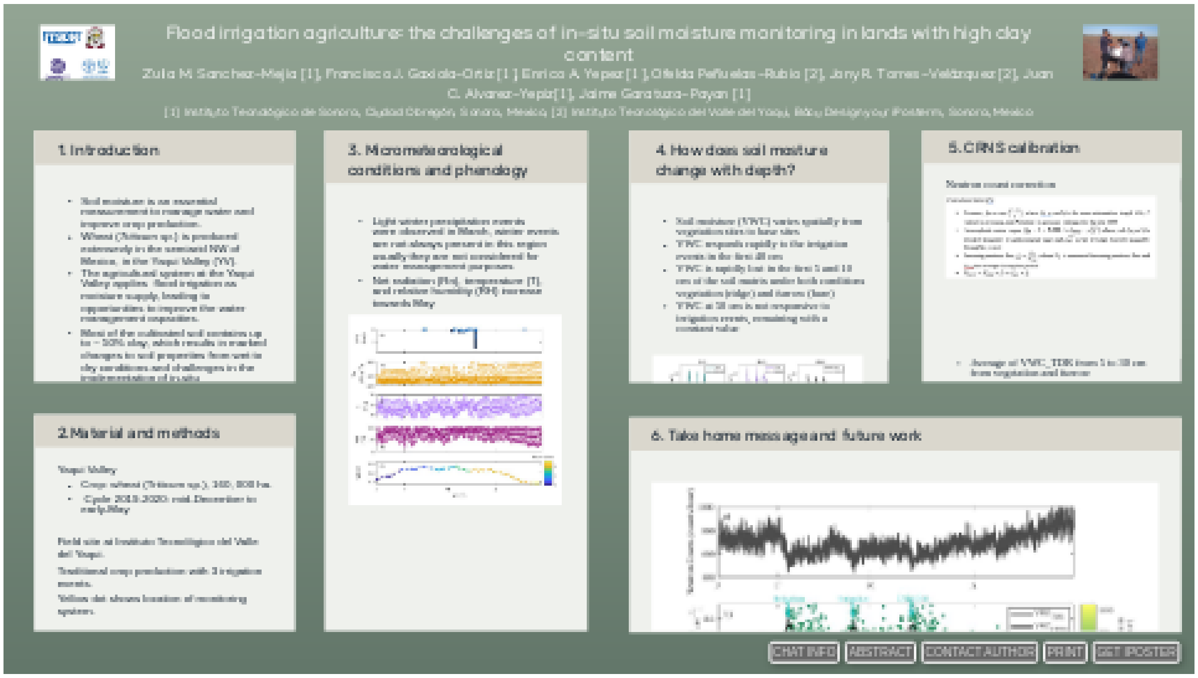
Flood irrigation agriculture: the challenges of in-situ soil moisture monitoring in lands with high clay content



