"Fog plants of the Atacama Desert as models for structure, functioning and dynamics of mini ecosystems"

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1. Projektbriefing

This project was about how to apply nature-inspired technologies to get water in an arid environment ! The pilot project is based on the idea that fog harvesting plants initiate the succession of mini ecosystems in deserts by modifying the abiotic environment to their favor, thereby building niches for other organisms. The field work was at Caldera and Research Station Alto Patache and National Parc Pan Azúcar, where we took data on plant response to different climate conditions. We also studied plant morphological adaptions to harvest water directly from the atmosphere.

2. Project Highlights

Presence of plants induces the formation of sand-hills, so called “nebkhas”.
Plant growth and nebkha formation enhance fog interception.
Tillandsia landbekii tussocks modify the substrate and atmospheric conditions creating microhabitats for above- and below-ground biota.

3. Results

In August 2023 a field campaign was executed in the Atacama Desert of Northern Chile to plan a research project on structure, function and dynamics of fog driven ecosystems in this hyperarid environment.
Analysis of vegetation pattern of Northern Chile aimed at identifying study areas for research on fog plants. We analyzed landscape and vegetation structure along a stretch from La Serena to Iquique (approximately 2000 km long) focused on the coastal cordeliere. We confirmed the overall picture (Fig. 1).
That the climate conditions, derivable from vegetation cover a) change gradually from semiarid to hyperarid conditions towards the North and b) there is a zone of increased vegetation cover in the ocean directed escarpment of the coastal cordillera between 600 and 900 m altitude, clamped between the beachline and the hyperarid inter valley.
The intervalley between the coastal cordilleras and the volcanoes of the high Andes proved to be almost devoid of permanent higher plants. Higher evaporation rates in ABFLUSSLOSE BECKEN generate salt pans. Tree covered areas like the TAMURUGAL owe their existence to groundwater originating from high altitudes of the Andes.

In higher altitudes directed towards the central cordeliere vegetation cover reappears due to lower saturation deficit of the atmosphere, which lowers water stress. This Puna vegetation is dominated by herbs (and grasses) Vegetation cover gets denser and woodier along river systems fed by snow fields of the Andes.
The vegetated stripe located within the coastal cordillera is of particular interest for this project aimed at fog driven ecosystems, as its presence is related to the attitude range where low clouds which formed above the cold Humbold current (and thereafter drawn towards to the low-pressure cells of the heated land mass) hit the coastal cordillera. During the longitudinal transect we studied during the field campaign we confirmed that the coastal cordeliere above 300 m is frequently affected by fog. This fog reevaporates abruptly at the device towards the hyperarid inter valley within a distance of less than 50 km. From the North in Iquique to Caldera further South the lower boarder of fog impact seems to decline almost to sea level, as permanent vegetation dominated by cacti are as well present in the littoral plain. Near Pellegrini.
A study site representative for the situation in the transition between semiarid and hyperarid section of the Coastal cordillera in the Northern Atacama is the National Parc Pan the Azúcar. A steep escarpment arises from the coastline to an altitude of 700 m. From there a 15 km plateau slightly descends towards the continent cut by a riverbed which brings meltwater from the high Andes to the coast. The escarpment line is affected by fog originating from clouds rising at the coastal slopes.
10 km North of Caldera a broad valley cuts the coastal cordillera giving rise to a continuously rising corridor which cuts into the mountain ranges on a distance of 50 km to an altitude of 800 m. The ground of this valley is covered by sand. Around 20 km from the coast at 200 m altitude, the valley ground is covered by fields (intensively settled by tussocks) of *T. landbeckii*.

