Sensorscope

Design Project – SIE 2015

Exploring materials for low cost soil pressure sensor

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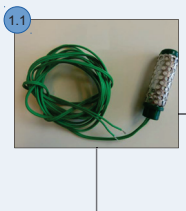
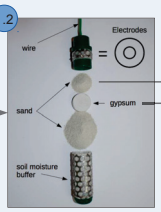
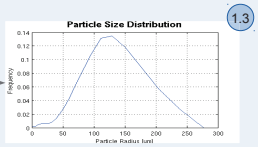
Background: An adequate irrigation of agricultural lands aims to optimize the water consumption by providing plants the exact amount of water they need on time. To achieve this, it is necessary to measure soil water tension, which is the effort required by root systems to extract water from the soil (also called suction). However, most available reference soil water sensors (Watermark®) are currently complex and expensive - and therefore not adapted in many poor regions where water scarcity is a major issue.
The aim of the project is to identify a reference material made of cheap and widely available components that would match (or exceed) the performance of currently available Watermarks.
Three objectives have been considered to design a new low cost soil moisture sensor. First, the Watermarks characterisation to deeply understand how a soil tension sensor works. Second, the casting and analysis of different mortars to target a well suited material to measure soil's tensions. Third, the design of such a sensor to bring knowledge to a further development.

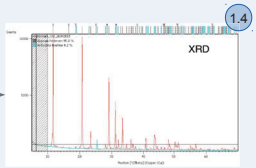
Watermark Probe Characterisation

The probe of the Watermark (1.1) is made of **electrodes** and two **sand compartments** separated by a **pastille of gypsum** (1.2). A Particle Size Distribution of the sand (PSD - 1.3) and a X-Ray Diffraction (XRD) analysis of the gypsum ring (1.4) allowed to understand how Watermarks are working. The soil moisture is **captured** by the sand, **filtered** by the gypsum and **transferred** to the sand in contact with the electrodes where a current is applied to **measure resistivity**.

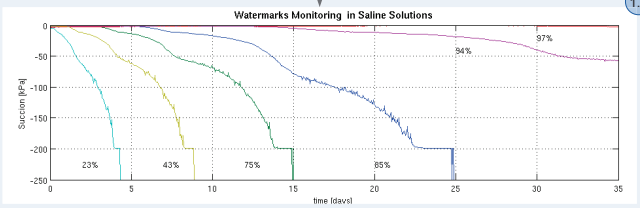








This study revealed that no specific materials or complex electronics are used. This shows that **adaptation with mortar** of this measurement process **has to work**.



To understand how Watermarks are going into **equilibrium with the environment**, an experiment was carried out placing several devices into different environmental conditions (1.5). As they are designed for agricultural purposes, they are **not adapted** for relative humidities **below 95%**.

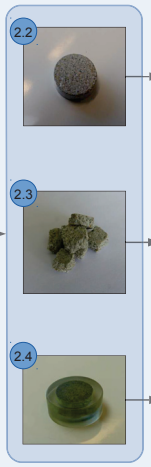
Mortar Casting and Analysis

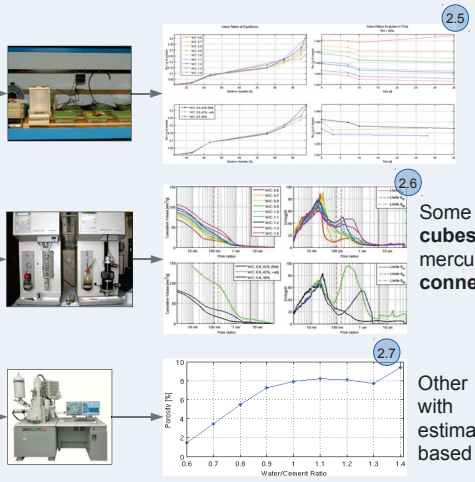
Electric resistivity of mortars is **linked to the water suction of the material** through the size, connectivity and distribution of the porosity. As for Watermarks, a **calibration curve** is needed.

Different mortar were cast varying the **water to cement ratio** (*w/c*), sand's **PSD** and eventual **additives**. Samples were cast in small tubes (2.1) and analysed at **28 days** after casting.

Saline Solution Equilibrium (SSE) (2.5), **Mercury Intrusion Porosity (MIP)** (2.6) and **Scanning Electron Microscopy (SEM)** (2.7) were used to analyse the porosity of the samples.

Also considering their **resilience**, it has been decided to select a mortar with a ***w/c* of 0.8**.





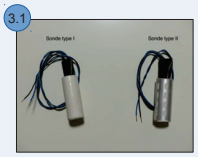
Mortar samples were **cut into slices** (2.2) and **placed above different saline solutions** to measure water masses.

Some slices were **crushed into cubes** (2.3) and intruded with mercury to obtain **size and connectivity** of the micropores.

Other slices were **impregnated** with epoxy resin (2.4) to estimate the total porosity based on **SEM image analysis**.

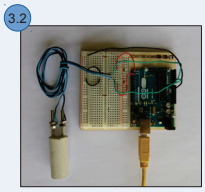
Sensor design possibilities

This project has always been motivated by **actually building** soil suction probes. However, more work is required to test and calibrate different designs of sensors. Some possible **design examples** previously created with pure gypsum are shown in (3.1).



The effect of different **soil matrix** on the suction as well as the **influence of the temperature** on the resistivity are all parameters to include in a further step.

The next step of this project will be to **compare** a set of probes (3.2) with mechanical tensiometers (3.3) in a controlled environment (3.4) in order to **establish** a **calibration** and **evaluate** the **robustness** of the new mortar-based probes.



Conclusion: This project has shown that there is a potential in the development of mortar soil tension sensors. Moreover, the raw materials for mortar casting, *i.e.* cement, water and sand, are available almost everywhere around the world at low cost. By developing an open source manual to cast such probes and easily acquire their data, there is a high potential for small scale agriculture projects to save precious water resources and allow financial sustainability in this activity.

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