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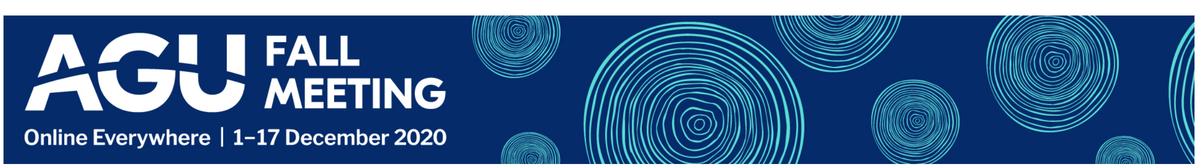
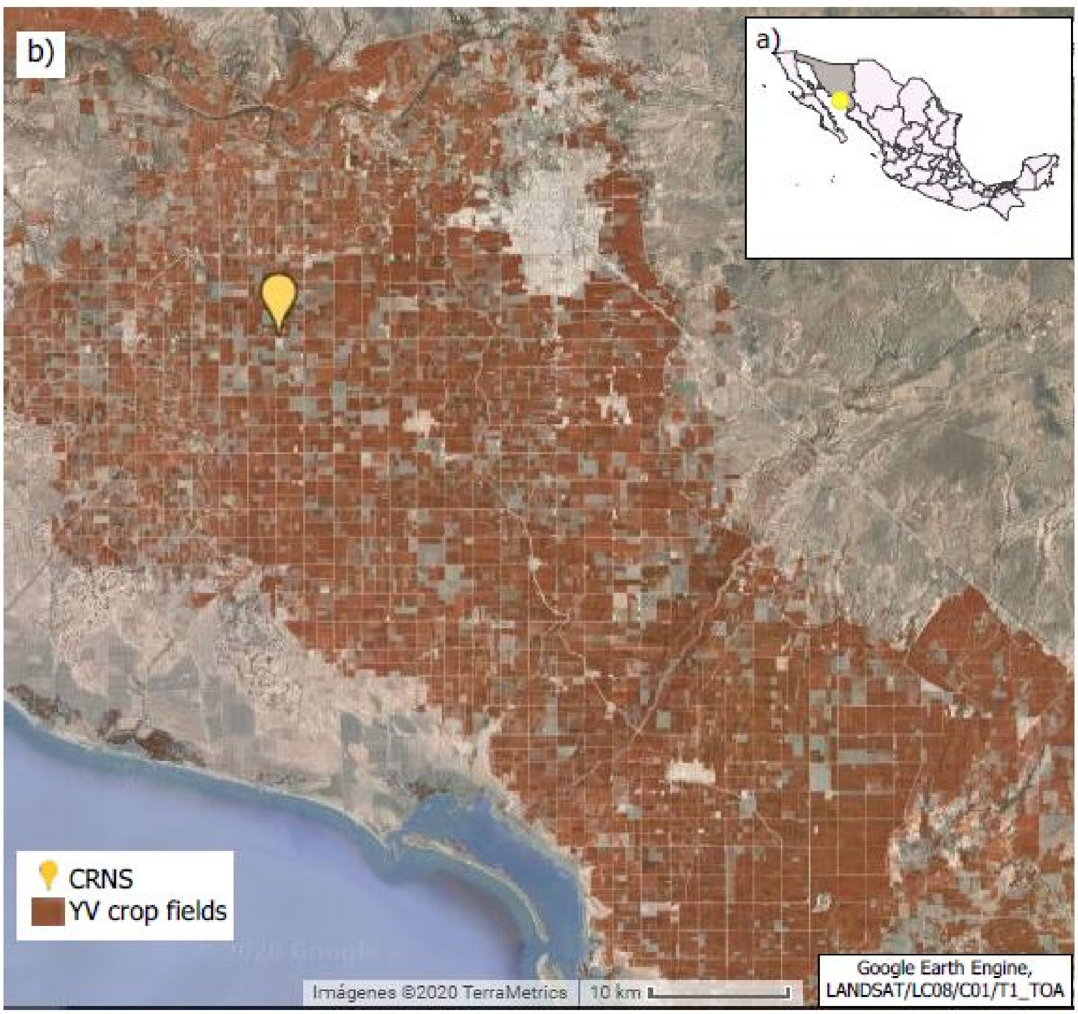


1. INTRODUCTION

- Soil moisture is an essential measurement to manage water and improve crop production.
- Wheat (*Triticum sp.*) is produced extensively in the semiarid NW of Mexico, in the Yaqui Valley (YV).
- The agricultural system at the Yaqui Valley applies flood irrigation as moisture supply, leading to opportunities to improve the water management capacities.
- Most of the cultivated soil contains up to ~ 50% clay, which results in marked changes to soil properties from wet to dry conditions and challenges in the implementation of in-situ measurements of soil moisture.

Yaqui Valley



Flood irrigation

Objective

- To test the Cosmic-Ray Neutron Sensor (CRNS) to generate high-resolution soil moisture measurements.
- Compare CRNS estimates with the TDR-profile measurements.

