spinosa*, seedlings of 6 (CS6) and 12 months (CS12)

Experiment design

Irrigation treatments:

- Treatment a – irrigation for 3 years after planting (until 1999)
- Treatment a1 – irrigation for 3 years after planting and shelter
- Treatment b – irrigation for 2 years after planting (until 1998)
- Treatment b1 – irrigation for 2 years after planting and shelter
- Treatment c – no irrigation
- Treatment c1 – no irrigation and with shelter

Materials and methods

Monitoring:

•**survival rate, height and root-collar diameter** in 1996, 1999, 2002, 2007, and 2010

•**Carbon stock in trees** estimated for 1996, 1999, 2002, 2007, and 2010

$$C = \pi \, {cd^2}/_{4} \, h \, d \, f$$

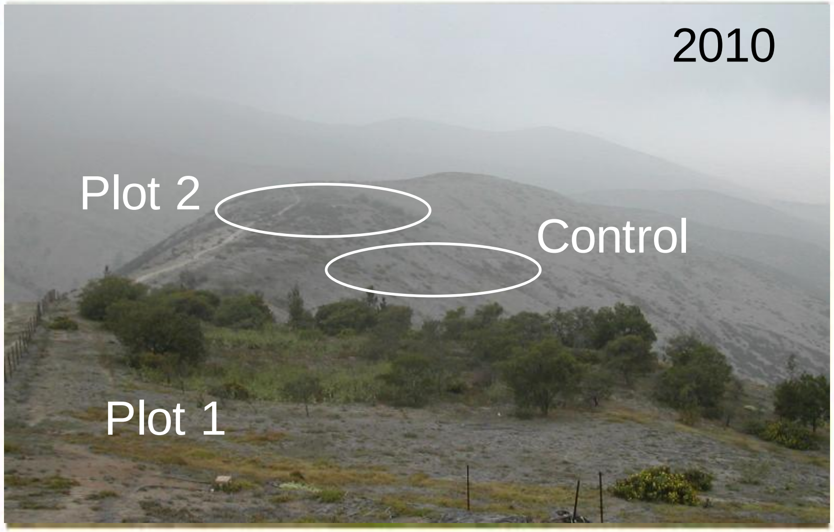
C – carbon stock
cd – collar diameter
h – tree height
d – wood density of the species
f - is the fraction of C on the total
by Thomas and Martin (2012).

•**Stocks of C and N** sequestered in soil determined **in 2010** for the <u>two afforested plots and a non-forested one in between + 1 Acacia covered sub-plot</u>

Fifty-two spots located at intervals of 1.5 m on north south and east west oriented perpendicularly-crossing transects

•**Persistence of forest cover** *i-Tree canopy* tool used in 2003, 2013, 2018

Results



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Results

Native species

Table 2. Ratio and number (in parentheses) of alive individuals.

