Supporting material for poster: **Soil moisture drydown curves after flooding events across an irrigated farmland**

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Methods and equations

1. Soil moisture observations

1.1 Integrated soil moisture (θ) from the TDR sensors.

Two TDR θ sensors (see section 4) were buried in the study site, both observe 6 depths simultaneously (5, 10, 20, 30, 40 and 50 cm). To be compared with a CRNS we only used the depths up to 30 cm, so we obtained daily means for the 5, 10, 20 and 30 cm from both sensors. The θ of all the depths was averaged for every sensor (eq 1 and eq 2) and then averaged between both sensors daily (eq 3).

$$\theta_{veg} = (\theta_{5cm} + \theta_{10cm} + \theta_{20cm} + \theta_{30cm})/4 \quad \text{(eq 1)}$$

where θ_{veg} is the daily integrated soil moisture for the sensor in the vegetation (ridge) site (cm³/cm³) and θ_{5-30cm} is the daily soil moisture for every specific depth for the sensor in the vegetation (ridge) site (cm³/cm³).

$$\theta_{bare} = (\theta_{5cm} + \theta_{10cm} + \theta_{20cm} + \theta_{30cm})/4 \quad \text{(eq 2)}$$

where θ_{bare} is the daily integrated soil moisture for the sensor in the bare soil (furrow) site (cm³/cm³) and θ_{5-30cm} is the daily soil moisture for every specific depth for the sensor in the bare soil (furrow) site (cm³/cm³).

$$\theta_{TDR} = (\theta_{veg} + \theta_{bare})/2 \quad \text{(eq 3)}$$

Where θ_{TDR} is the daily integrated soil moisture for the first 30 cm and both sensors (cm³/cm³), θ_{veg} is the daily integrated soil moisture for the sensor in the vegetation (ridge) site (cm³/cm³) and θ_{bare} is the daily integrated soil moisture for the sensor in the bare soil (furrow) site (cm³/cm³).

1.2 Cosmic-Ray Neutron Sensor (CRNS) calibration and estimate of θ.

A CRNS is a tool that observes neutrons, to use it to estimate θ we first must correct and calibrate the neutron counts observed by the sensor following a standardized procedure (Franz et al., 2020). To do this, a field sampling took place to obtain θ from the gravimetric method. Then, the time series of the CRNS for that specific day was used to apply the corrections for air pressure (eq 4), water vapor (eq 5) and neutron intensity (eq 9) (Desilets et al., 2010; Desilets & Zreda, 2006; Rosolem et al., 2013). Equations 6, 7 and 8 are for absolute humidity (ρ_v), actual vapor pressure at surface (e) and saturated vapor pressure at surface (e_o) respectively, obtained from (Stull., 2011).

$$f_p = \exp\left(\frac{P-P_o}{\lambda}\right) \quad \text{(eq 4)}$$

where f_p is the air pressure correction factor, P is the real air pressure (hPa), P_o is the air pressure reference por the site (hPa, constant 1,009 hPa obtained from http://cosmos.hwr. arizona.edu/Util/calculator.php) and λ is the mass attenuation length (g/cm², constant 130 g/cm²).

$$f_{wv} = 1 + (0.0054 * \rho_v) \quad \text{(eq 5)}$$

where f_{wv} is the water vapor correction factor and ρ_v is absolute humidity (g/m³) obtained from equation 6.

$$\rho_v = \left(\frac{e}{R_v*(T+273.15)}\right) * 1000 \quad \text{(eq 6)}$$

where ρ_v is absolute humidity (g/m³), e is actual vapor pressure at surface (Pa) obtained from equation 7, R_v is gas constant for water vapor (J/K / kg, constant 561.51 J/K / kg) and T is temperature (°C).

$$e = \left(\frac{RH}{100}\right) * e_o \quad \text{(eq 7)}$$

where e is actual vapor pressure at surface (Pa), RH is relative humidity (%) and e_o is saturated vapor pressure at surface (Pa) obtained from equation 8.

$$e_o = 611.2 * exp\left(\frac{17.67*T}{243.5+T}\right) \quad \text{(eq 8)}$$

where e_o is saturated vapor pressure at surface (Pa) and T is temperature (°C).

$$f_i = \frac{N_m}{N_{avg}} \quad \text{(eq 9)}$$

where f_i is the high neutron intensity correction factor, N_m is the measured incoming neutron flux (neutrons) and N_{avg} is the average of neutrons during the period (neutrons).