2.MATERIAL AND METHODS

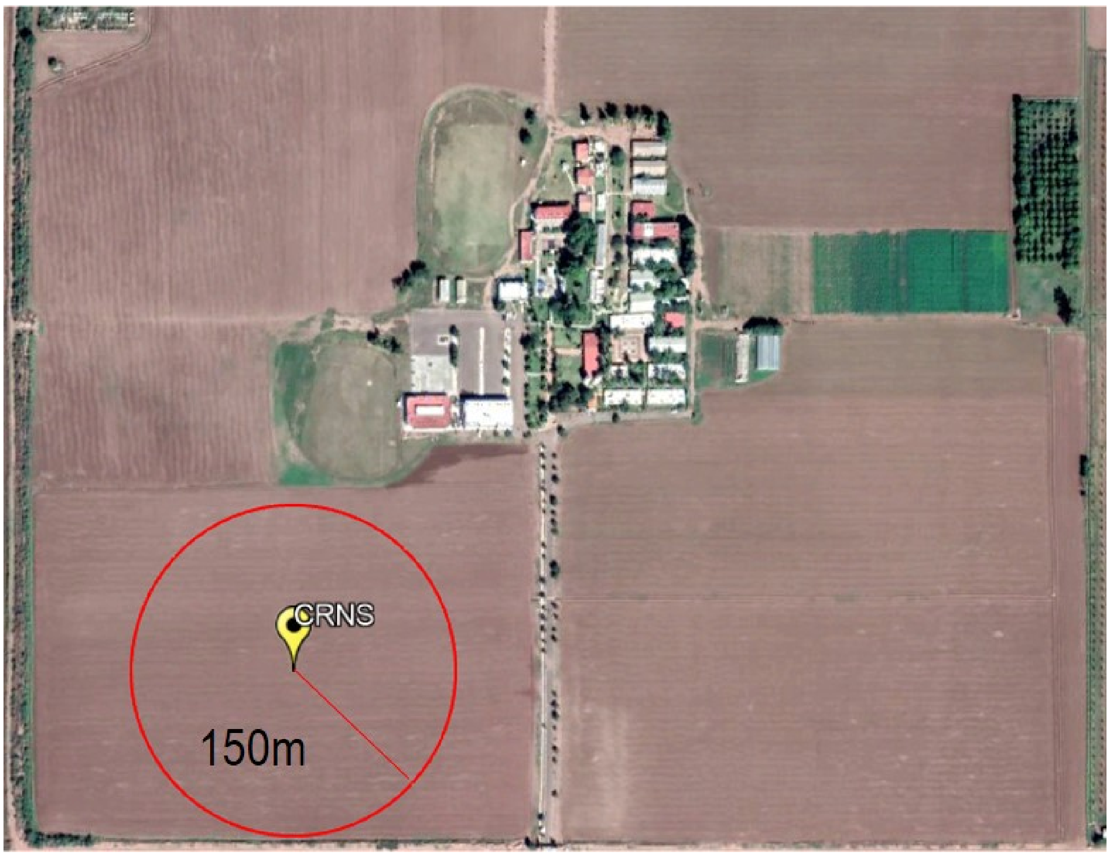
Yaqui Valley

- Crop: wheat (Triticum sp.), 160, 000 ha.
- Cycle 2019-2020: mid-December to early-May

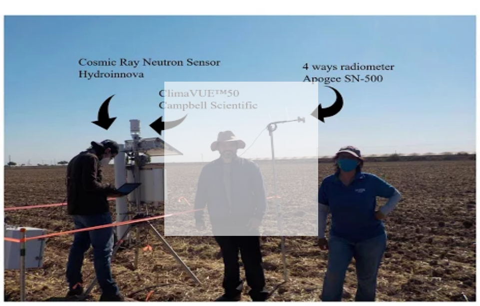
Field site at Instituto Tecnológico del Valle del Yaqui.

Traditional crop production with 3 irrigation events.

Yellow dot shows location of monitoring system.

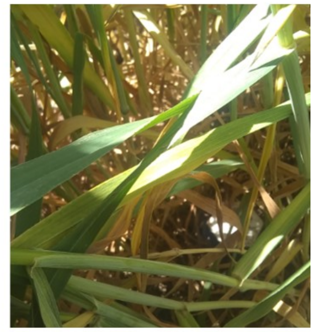


Installed equipment:

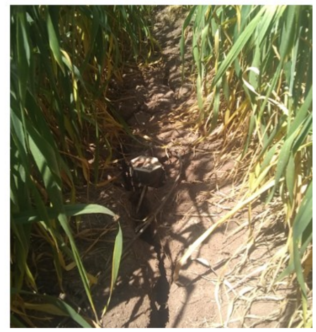


ue-50 (https://www.campbellsci.com/climavue-
.html (http://hydroinnova.com/ps_soil.html)),
mpbellsci.com/soilvue10)), one under vegetation