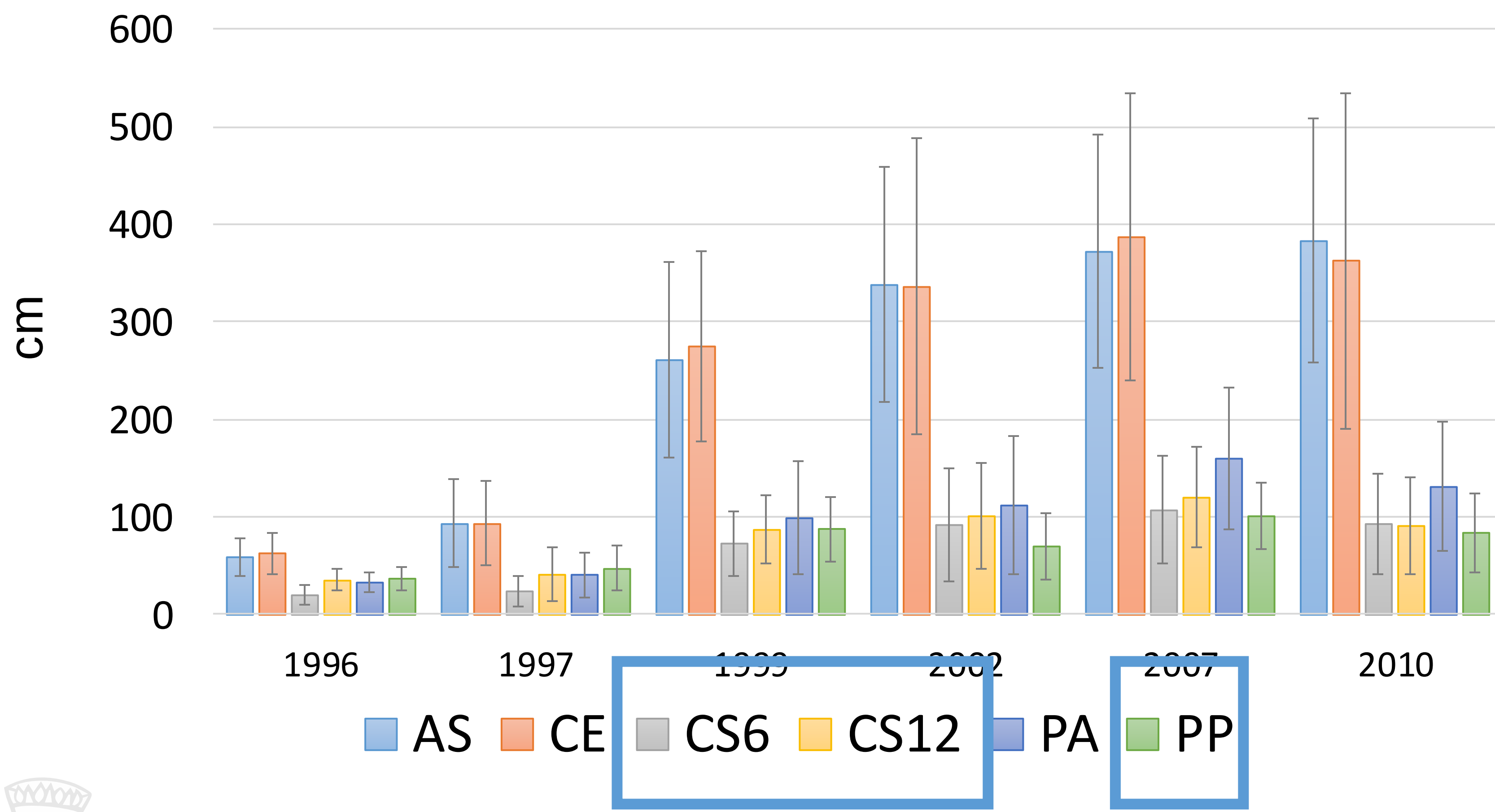
	1996	1997	1999	2002	2007	2010
AS	100% (144)	98% (141)	83% (119)	80% (115)	74% (107)	60% (87)
CE	100% (144)	97% (140)	69% (100)	67% (96)	63% (91)	41% (59)
CS6	100% (144)	99% (143)	89% (128)	82% (118)	81% (117)	75% (108)
CS12	100% (144)	100% (144)	93% (134)	90% (129)	88% (127)	81% (117)
PA	100% (144)	99% (142)	65% (94)	57% (82)	56% (80)	40% (58)
PP	100% (144)	99% (143)	89% (128)	81% (116)	79% (114)	72% (104)

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	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$