Finally, to correct the neutron observations we applied equation 10.

$$N_{corr} = N_m * f_p * f_{wv} * f_i \quad \text{(eq 10)}$$

where N_{corr} is the corrected neutron counts (neutrons), f_p is the air pressure correction factor, f_{wv} is the water vapor correction factor and f_i is the high neutron intensity correction factor.
Now, for the day of the sampling we obtained an average for the N_{corr} in the whole day and used equation 11 to obtain N_0 (Desilets et al., 2010).

$$N_0 = \frac{N_{corr}}{\left(\frac{0.0808}{\theta_{grav}+0.115}\right)+0.3372} \quad \text{(eq 11)}$$

where N_0 is the neutron counting rate over dry soil (neutrons), N_{corr} is the corrected neutron counts (neutrons) and θ_{grav} is the volumetric water content of the soil for the date of the field sampling (cm³/cm³) along with bulk density.
Now, with N_0 obtained, we can use (Desilets et al., 2010) equation to our entire database of corrected neutron counts to obtain θ from neutron counts (eq 12).

$$\theta_{CRNS} = \frac{0.0808}{\frac{N_{corr}}{N_0}-0.372} - 0.115 \quad \text{(eq 12)}$$

where θ_{CRNS} is the volumetric water content from CRNS (cm³/ cm³), N_{corr} is the corrected neutron counts (neutrons) and N_0 is the neutron counting rate over dry soil (neutrons) obtained from equation 11.

2. Soil moisture drydown curves.

To obtain the drydown curves for each irrigation event we had to identify the date of every irrigation event in the θ database, knowing that there were 3 events. We selected the day for the peak of irrigation (higher θ) and the following 18 days (for the 1st and 3rd irrigation events) and 16 days (for the 2nd irrigation event). The exponential model in equation 13 was fit to obtain θ_{decay} and $\theta_{threshold}$ (Sanchez-Mejia & Papuga, 2014).

$$\theta(t) = (\theta_i - \theta_f)e^{(-t/\tau)} + \theta_f \quad \text{(eq 13)}$$

where θ is the volumetric soil moisture (cm³/cm³), t is the time in days after the irrigation event, θ_i is the soil moisture on the first day of the irrigation event (cm³/cm³), θ_f is the soil moisture on the last day of the drydown curve (cm³/cm³) and τ is the exponential time constant.

τ represents the value of θ_{decay} and at time (1/τ) we have our $\theta_{threshold}$ which represents 1/3 of the moisture left.

3. Micrometeorology

3.1 Evapotranspiration (ET).

From ClimaVue (weather station, see section 4) we obtain reference evapotranspiration (ET_o). To estimate actual ET we used equation 14 and a crop coefficient (K_c) according to (Allen et al., 1998; Garatuza-Payan et al., 1998).

$$ET = ET_o * K_c \quad \text{(eq 14)}$$

where ET is the crop evapotranspiration (mm/day), ET_o is the reference evapotranspiration (mm/day) and K_c is the crop coefficient.

The crop coefficient depends on the phenological phase of the crop (winter wheat in this case)(Fischer, 2016), so K_c values were obtained from the same paper to 3 different phases and were distributed as follows (our time series goes from Julian day 14 to 121):

- $K_c = 0.7$ for Julian day 14 to 29.
- $K_c = 1.15$ for Julian day 30 to 90.
- $K_c = 0.25$ for Julian day 91 to 121.

