Field-water data mining preliminary report

Precipitation uncertainty, error assessment and recalibration of SENTEK probes

Tomás Roquette Tenreiro

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1. Introduction

The present document aims to discuss briefly the uncertainty related to precipitation input data regarding spatial variations of rainfall, captured both at field level and among different weather stations nearby located. The methodology that was followed in the assessment of error, associated with field measurements of soil water content (SWC) using capacitance probes (SETENK-D&D 90 cm), as well as the correction approach taken on probes data are also described. The data here presented and discussed, corresponds to the 2020 winter wheat experiment (WP 2.1), conducted in '*Finca las trescientas*', located in Guadalcázar, Cordoba, Spain.

2. The uncertainty regarding rainfall data

Rainfall was monitored with a METER Environment pluviometer (automated ZL6-data-logger) installed at 650 meters from the centre of the experimental plot. In order to explore within field spatial variation of rainfall distribution, manual rain gauges were distributed over soil surface at two separated rainfall events (Figure 1), following a sampling scheme based on the spatial heterogeneity of multiple field properties[1].

Point based measurements were spatially interpolated through the 'k-nearest neighbour's algorithm (k-NN) and the corresponding rainfall coefficient of variation was estimated (i.e. 9.55%).

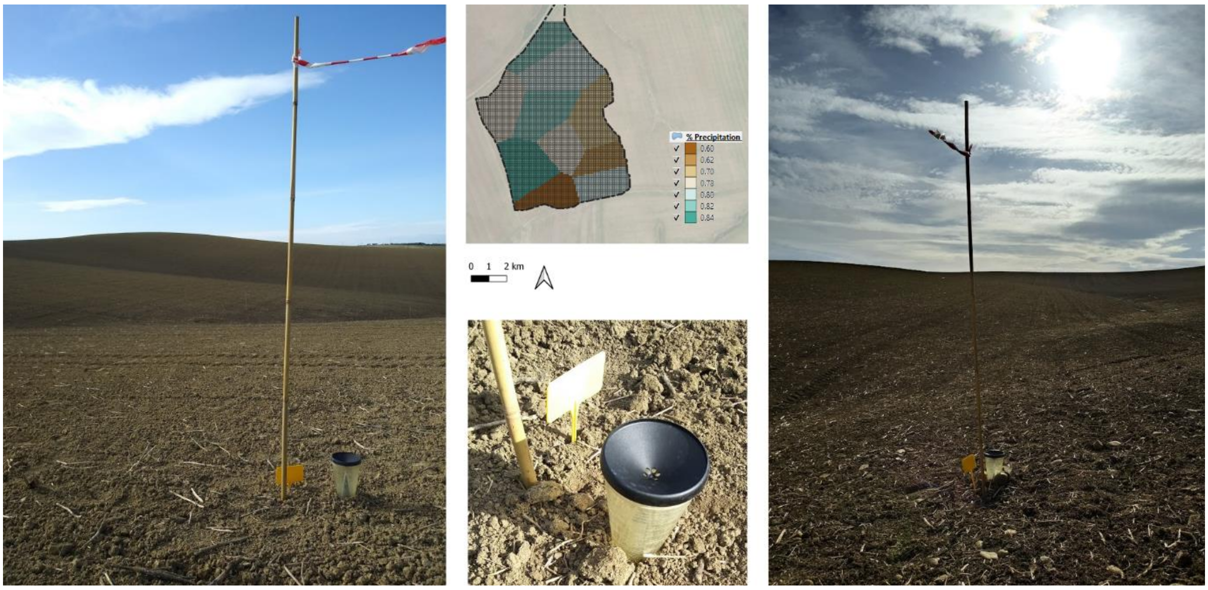


Figure 1. Manual field measurements of rainfall distribution, rain gauges spatially distributed over soil surface and a map of relative rainfall distribution in respect to METER pluviometer data.

In addition to the elementary assessment of rainfall distribution, previously described, field daily rainfall values (i.e. daily sum of data registered by the METER pluviometer from crop emergence to maturity) were compared with the daily values reported by a weather station located at approximately 10 km, i.e. the IFAPA weather station in Alameda del Obispo, Córdoba (Figure 2).

[1]https://github.com/RoquetteTenreiro/Mapping2Sampe_R/blob/master/Markdown_code.md.