I-tree analysis:
T1 – Test site 1
T2 – Test site 2
WA – Wider control Area

Results

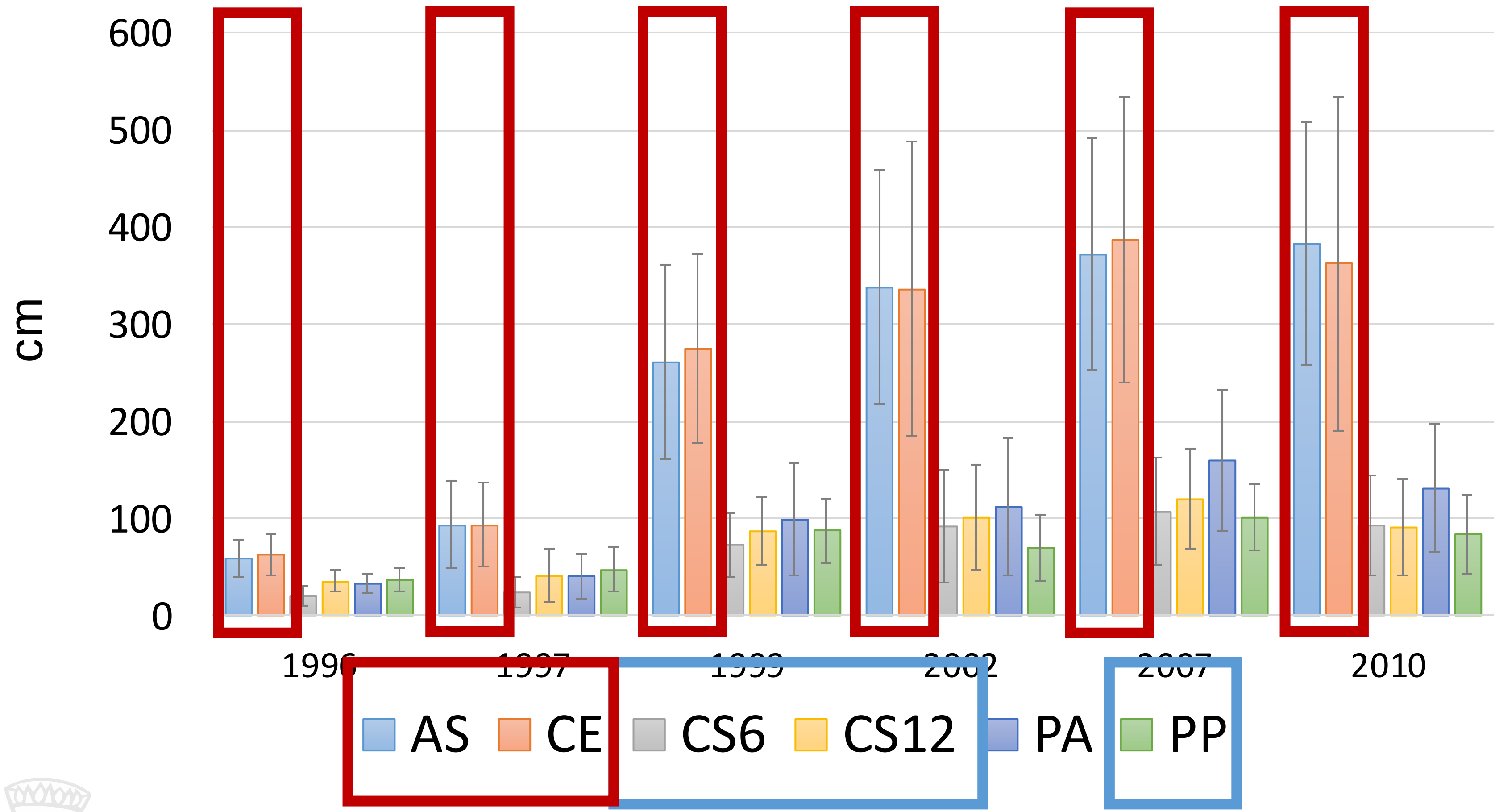
Native species



Average height and standard deviation of alive tree individuals (cm)

Results

Native species



Average height and standard deviation of alive tree individuals (cm)

Results Carbon stock in trees (neglecting leaves) [kg C]