Ridge-Vegetation

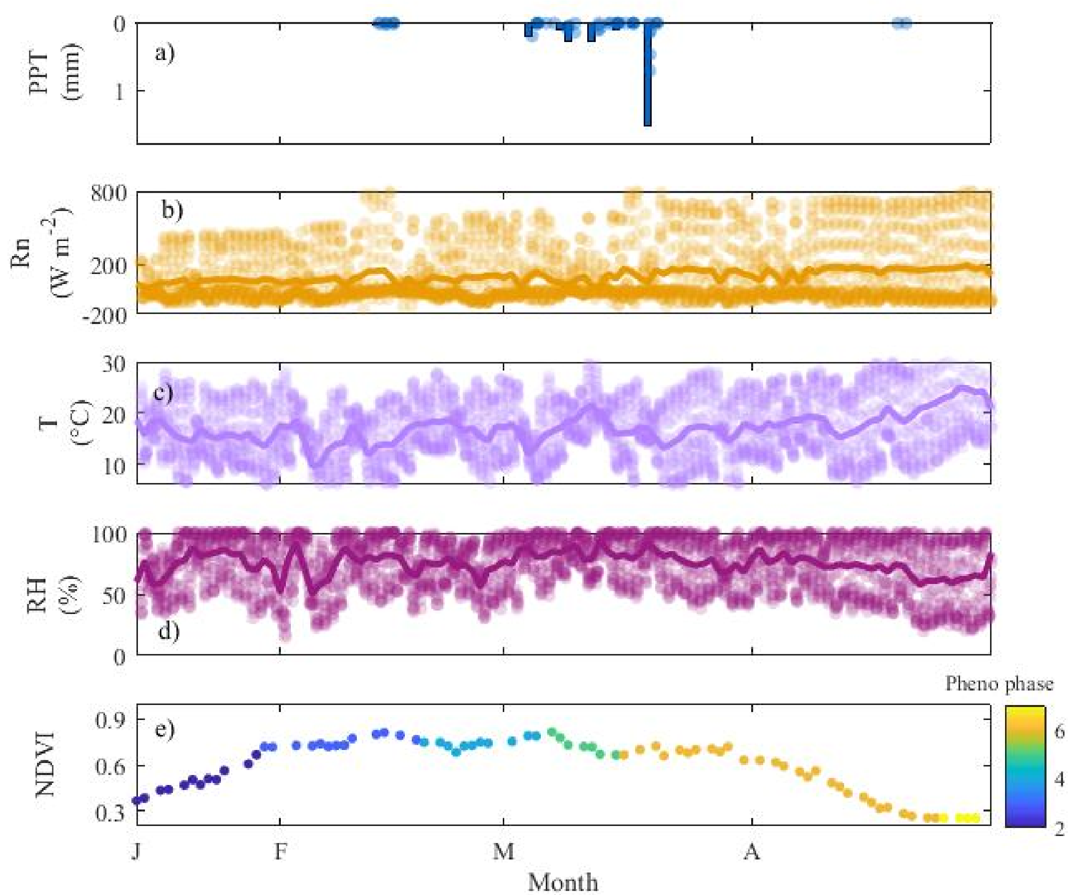


Furrow-bare



3. MICROMETEOROLOGICAL CONDITIONS AND PHENOLOGY

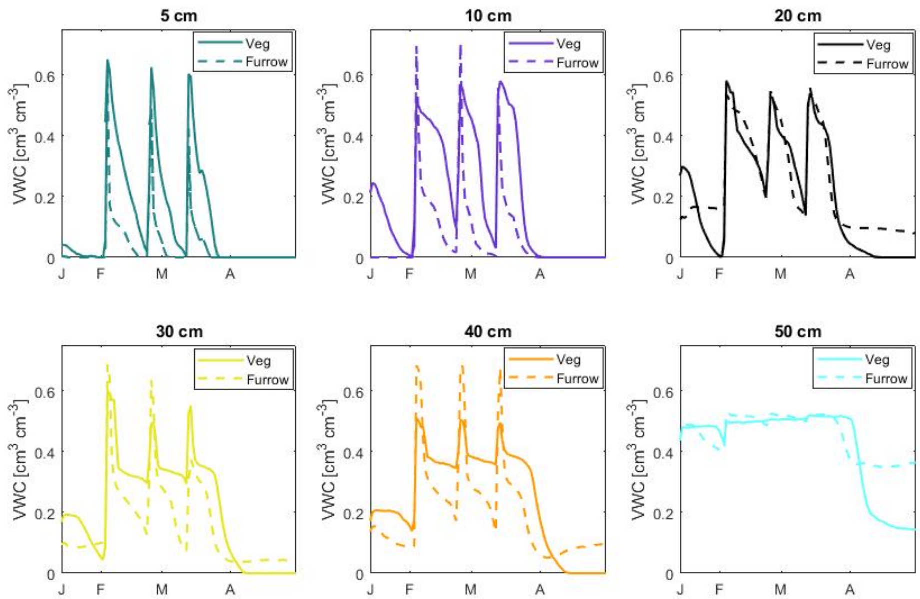
- Light winter precipitation events were observed in March, winter events are not always present in this region usually they are not considered for water management purposes