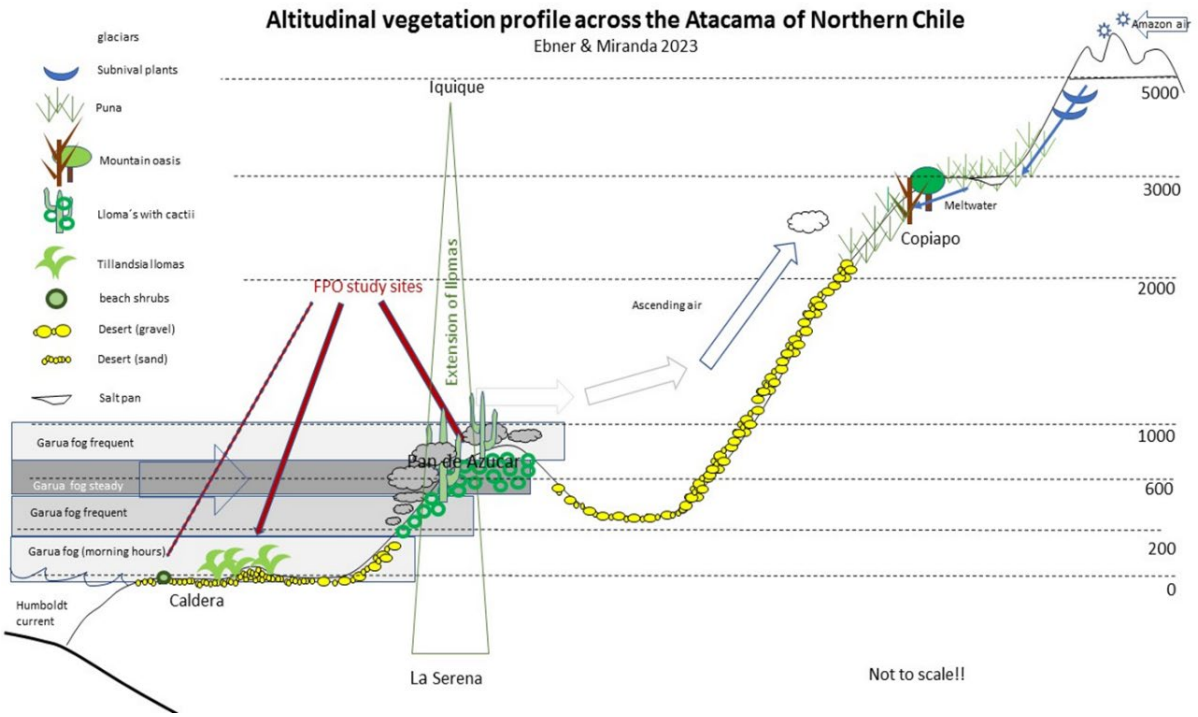


Figure 1: Shows the profile of the studied transect from La Serena to Iquique, emphasizing the vegetation occurring at different altitudes.

Study plants

According to our field observations and literature research we propose the following plants from the Atacama Desert (Fi. 2-4) to be promising candidates for comparative earlier studies (Ebner et al. 2025) with the desert-plants from the Namib Desert in Africa.

1) *Tillandsia landbeckii* and other *Tillandsia* species settling on sandy ground
2) *Eulychnia iquiquensis* and other columnar cacti

Further candidates are

3) *Nolana* beach shrubs
4) *Euphorbia* shrubs
5) *Ephedra*

Criteria for being a adequate plant are

1) Related to the fog zone
2) Harvesting fog water
3) Settling on sandy ground with poor water retention capacity
4) Transfer of fog water to the substrate
5) Formation of nebkhas (sand heaps)

