LIFE 15/CCA/ES/125

Additional report Name: SENSOTERRA – SOIL MOISTURE MONITORING

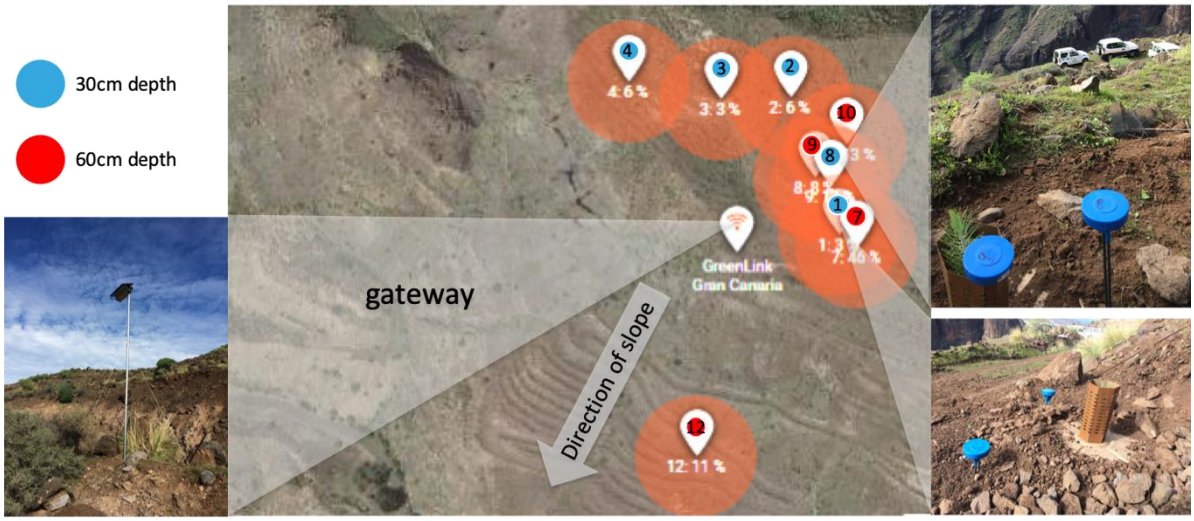
Action D1. Monitoring and project performance indicators

Compiled by: LLC

Date: December 2019

Sensoterra soil moisture monitoring equipment has been introduced within the GreenLink project to follow tree establishment in relation to plant available moisture content in the soil profile.
For this purpose at the end of 2016 and in 2017 in each trial area ~15 Sensoterra soil moisture probes (SMP) have been introduced at 0-30 and 30-60 cm depth intervals, particularly to monitor soil moisture changes near and directly below Cocoon depth. Changes in SMP-recordings over time are linked to

1. *increasing* soil moisture content through Cocoon delivery and rain events (including run-on), whereas,
2. *decreasing* soil moisture content, resulting from evaporation losses (top layer) and water uptake by roots (subsurface layer), including some redistribution by capillary rise and deep percolation.



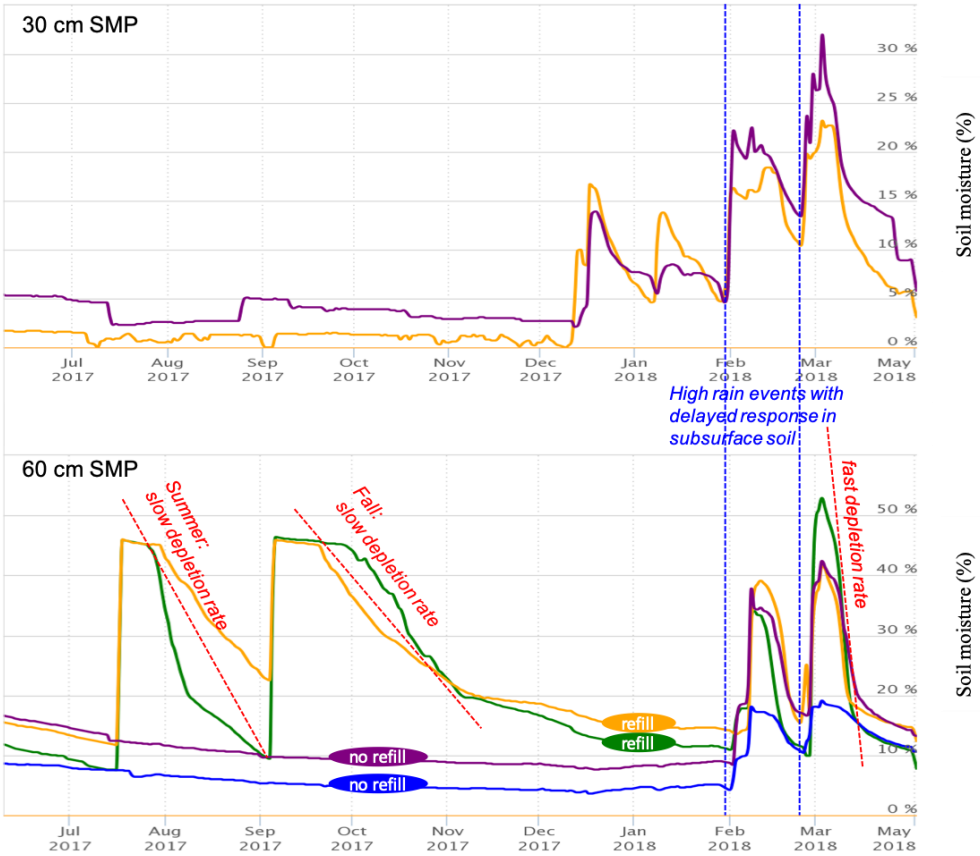
Gran Canaria: Location of Sensoterra SMP and GateWay