- Net radiation (Rn), temperature (T), and relative humidity (RH) increase towards May



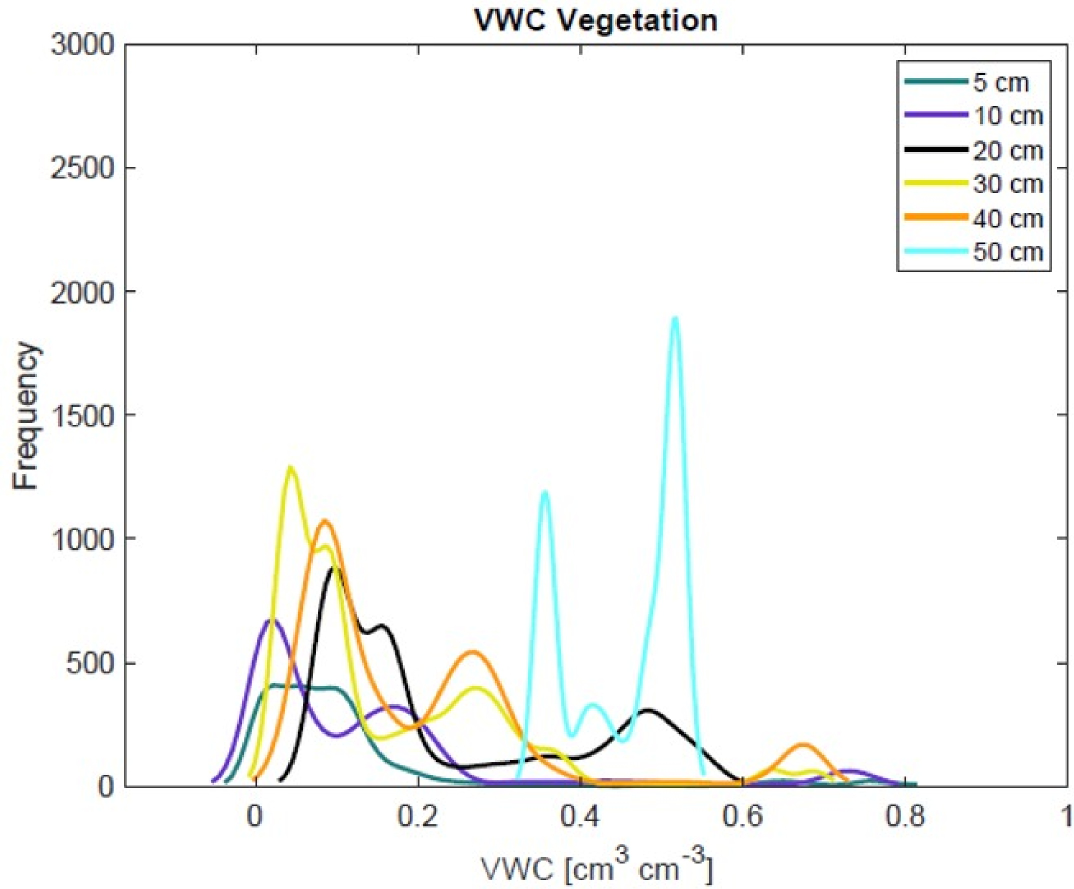
- Maximum NDVI goes from the stem extension to early ripening stage, basically February and March
- Irrigation events are programmed during the peak of leaf biomass (high NDVI)