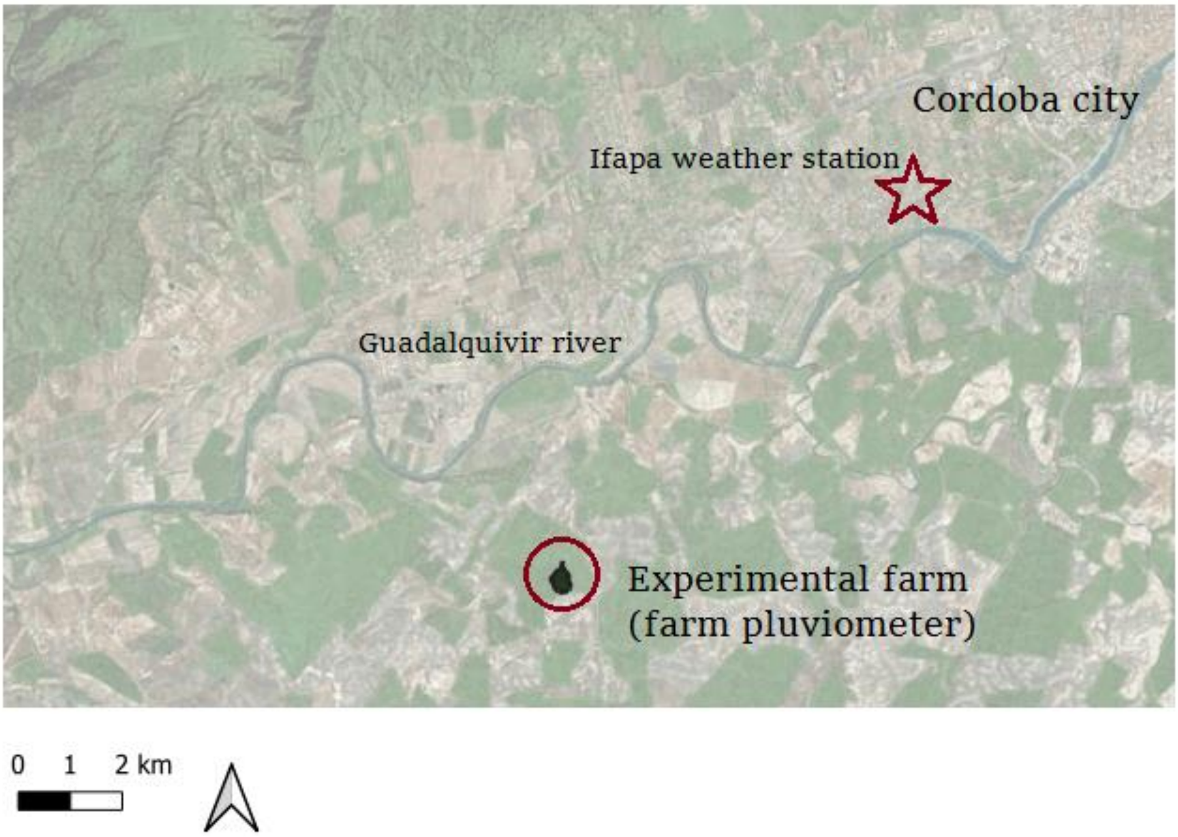


Figure 2. Map of the region, location of the experimental farm (pluviometer) and the weather station used for comparison (IFAPA weather station, approximately 10 km from the experimental farm).

In general, daily values from each rainfall monitoring point were well correlated (i.e. the coefficient of determination equals 0.87, the slope and x-intercept are respectively close to one and zero, see Figure 3). However, it is important to note that approximately 13% of rainfall variance is not predicted by the existing correlation. This is partly in line with the results previously described (i.e. a 9.55% of within spatial variation of rainfall).

From these two exploratory analyses here described, the main conclusion to be drawn highlights that, in this particular case, working with a single data source (i.e. farm located METER pluviometer) will inevitably introduce a certain level of uncertainty, mostly when trying to distribute water inflows over the horizontal space (as rainfall varies spatially on about 9- 13% under the addressed scales, but one single value will be taken each day).