Consequently, changes in soil moisture levels in subsurface strata during the dry season reveal soil water uptake activities. Already within the first growing season a soil moisture content within the 30-60 cm profile has dropped to levels at which plants cannot absorb water further (e.g. Italy). Considering that vigor ratings at this stage were still 2 or higher (i.e. hardly drought stresses), suggesting that tree roots were tapping into deeper layers with adequate water availability to cover their water requirement resulting from transpiration losses. With root system striking deeper substrata tree seedlings are getting established, thus increasing their resilience to drought. This also clearly illustrates the Cocoons ability to bridge the drier upper layers, in which roots of young tree seedlings would normally reside, thus competing with evaporation losses as well as water use by competing weeds.

Monitoring SMP data in the second growing season suggest that the upper soil layers were depleted even earlier after the last (spring) rains (see SMP-graphs Gran Canaria below), which may be explained by the increased water consumption by larger trees with a larger water transpiring canopy. However, also a higher evaporative demand could have played a role, or the presence of reestablishing weeds over the years after planting.

With SMP generating information on soil moisture *depleting* rate over time, it can also provide information on soil water *recharge* rates, in relation to rain intensity and daily rain amounts, as well as run-off. The latter was shown by improved recharge rates in valley compared to higher parts (Almería).
Ideally, information on depletion rates collected over +10 years could reveal a favorable change in rain infiltration in the topsoil, as the organic matter building up softens the sealing crust, thus also reducing erosion hazard. Additionally, soil water retention and porosity in substrata may be improved, following soil life activity. However, such information cannot be inferred from the collected data in these trials, as this would require many more SMP, in sufficient number of

replications, using on-site meteo-stations with information on rain intensity and potential evaporation. Such setup would draw heavily on available funds.



Gran Canaria: SMP at 30 and 60 cm depth, showing (1) delayed infiltration in subsurface soil (2) refilling of Cocoons in summer 2017, and (3) depletion rate at 60 cm, associated with water uptake by roots.

In general, the distribution of the relatively small number of SMP's over all sites resulted not to be the most ideal setup, since preliminary conclusions following soil depletion rates only provide anecdotic proof, lacking sufficient replications over Cocoon raised trees versus control trees. Additionally, to eliminate the impact of water withdrawal by weeds, strategic weed clearing should have been applied, since SMP cannot discern between water loss by trees or by weeds..

More practical restrictions to obtain high quality soil moisture data sets for more solid conclusions were resulting from:

- Late installation of sensors, sometimes months after Cocoon installation (for example due to logistical issues in Ptolemais where the probes took a long time to arrive at the trial site)
- Difficult soil conditions hampering SMP installation at required depth, such as dry clay loam (Almería) and stones (El Bruc, Gran Canaria) and in generally also enabling measurements down to 60-90 cm interval.
- SMPs sometimes located too far from Cocoon trees, not providing representative results (Almería)
- Fauna attacks (wild boars) and strong winds moving the SMP's head, especially the less anchored 30 cm SMP, thus interrupting probe-soil contact (El Bruc, Jijona)
- Extreme flooding, washing out and short-cutting SMP's (San Marco Argentano)
- SMP batteries do not allow recordings longer term (5+ years)
- SMP's not placed in-line of sight with Gateway (mountainous site at Gran Canaria), implying lack of data transmission for storage.

Valuable lessons from applying Sensoterra's SMPs within the Green Link with implications for future land restoration schemes:

1. SMP's help determining active rooting depth without the need for excavating trees.

2. In combination with vigor rating, SMP values are indicative for proper tree establishment,
3. SMP's track water uptake by root systems. Hence, a comprehensive water balance monitoring inputs (i.e. rain, runon, subsoil capillary rise) and outputs (i.e. evaporation, runoff, deep percolation, daily tree water uptake) enables calculation of overall water requirement per individual tree. In combination with different overall soil moisture levels, stress build up can be monitored as well and related to vigor rating. Such information is used in determining optimum planting configuration.
   This however, requires a comprehensive setup of SMP's at different radii around a tree stem and at 30cm-depth-intervals down to at least 3m, thus requiring 'easy' soil conditions, as well as site specific meteo data on temperature, precipitation and evaporation. Ideally, such setup is replicated for a number of trees species to obtain significant results.
4. SMP recordings should be maintained over an extended period of time to follow up on longer-term changes in soil physical conditions, most notably rain infiltration rate and water retention, in relation to organic matter build up.

Hence, LLC will continue to place SMP's at other locations to obtain further evidence of the Cocoon's role in restoring nature and more in particular in ameliorating degraded drylands.