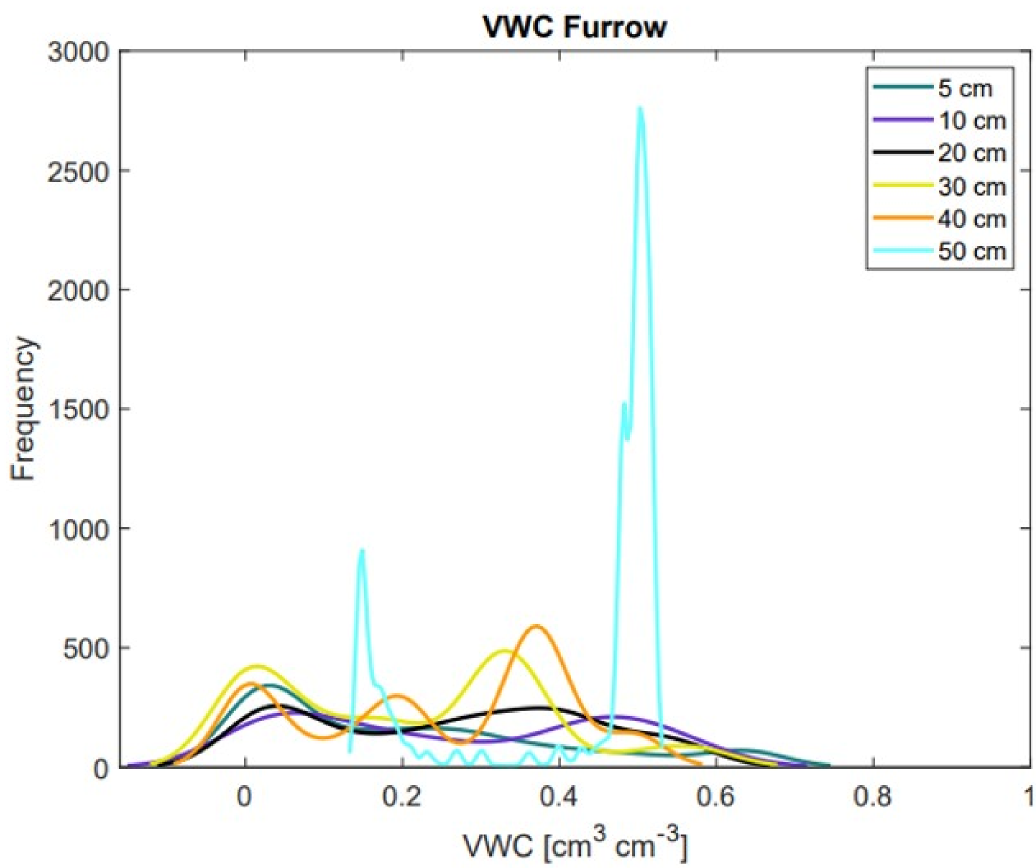
4. HOW DOES SOIL MOSTURE CHANGE WITH DEPTH?

- Soil moisture (VWC) varies spatially from vegetation sites to base sites
- VWC responds rapidly to the irrigation events in the first 40 cm
- VWC is rapidly lost in the first 5 and 10 cm of the soil matrix under both conditions vegetation (ridge) and furrow (bare)
- VWC at 50 cm is not responsive to irrigation events, remaining with a constant value



- Data variability in the first 30 cm is high in the vegetation site, which does not happen in the furrow site
- Higher VWC >0.6 cm^3cm^{-3} are not that frequent in either vegetation or furrow, reinforcing the response to irrigation pulses
- Observations from first 30 cm at the vegetation site are skewed between 0 and 0.2 cm^3cm^{-3}, in contrast at the furrow site the probability of overlap is higher leading to an homogeneous distribution
- At depths beyond 40 cm, VWC frequency is higher between 0.2 and 0.6 cm3cm-3