Native species

Species		1996	1997	1999	2002	2007	2010
AS	average	0.01 (0.01)	0.05 (0.06)	3.09 (2.61)	22.3 (20.0)	28.2 (26.9)	42.5 (38.5)
	total	1.14	7.00	367	2560	3010	3700
CE	average	0.01 (0.00)	0.03 (0.03)	1.52 (1.44)	6.26 (7.82)	5.11 (9.08)	15.0 (25.5)
	total	0.75	3.81	152	601	465	871
CS6	average	0.00 (0.00)	0.00 (0.00)	0.04 (0.06)	0.57 (3.15)	0.35 (0.50)	0.64 (0.75)
	total	0.52	0.68	5.61	66.8	40.8	68.6
CS12	average	0.01 (0.01)	0.02 (0.02)	0.07 (0.05)	0.31 (0.46)	0.39 (0.49)	0.67 (1.04)
	total	1.63	2.27	8.91	40.3	49.8	78.2
PT	average	0.00 (0.00)	0.00 (0.00)	0.05 (0.08)	0.21 (0.34)	0.29 (0.43)	0.49 (0.89)
	total	0.34	0.55	5.13	17.1	23.6	28.5
PP	average	0.00 (0.00)	0.01 (0.01)	0.08 (0.08)	0.25 (0.39)	0.56 (1.04)	0.91 (1.92)
	total	0.49	1.17	10.2	29.6	63.5	94.1

Results: C and N stocks in 2010

	C in the organic horizon [kg/m²]	C in the top 10 cm of mineral soil [kg/m²]	N in the organic horizon [kg/m²]	N in the top 10 cm of mineral soil [kg/m²]
T1 1 (n=52)	**1.690 (0.435)**	2.108 (0.052)	**0.100 (0.026)**	0.202 (0.006)
Control plot (n=52)	**0.390 (0.223)**	1.743 (0.059)	**0.021 (0.012)**[b]	0.065 (0.030)
T2 (n=52)	**1.178 (0.535)**	2.240 (0.052)	**0.065 (0.030)**	0.193 (0.005)
Acacia-covered area in plots T1+T2 (n=21)	**6.637 (1.092)**	2.364 (0.089)	**0.383 (0.062)**[c]	0.213 (0.009)