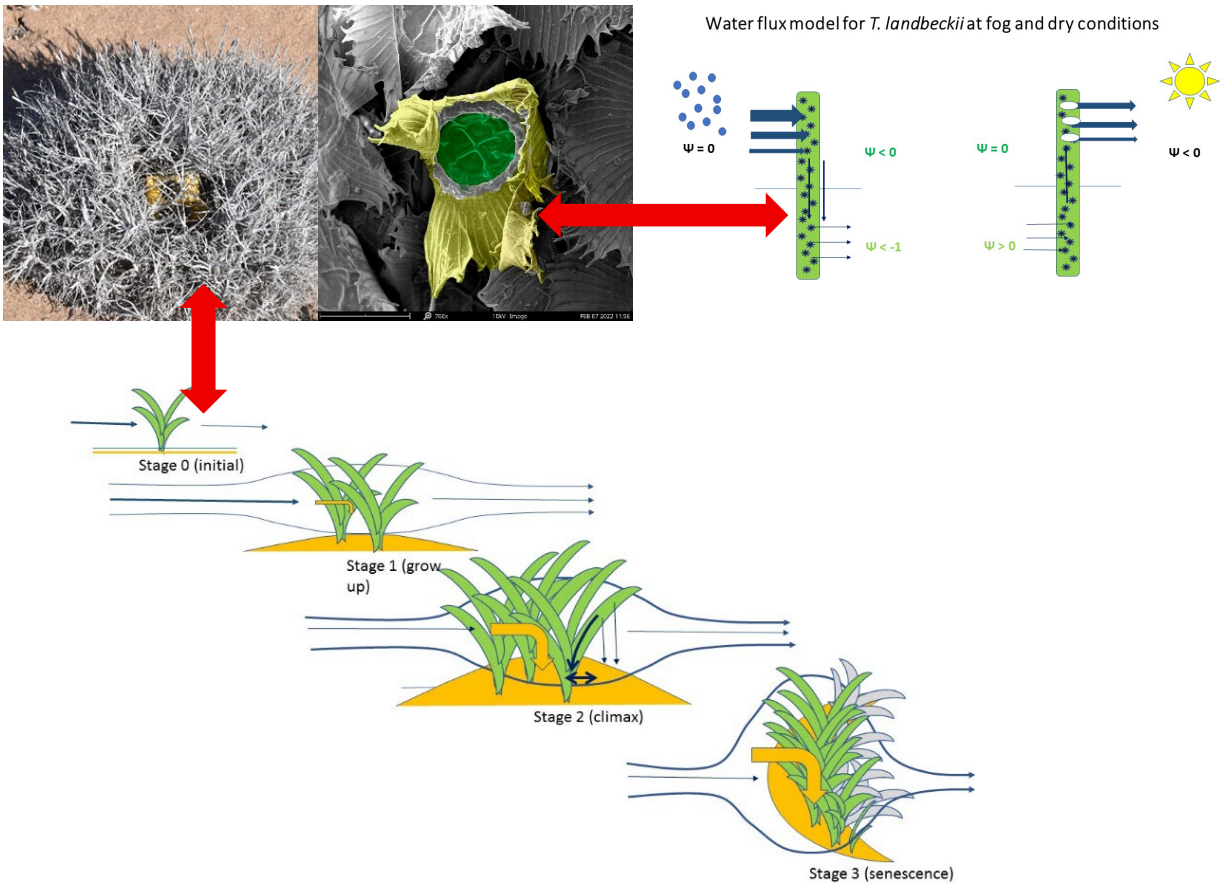


Figure 2: Top left: Shows *T. landbekii* with a climate logger. Top right: SEM picture of a water-sucking trichome found on the leaf of this bromeliad. Below: the plant's development at different stages of growth, and its strategy for collecting atmospheric water with its thin leaves covered with trichomes specialized in harvesting fog.

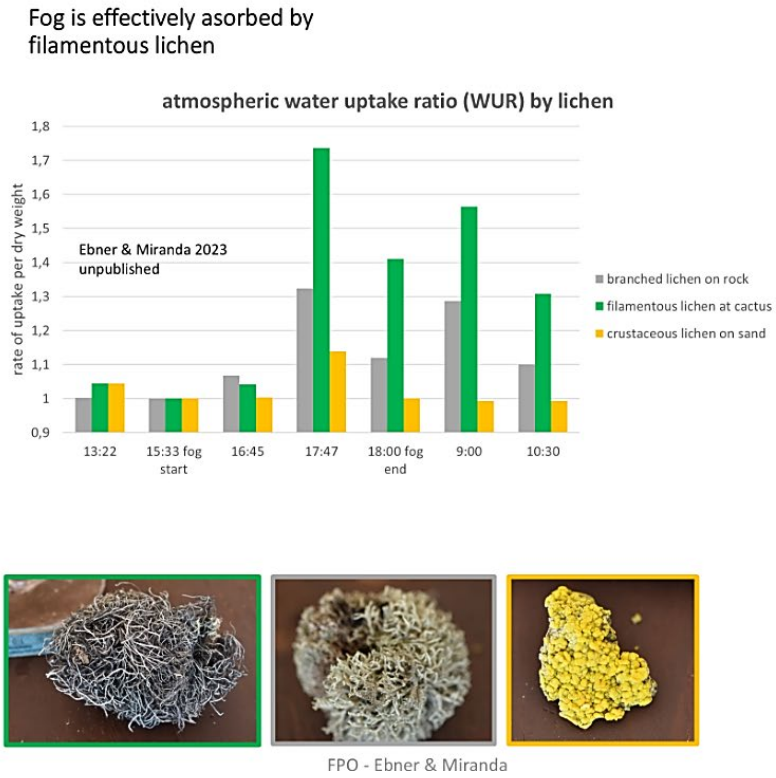
Eulychnia iquiquensis is a columnar cactus which occurs in the fog zone of the coastal cordeliere. The trunk is 2-7 m high, branched and has 12 to 15 rips with heaps on it. The heaps are the base of 10 to 20 thorns, which are 2 to 12 cm long (Fig, 3 left).
At many sites we observed that the thorns are draped by dense garlands of lichen
Crusty Lichen as well cover the crests of *Eulychnia*.
There are 12 to 15 ribs, which are slightly humped. The arueoles on them are covered with short white wool. The 10 to 20 variable thorns that emerge from them cannot be distinguished into central and marginal thorns. They are protruding and 2 to 12 centimeters long.

