Unsupervised irrigation, how GUARDIAN scientists satisfy their thirst for innovation

Automatic preventive irrigation through water canyons is one of the several fire management actions that GUARDIAN is implementing at La Vallesa Wildland-Urban Interface (WUI). This is perhaps the most innovative aspect the project is working on as very few (inspiring!) examples exist worldwide. To our knowledge, GUARDIAN is the first attempt undertaken in Mediterranean ecosystems in which, capitalizing on surplus water from a waste water treatment plant, advanced water technology and infrastructure is put in place for wildfire management. Prof. del Campo and his team of scientists from the Universitat Politècnica de València (UPV) have been in the field for weeks developing front-line research to give answers on where and when preventive irrigation is effective and how much water is needed to improve forest ecological conditions to face the impact of fires. This is a critical study, as its outcomes will be used for the design of unsupervised water irrigation patterns to be applied during the fire season in Riba-Roja and Paterna WUI. Let me guide you through this exciting process!

Forests and the water cycle

It is well known and understood that forests play a critical role in the global hydrological cycle, the never-ending process in which water circulates from clouds, to land, to water bodies and back to the clouds over again. When it rains, precipitation is partially intercepted by the canopy of trees and absorbed by the soil. Trees pull water from this soil through their roots to uphold their life processes. Trees also release water into the atmosphere (i.e. transpiration), which is lost through pores in their leaves or needles. This water, together with the water evaporated from other system surfaces (i.e. evapotranspiration) comprises the total amount of water vapour which returns to the atmosphere to keep the cycle running. (Check this nice video form the National Science Foundation for a deeper yet simple explanation on the main flows and storage processes of the Water Cycle)

https://www.youtube.com/watch?v=al-do-HGuIk

Let's dig deeper into the **transpiration** process to better understand water flows and needs in trees. I'll try to keep it simple, as Prof. del Campo admirably does when he shares his wealth of knowledge with the GUARDIAN partners and stakeholders.

Figure 1. Professor Antonio de Campo (the one holdign the laptop) briefing Guardian stakehloders at the study site a few weeks ago (frame extracted from the TV Riba-Roja report https://www.youtube.com/watch?v=vTtzcyR3KI8&feature=emb_logo in Catalan)

Liquid water flows from the roots to the leaves driven by capillarity and by water potential differences (measured in MPa) which is the magnitude used in plant physiology to measure the tendency of water to move from one area to another due to diverse physical or chemical phenomena like osmosis, gravity, mechanical pressure, etc. Overall, the energy driving transpiration is the difference in energy between the water in the soil and the water in the atmosphere. As such, water always moves from the system with a higher water potential (soil) to the system with a lower water potential (atmosphere), as can be seen in the figure (watch out! water potential is a negative variable in our system at hand!).

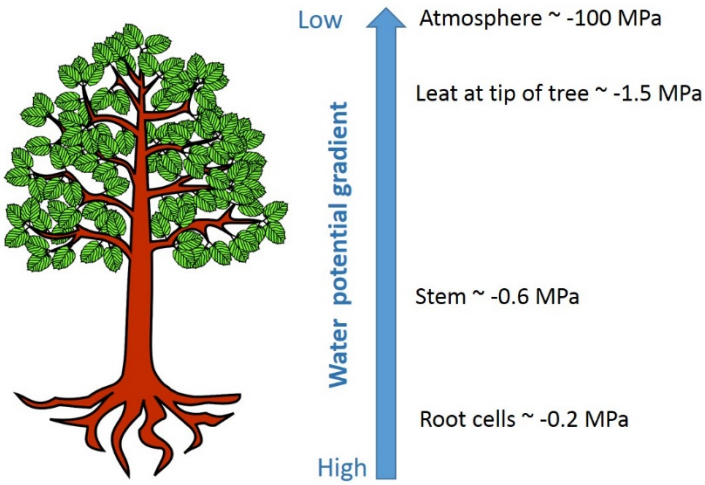

Figure 2. Water move upwards from the roots through the xylem to leafs and incorporated into the atmosphere due to the water potential gradient through the different compartments (soil, plant and atmosphere).

The atmosphere to which the leaf is exposed drives transpiration, causing massive water loss from the plant under severe drought periods. Dehidratation in plants may cause physiology changes (e.g. trees may stop carrying out photosynthesis and stop growing) ending up to irreversible effects causing death. You may want to know more about how drought kills plants (if so check out this outstanding piece of work from CREAF scientists) but, the topic covered in here deals with how to **keep trees alive and vigorous**!