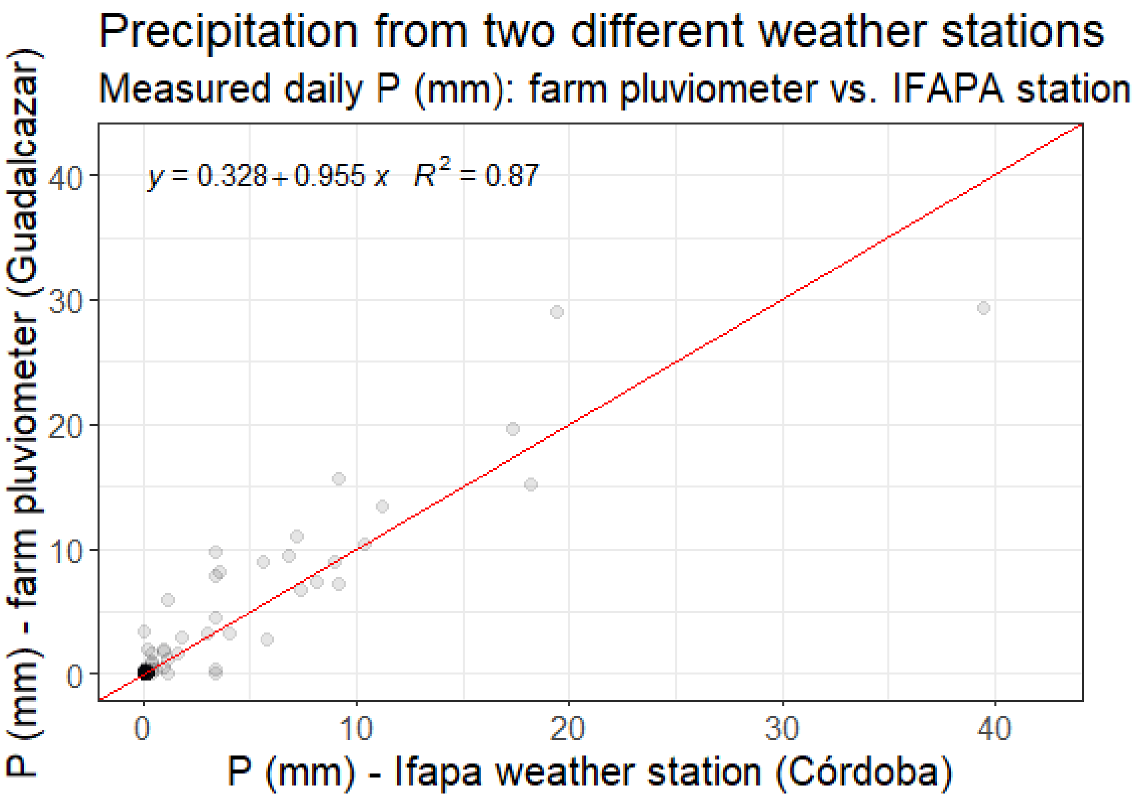


Figure 3. The correlation between the two independent data sources of daily rainfall (i.e. the pluviometer located on the experimental farm and the IFAPA weather station, approximately 10 km apart). The red line represents the 1:1 line.

3. The assessment of capacitance probes error

Capacitance probes showed a considerable error in the final estimates of SWC in absolute terms. This general trend was observed for all probes and sites within the field. The relative error (δ) was estimated as following:

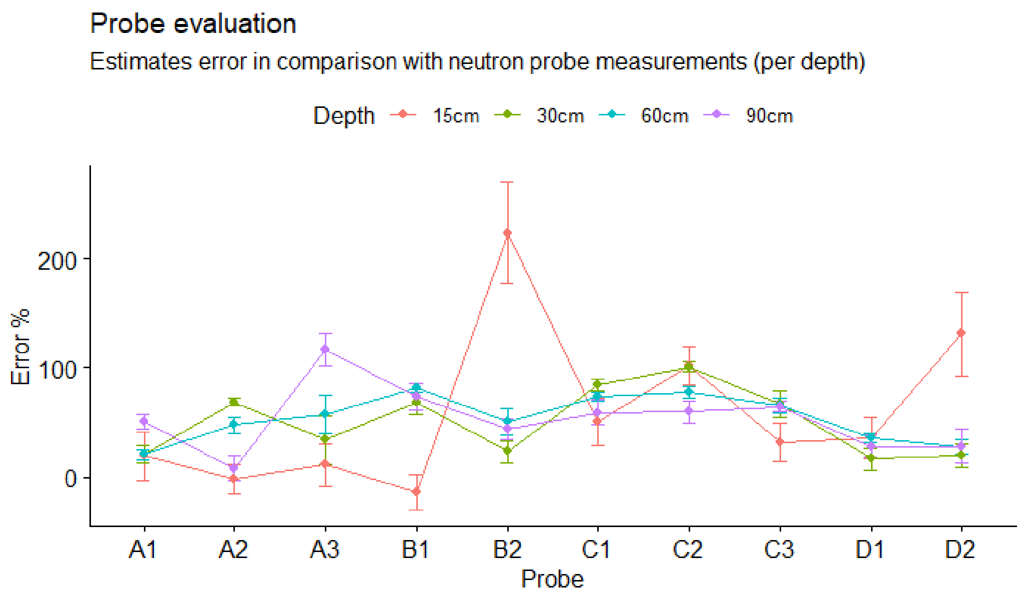
$$\delta = \frac{(x - x_0)}{x_0} \quad (1)$$