Figure 3: Left: The cactus *Eulychnia iquiquensis* at National Parc Pan Azúcar with a guanaco (Camelidae). Right: The diagram shows the dynamics of the air-fog stream that flows around the *E. iquiquensis* cactus. Observe that the boundary layer prevents the fog from directly reaching the cactus, and the spines are the organs responsible for collecting the fog water.

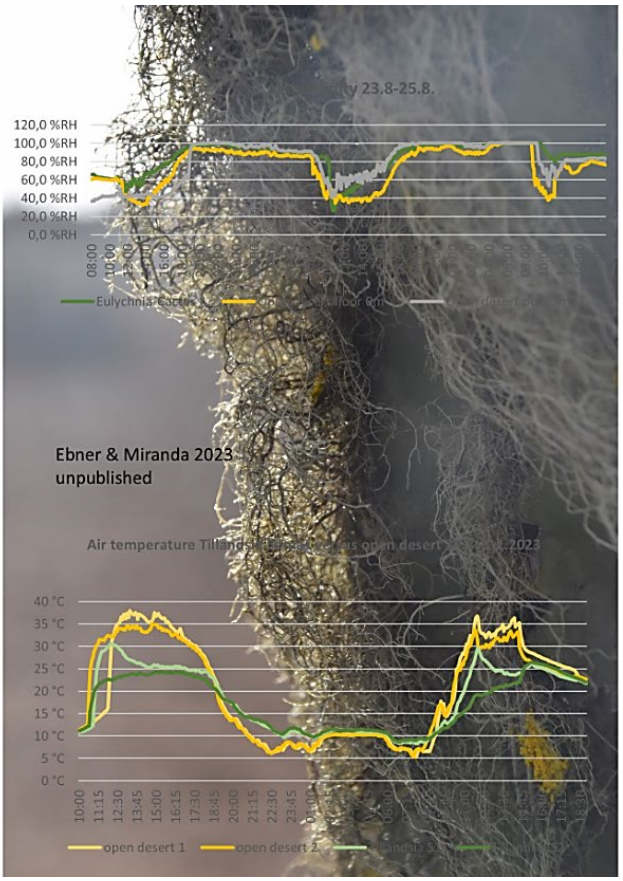
Figure 4. Field work at Research station Alto Patache from PUC-Chile, researchers Pablo Osses and Tatiana Miranda. Right: Gravimetric studies on lower plants, lichens, and fungi.

To test the hypothesis that lichen have the capacity to take up significant amounts of water directly from the atmosphere we conducted a series of gravimetrical measurements addressed to the Change of water status of different lichens.