Actually, in the following paragraphs I'll try to summarize the efforts taken at the Guardian project to improve fire resilience and ecosystem services in la Vallesa through ecohydrological-based forest management practices. What a complex name, when we can call it proactive silviculture!

Proactive silviculture, or how to manipulate the water cycle

Hidrology-oriented silviculture embraces forest management practices aimed at quantifying and manipulating the water cycle components according to specific goals. When those goals lie in maximizing economic, ecological and social returns without compromising ecosystems functionality, or better expressed, with a clear aim of **improving ecosystems services,** we can surely start talking about **eco**hidrology-oriented silviculture. This is indeed a way of doing proactive (vs reactive) management, by which forest managers can design actions to ensure, among others, the following objectives:

- Create favourable conditions to improve forests response to extreme droughts
- Modify tree and forest structures to increase resilience to wildfires
- Improve forests aesthetic and recreational components

Prof. del Campo has devoted a huge amount of effort in this field, and now he and his team at UPV are distilling the results of this research into the Guardian project. They are studying when, how much and by what means La Vallesa forest has to be watered to achieve the above-mentioned objectives.

They are approaching the problem at two scales:

1. The plot scale: to get insights on the ecohydrological processes of the soil-plant-atmosphere continuum of a particular site at La Vallesa forest.
2. The landscape scale: to relate afterwards key variables from those studied processes with satellite-sensed data for operational monitoring of la Vallesa watering needs.

While work at landscape scale is still under design process (and will surely have a dedicated web article in the future!), preliminary experiments at plot-scale have been successfully set, performed and analysed during this Autumn. Let's dive into La Vallesa forest to know more details about it!

The GUARDIAN preliminary field experiments

To select a representative area for their research, UPV scientists have firstly analysed La Vallesa area in depth, to come up with a clear map of forest categories in terms of diversity and canopy cover. By analysing images from hi-tech forest monitoring techniques, (yes! Guardian took a

LIDAR flight on October 29th 2019!)), they have discretized la Vallesa in 4 different classes (red, cyan, light green and dark green in Figure 3). Indeed, the most representative class is depicted in light green, corresponding to closed forest dominated by high-canopy pine trees.