where x and x_0 represent the SWC measured by the capacitance probe and a neutron probe, respectively.

The neutron probes were calibrated with linear regression coefficients obtained from gravimetric measurements of SWC, obtained for the same soil type. The calibration functions used for the neutron probe varied from depth to depth, considering four different depths of SWC sensing (15, 30, 60 and 90 cm), and they were characterised by R^2 values of 0.96-0.98 for deep soil layers (30-90 cm) and 0.81-0.85 for superficial depths (0-30 cm).

The relative error assessment of the capacitance probes was conducted by taking the neutron probe measurements as the control set. The capacitance probes here used have nine sensing depths (i.e. 5, 15, 25, 35, 45, 55, 65, 75 and 85 cm) per probe. The SWC measurements with neutron probe at 15, 30, 60 and 90 cm were respectively correlated with the capacitance probe sensors located at 15 cm, the average of 25-35 cm, the average of 55-65 cm, and the last sensor located at 85 cm.

The relative error of the capacitance probes is a function of sampling site (i.e. probe site ID), depth (0-90 cm) and the period of the year, because in this specific conditions, the soil structure changes considerably throughout the year due to expansion and shrinkage cracking of clay. Multiple calibration functions were tested in the software of SENTEK (IrriMAX Live) in order to minimize error fluctuations per probe and depth. The 'Sentek D&D cracking clays' calibration function, available in the IrriMAX Live software, was chosen as the best option. For most cases, an overestimation of the SWC (estimated with capacitance probe in comparison with the data from the neutron probe) was observed (Figure 4 and 5).



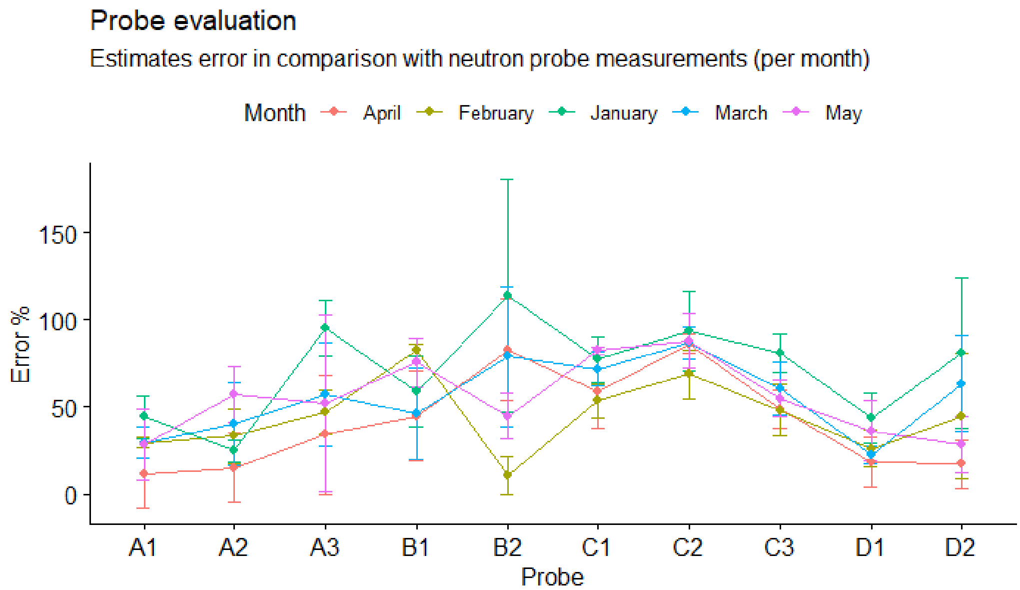


Figure 4. Mean error level per probe and depth (upper plot), and per probe and month (bottom plot). Data were collected at five different depths, one per month approximately, from crop emergence to maturity.