Results: impact of irrigation on AS and CE

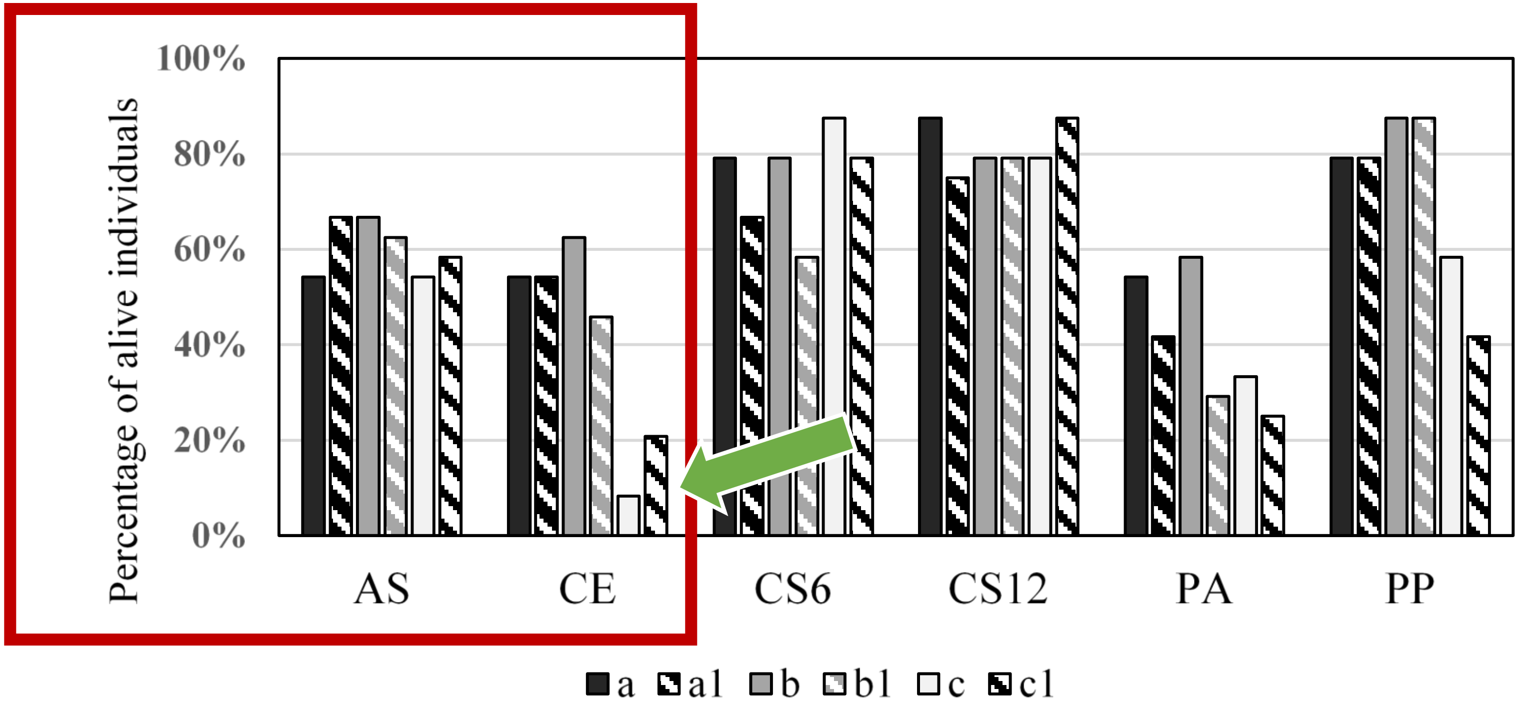


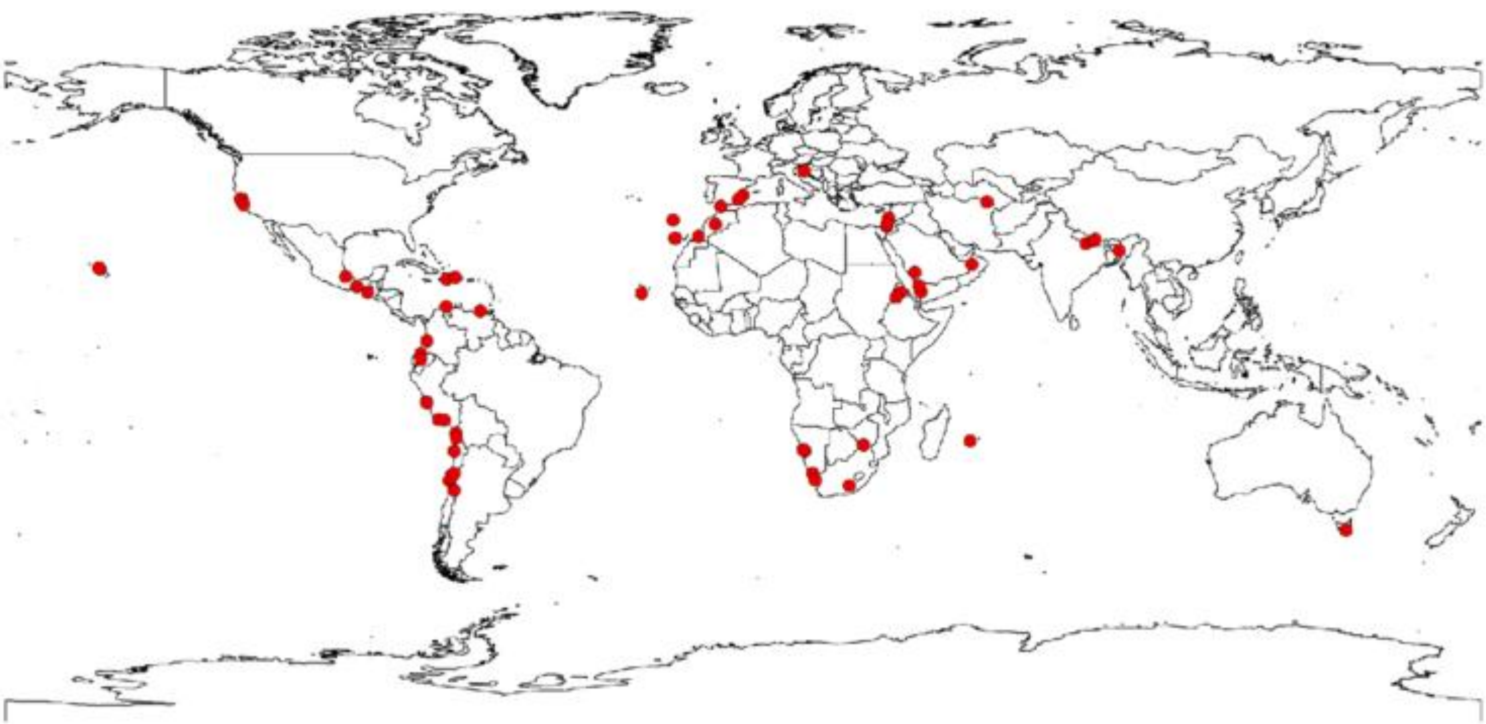
Figure 5. Percentage of alive individuals per treatment in 2010