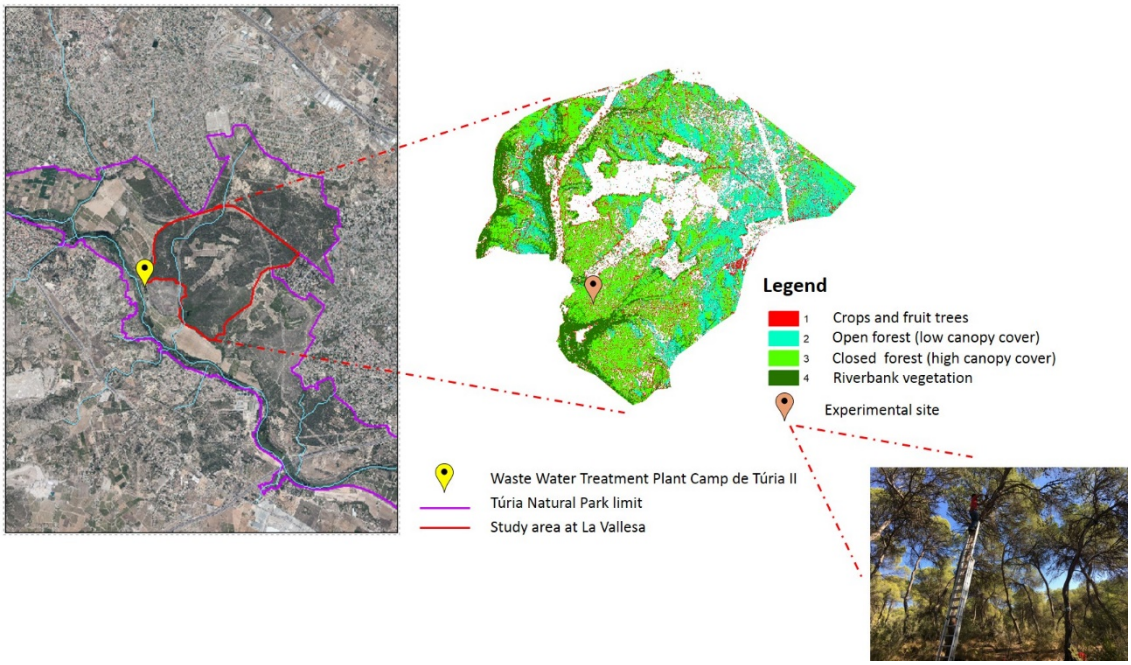

Figure 3. LIDAR data analysis results to select a representative study site

UPV scientists have then deployed their instruments and sensors in a specific plot representative of La Vallesa pine closed forest to study water dynamics at tree level. They have done an awesome job placing sensors of different types in the canopies and trunks of four trees as well as in the soil to explore watering efficiency (see Figure 4).

Figure 4. LEFT: UPV scientist programming an on-site datalogger. MIDDLE: Meteorological station set-up. UP RIGHT: Sap flow sensors in a tree trunk. DOWN RIGTH: Dendrometer to measure differences in tree diameter due to daily water dynamics.

Setting portable water canyons and infrastructure at the study area (Figure 5) and delivering this water in a controlled manner, they have come up with information on the effect of prescribed watering, on how water flows from the "artificial" rain provided by irrigation and to what extend this type of rain is efficient to quench trees' thirst in case of dryness.

Figure 5. TOP: Prescribed watering performed at the experimental site by 15th September 2020. BOTTOM: deployment of rain gauges to measure the amount of "artificial" rainfall

Results are already showing how effective prescribed water is to keep trees healthy and vigorous during drought periods! It has been found that the prescribed irrigation with GUARDIAN water

canyons is distributed from above, satisfactorily mimicking natural rain. These results, although preliminary, are in accordance with the proposed objectives and lay a solid foundation for the future systematization of irrigation cycles.

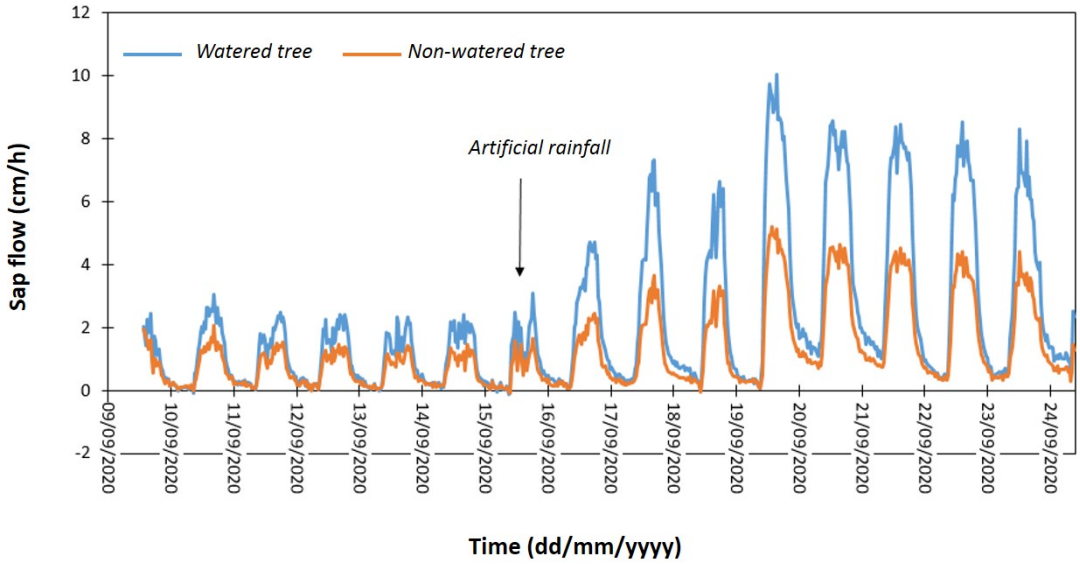

Figure 6. Sap flow detected during GUARDIAN field experiments. After the "artificial" rainfall, a watered tree exhibits in average more than the double sap flow as a non-watered tree for more than a week!

Good job UPV team! Keep hard working as now the challenge is even greater…how these results can be upscaled? How can irrigation patterns be optimized and achieve full system automation? As I said, this is now work in progress…but hopefully I'll be able to come back to you soon with some interesting answers!

Stay tuned at future GUARDIAN posts and journals, as this is just getting more and more interesting as milestones are reached!