The capacitance probes tend to overestimate SWC on about 25-75%, depending on both probe location and sensor depth (Figure 4). The amplitude of error variation was the greatest at surface layers (0-30 cm) but it appears to stabilize for deeper layers (which is likely to be explained by a decrease of the effects of hysteresis with soil depth).

The relative error obtained was larger than what is reported by Mwale et al. (2005)[2], who analysed this issue more in detail. Mwale et al. (2005) reported a 20% average error between capacitance and neutron probes (with an R^2 value of 0.7) but their measurements were conducted in lighter soils and under semi-controlled conditions.

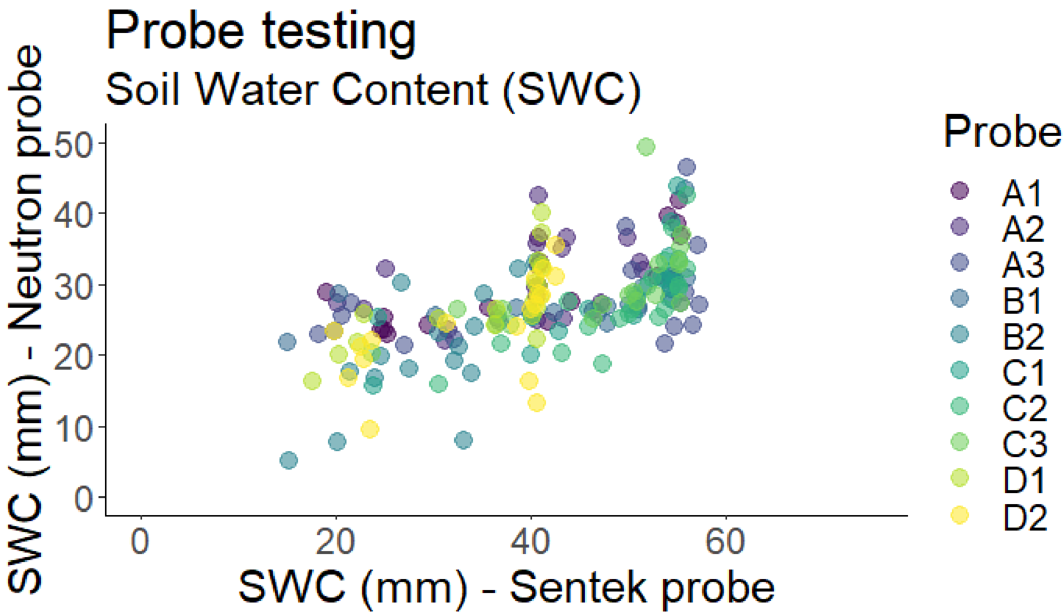


Figure 5. Sentek capacitance probe SWC plotted against neutron probe measurements of SWC.

[2] Mwale, S. S., Azam-Ali, S. N., & Sparkes, D. L. (2005). Can the PR1 capacitance probe replace the neutron probe for routine soil-water measurement?. Soil use and management, 21(3), 340-347.

4. The correction approach of probes data

Probes data were corrected by multiplying the SWC (capacitance probe measured) by a specific 'correction factor', defined according to each probe site and sensor depth (Figure 6). Two correction methods were tested for comparison, expressed as following:

$$SWC_c = \sum_{n\,=\,0\,cm}^{n\,=\,90\,cm}(SWC_{i,n} \cdot \omega_n) \tag{2}$$

$$SWC_c = SWC_{i,Z} \cdot \omega_Z \tag{3}$$

where SWC_c represents the corrected SWC (expressed in mm), for the entire profile, $SWC_{i,n}$ represents the non-corrected SWC (in mm) measured by the capacitance probe at depth n and ω_n is the correction factor estimated for each *probe* × *depth* (n) combination (unitless). $SWC_{i,Z}$ represents the sum of SWC measured by the capacitance probe, for the entire profile, and ω_Z is the correction factor when considering all sensing depths together (Figure 7).