The measurements took place in the Alto Patache station during the course of a day including a fog event. Filamentous lichens, which are frequently found on *Eulychnia* cacti showed the strongest response with more than 70% of weight increase after 1 hour of fog. At the end of the fog event the water uptake ratio (WUR) of this filamentous lichen instantly dropped to 1.4 due to fast reevaporating. During nighttime the water uptake ratio (WUR) increased again to 1.55. After sunset the value dropped to 1.3. The response pattern was similar to the filamentous lichen. A type of branched lichen which frequently occurs on rocks at the escarpment showed the fastest response to the fog event but only raised to a WUR of 1.3. A yellow type of crustaceous lichen which frequently covers rocks showed the slowest and less intense response to the fog with a WUR of 1.13 (Fig. 5)



FPO - Ebner & Miranda



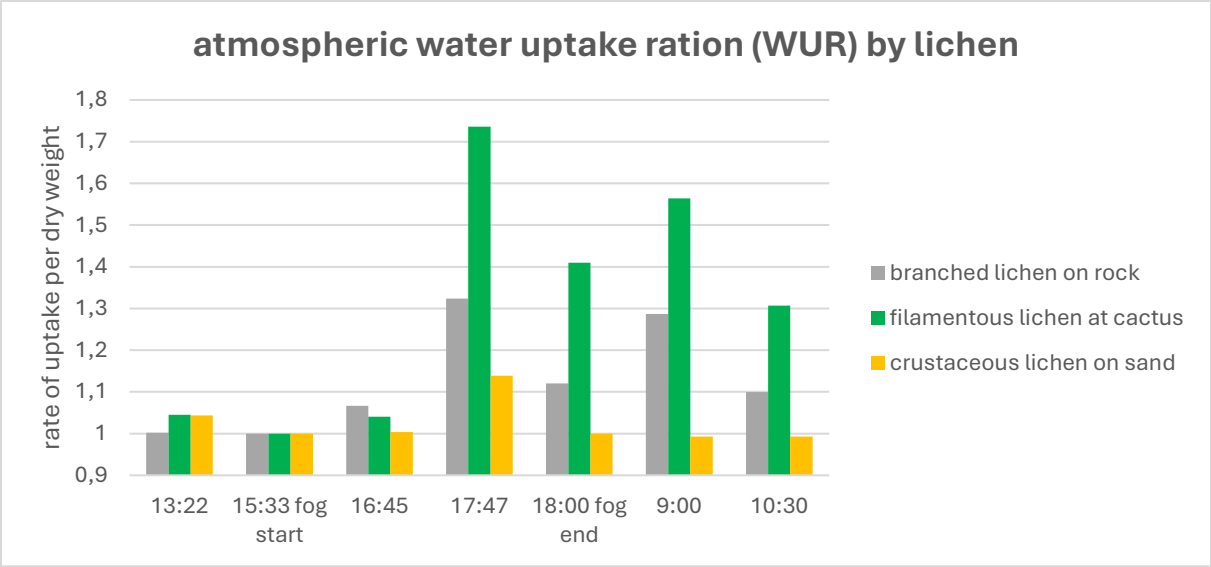


Fig. 5: Water uptake from the liches from Alto Patache Research Station.

We also determined the maximum water retention capacity of those lichens. In the saturated state the branched and filamentous lichen showed a WUR of more than 3, that means that they can hold 3 times as much water than their dry weight. The WUR of the crustaceous lichen was only at 1.24 (Fig. 6).