3.2 Vapor pressure deficit (VPD).

To estimate VPD we used equation 15.

$$VPD = e_o - e \quad \text{(eq 15)}$$

Where VPD is vapor pressure deficit (kPa), e_o is saturated vapor pressure at surface (kPa) obtained from equation 16 and e is actual vapor pressure at surface (kPa) obtained from equation 7.

$$e_o = 0.6108 * exp\left(\frac{17.27*T}{237.3+T}\right) \quad \text{(eq 16)}$$

Where e_o is saturated vapor pressure at surface (kPa) and T is temperature (°C).

4. Vegetation greenness

4.1 Normalized difference vegetation index (NDVI).

We downloaded the NDVI timeseries using the Google Earth Engine tool (Gorelick et al., 2017) to access the Landsat 8 collection (U.S. Geological Survey, 2021). In Matlab© we gapfilled missing dates to create a daily timeseries.

5. Instrumentation

The instrumentation (figure 1) used to develop this project is listed as follows:

a. Cosmic-Ray Neutron Sensor (CRNS, CRS-1000, Hidroinnova®, Albuquerque, New Mexico, U.S.A.)
b. 2 Soil Profilers, Time Domain Reflectometers (TDR, SoilVUE™10, Campbell Scientific®, Logan, Utah, U.S.A.)
c. Micrometeorological Station, Weather Sensor (ClimaVue™50, Campbell Scientific®, Logan, Utah, U.S.A.)
d. Radiometer (4-WR, Apogee Instruments®, Logan, Utah, U.S.A.)

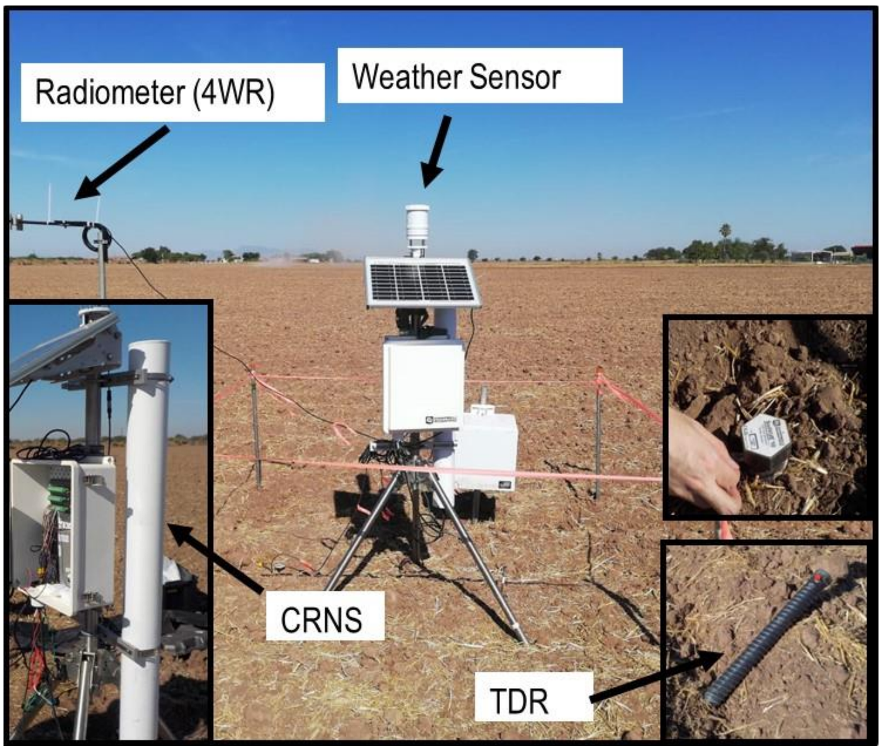

Figure 1. Instrumentation at the Yaqui Valley.

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