a – irrigation for 3 years after planting (until 1999)
a1 – irrigation for 3 years after planting and shelter
b – irrigation for 2 years after planting (until 1998)
b1 – irrigation for 2 years after planting and shelter
c – no irrigation
c1 – no irrigation and with shelter

Conclusions

- Advection fog is the sole source of water for many near-the-sea areas worldwide.
- We presented the results of a **long-term reforestation project in the peripheral zone (North) of Atacama Desert.**
- Trees were irrigated with artificially fog-collected water for three years.
- After 15 years from planting, about **65% of trees** were still alive and growing.
- **Reforestation induced fast and substantial carbon sequestration.**
- AS (*exotic*) was the most promising species, **irrigated** CE (*exotic*) the second one. AS showed potential as "natural fog collector"
- Native species best performed as survivorship while presenting slower growth trend as compared to exotic/introduced

Potential for 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.

Reference

Certini, G., Castelli, G., Bresci, E., Calamini, G., Pierguidi, A., Villegas Paredes, L. N., & Salbitano, F. (2019). Fog collection as a strategy to sequester carbon in drylands. *Science of The Total Environment*, *657*, 391–400.

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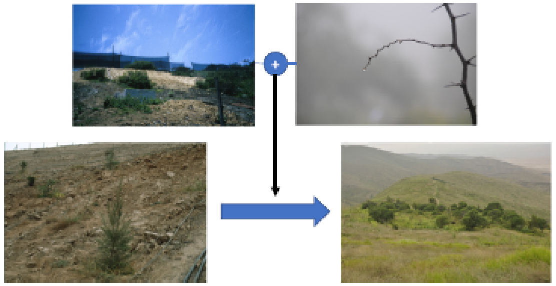
Giacomo Certini [a], Giulio Castelli [b,*], Elena Bresci [b], Gianfranco Calamini [b], Alberto Pierguidi [b], Luis Norberto Villegas Paredes [c], Fabio Salbitano [b]

[a] *Department of Agrifood Production and Environmental Sciences (DISPAA), Università degli Studi di Firenze, Florence, Italy*
[b] *Department of Agricultural, Food and Forestry Systems (GESAAF), Università degli Studi di Firenze, Florence, Italy*
[c] *Universidad Nacional de San Agustín, Arequipa, Peru*

HIGHLIGHTS

- Advection fog is the sole source of water for many near-the-sea areas worldwide.
- We present the results of a long-term reforestation project in the Atacama Desert.
- Trees were irrigated with artificially fog-collected water for three years.
- After 15 years from planting, about 65% of trees were still alive and growing.
- Reforestation induced fast and substantial carbon sequestration.

GRAPHICAL ABSTRACT



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(1) Department of Agriculture, Food, Environment and Forestry (DAGRI) - Università degli Studi di Firenze (Italy)
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