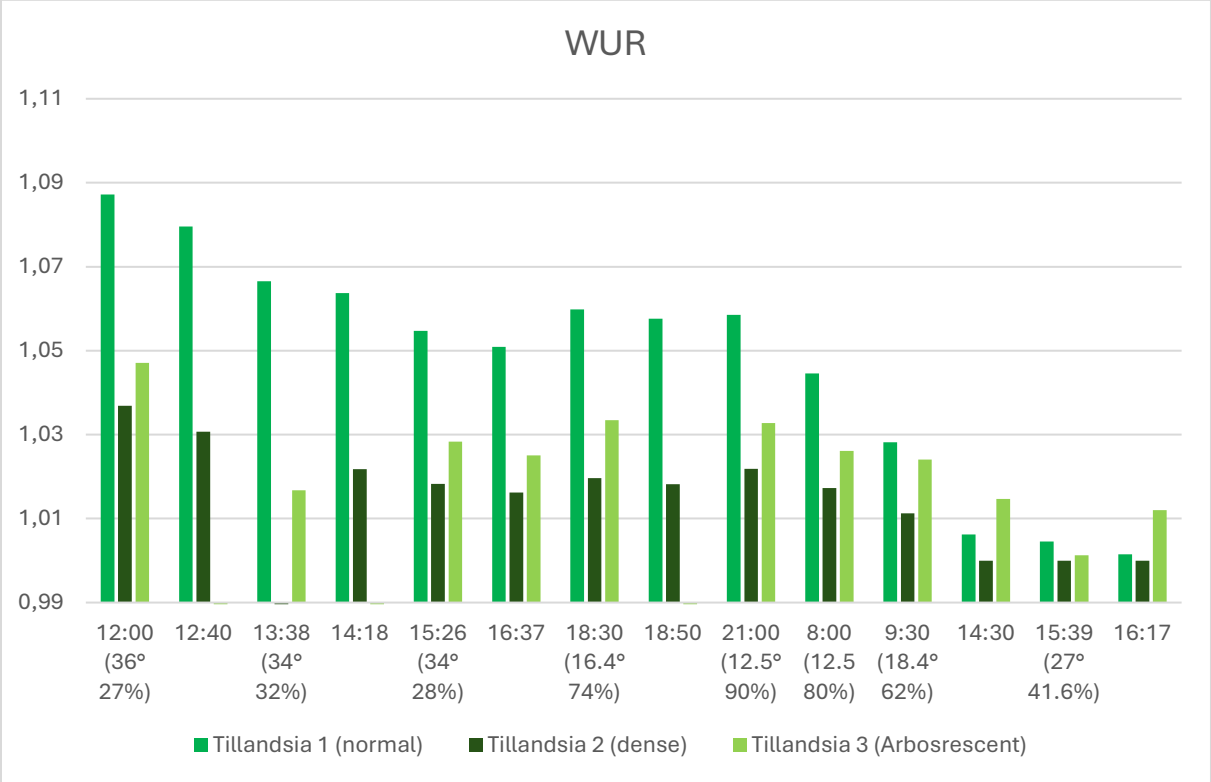


Figure 6: Results of gravimetric studies for *T. landbekii* occurring in the dunes of the Caldera desert.

Modification of microclimatic conditions by fog plants

During the field campaign several plants growing within the fog zone where analyzed in terms of micrometeorological conditions. The course of temperature and humidity recorded within the canopy of the FPOs were compared to the conditions in the open desert (OD) in the vicinity.

1. *Tillandsia landbeckii* in the Caldera area

We logged into temperature and humidity within *Tillandsia* FPOs of different stages of development and compared it with 2 sites, the open desert (Fig. 2 and 7).
In the night from 30.8. to 1.1. air humidity at the open desert sites reached 100% during 11 hours from 21:00 to 8:00. Within the canopy of an initial stage of *Tillandsia* (S1) saturation lasted only 8 to 9 hours. In The advanced stage interestingly, humidity never exceeded 90% during the entire fog event. During noon and afternoon humidity in the desert dropped to less than 25% humidity within the canopy of the dense canopy in the advanced state S2 did not underrun 40%.