VWC Vegetation
3000
2500
2000
1500
1000
500
0
Frequency
0
0.2
0.4
0.6
0.8
1
VWC [cm3 cm-3]
5 cm
10 cm
20 cm
30 cm
40 cm
50 cm


VWC Furrow
3000
2500
2000
1500
1000
500
0
Frequency
0
0.2
0.4
0.6
0.8
1
VWC [cm3 cm-3]
5 cm
10 cm
20 cm
30 cm
40 cm
50 cm

5. CRNS CALIBRATION

Neutron count correction

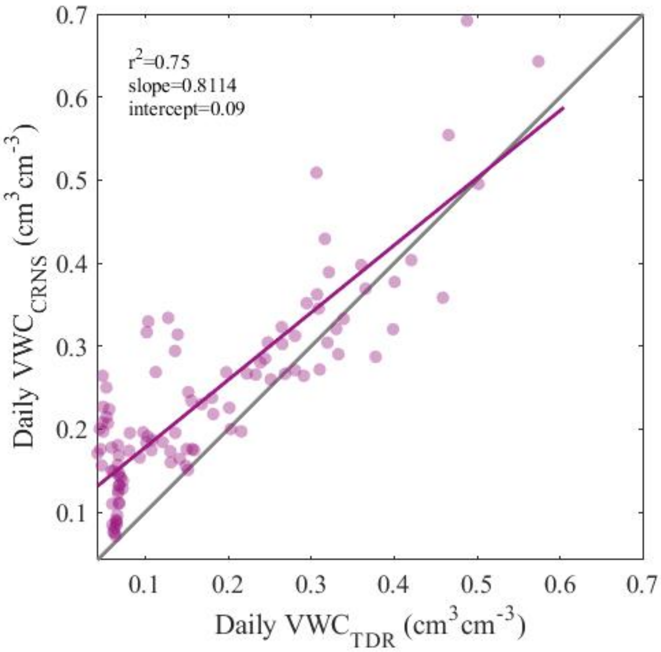
Correction factor (f):

- Pressure, $f_P = exp\left(\frac{P-P_0}{L}\right)$, where L(gr cm2) is the mass attenuation length 130, P (mbar) is pressure, and P_0 (mbar) is pressure referees for the site 1009
- Atmospheric water vapor, $f_{wv} = 1 + 0.0054 \times \left(\rho_{v0} - \rho_{v0}^{ref}\right)$ where $\rho v0$ (kg m^3) is absolute humidity at measurement time and ρ_{v0}^{ref} is the average absolute humidity during the period
- Incoming neutron flux, $f_i = \frac{N_m}{N_{avg}}$,where N_m is measured incoming neutron flux and N_{avg} the average during the period
- $N_{corr} = N_{obs} \times f_P \times f_{wv} \times f_i$

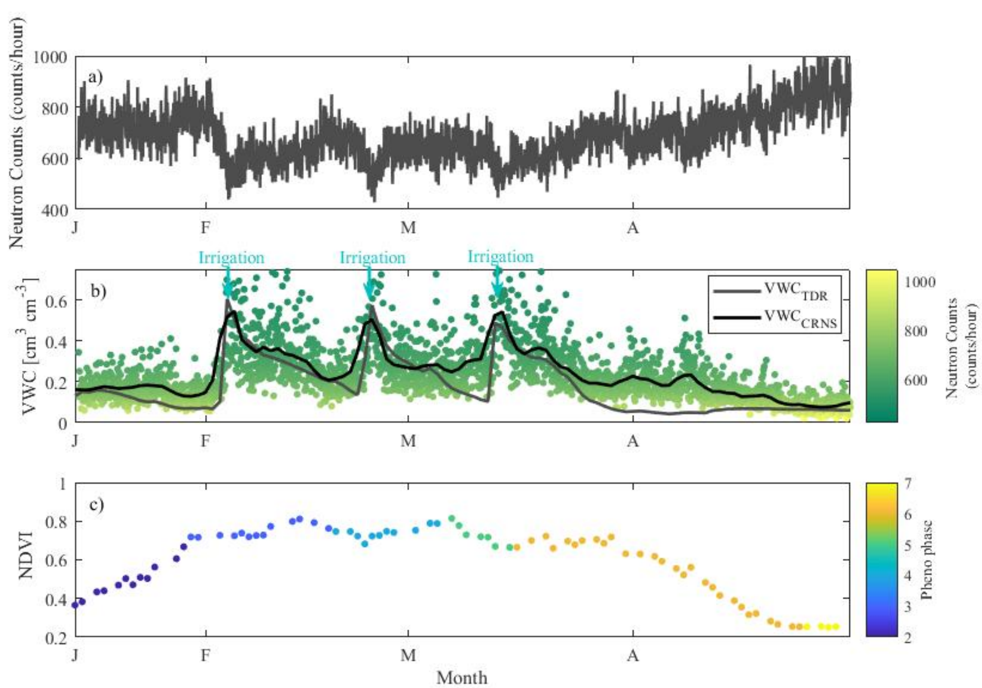
- Average of VWC_TDR from 5 to 30 cm from vegetation and furrow
- Find data points above 0.2 cm3cm-3 for VWC_TDR and Neutron counts, to estimate N0 dry count rate by inverting Desilets et al 2010 equation
- VWC_CRNS calculation

$$VWC(N) = \frac{0.0808}{\frac{Ncorr}{N_0} - 0.372} - 0.115$$

We observe an overestimation on VWC estimated with the CRNS during low VWC events, because TDR sensors are not capable of measuring due to soil cracks



6. TAKE HOME MESSAGE AND FUTURE WORK



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- CRNS is sensitive to irrigation events and pulses of precipitation
- TDR is sensitive to irrigation events, however measurements will be challenging to implement in intensive agricultural soils with high clay content, because of soil cracks
- Next calibration process will be performed using gravimetric soil moisture
- Further exploration of soil moisture with depth could consider root weighted soil moisture averages
- Compare evapotranspiration measurements and phenophases with soil moisture dynamics

Acknowledgement

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

Coordinated Research Project (CRP) D1.20.14 Enhancing agricultural resilience and water security using Cosmic-Ray Neutron Sensor

CONACYT-CB-286494-Transporte y deposición de partículas atmosféricas en un gradiente cuenca arriba (Valle agrícola – pie de monte)

The help of Miguel Rivera and Guillermo López Castro, and ITVY field managers

ABSTRACT

Soil moisture is an essential measurement to manage water and improve crop production. However, agricultural research in the Yaqui Valley (in northwestern Mexico) with extensive wheat fields (*Triticum sp.*) have focused on other monitoring schemes (e.g. remote sensing) with less attention to soil moisture. Most of this cultivated soil contains up to ~ 50% clay, which results in changes to soil properties from wet to dry conditions and challenges in the implementation of in-situ measurements of soil moisture. For this research, we selected a 1-ha wheat field in the Yaqui Valley representative of a typical flood irrigation system. We measured meteorological variables (ClimaVUE™50), and soil moisture for the winter crop-cycle from December 2019 to Abril 2020. Volumetric water content (VWC) was recorded from 5 to 50 cm using two TDR (SoilVUE™10), one located in the bottom of the furrow under bare conditions, and the other on the top under the vegetated condition for further integration and comparison. A Cosmic Ray Neutron Sensor (CRNS) was located alongside the meteorological sensor. The universal calibration equation was used to estimate VWC based on neutron counts. The comparison from the CRNS and the integrated TDR (5 to 50 cm) resulted in an RMSE of 0.02 m^3m^{-3} and an $r^2 = 0.73$. While both technologies respond to water inputs, the CRNS is a more reliable measurement during the dry-down periods when the high-clay soil cracks to the extent of 40 cm where soil is exposed to air. During this driest period, recorded VWC at 50 cm was, on average, 0.25 m^3 m^{-3}, while measurements with the CRNS was on average, 0.16 m^3 m^{-3}. Interestingly, both sensors peaked at 0.56 m^3 m^{-3} during the flood irrigation event.

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