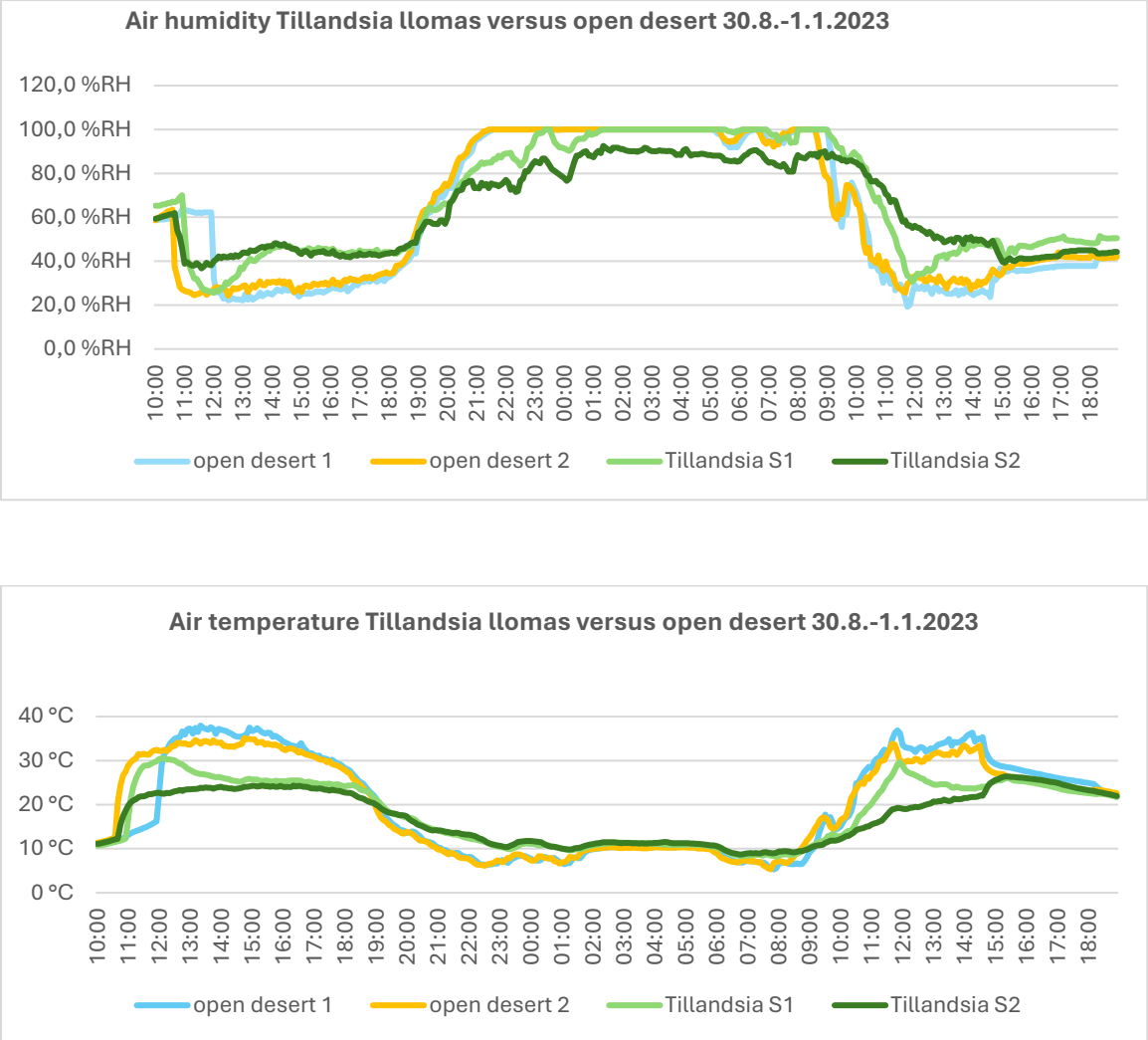


Figure 7: Comparison of humidity and temperature curves in the Llomas vegetation and in the open desert.

4. New Partners: Prof. Leandro Paulino and Dr. Lisberh van den Brink (University Concepción)
   Prof. Pablo Osses (PUC-Chile)

Outlook

With the results found so far in the Namib and Atacama deserts, we want to write and seek funding for a project that enables the development of artificial mini oases for collecting water from fog and modifying the substrate to change the fauna and flora of decertified or degraded environments. For exemple: Project title: Fog plant oases in the Atacama as models for establishing agricultural systems in arid regions.

References

Ebner M, Roth-Nebelsick A, Bocherens H, Gschwender F, Baumeister M, Miranda-Ebner N, Hohberg K, Gan H-Y, Schneider C, Maggs-Kölling G, Marais E, Lehmitz R and Miranda T. 2025. The fog harvesting Namib Desert dune grass *Stipagrostis sabulicola* promotes niche building by modifying substrate and atmosphere conditions, J of Arid Env., V.227, 105312, ISSN 0140-1963, https://doi.org/10.1016/j.jaridenv.2024.105312.

Study area -Pan de Azúcar
shallow clouds provide fog to the coastal cordillera