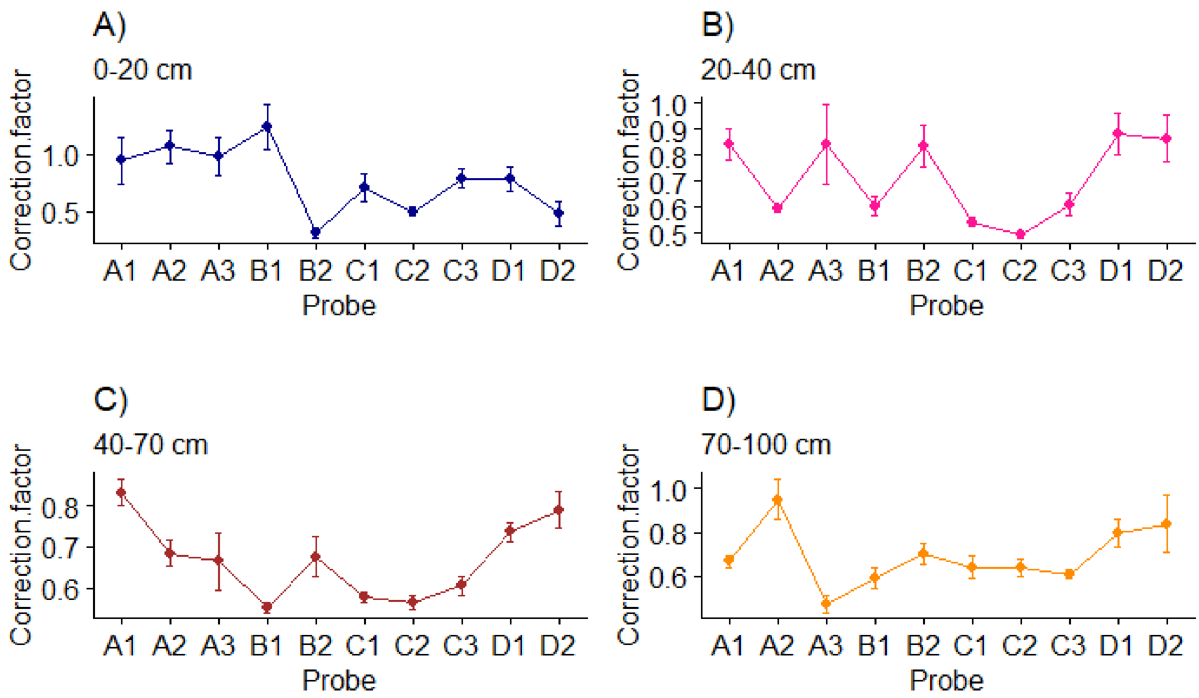


Figure 6. The correction factors estimated for each probe and depth.

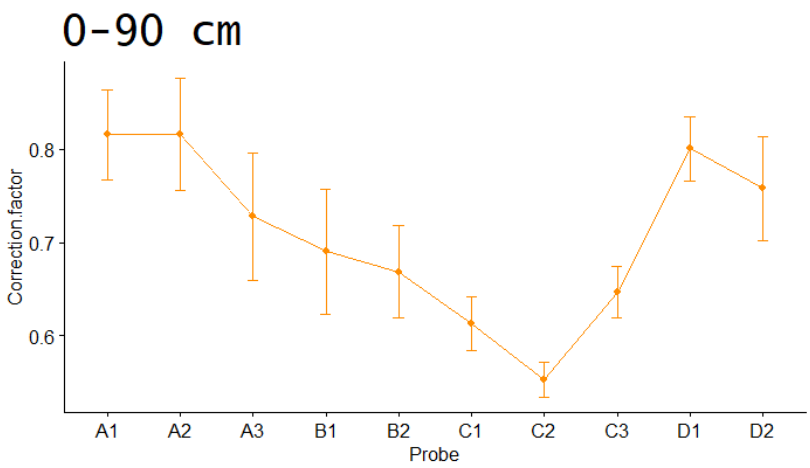


Figure 7. The correction factors for each probe (when integrating all sensing depths).

The comparison between the two methods showed only very slightly differences, which highlights that both options are equally valid to be used (Figure 8).

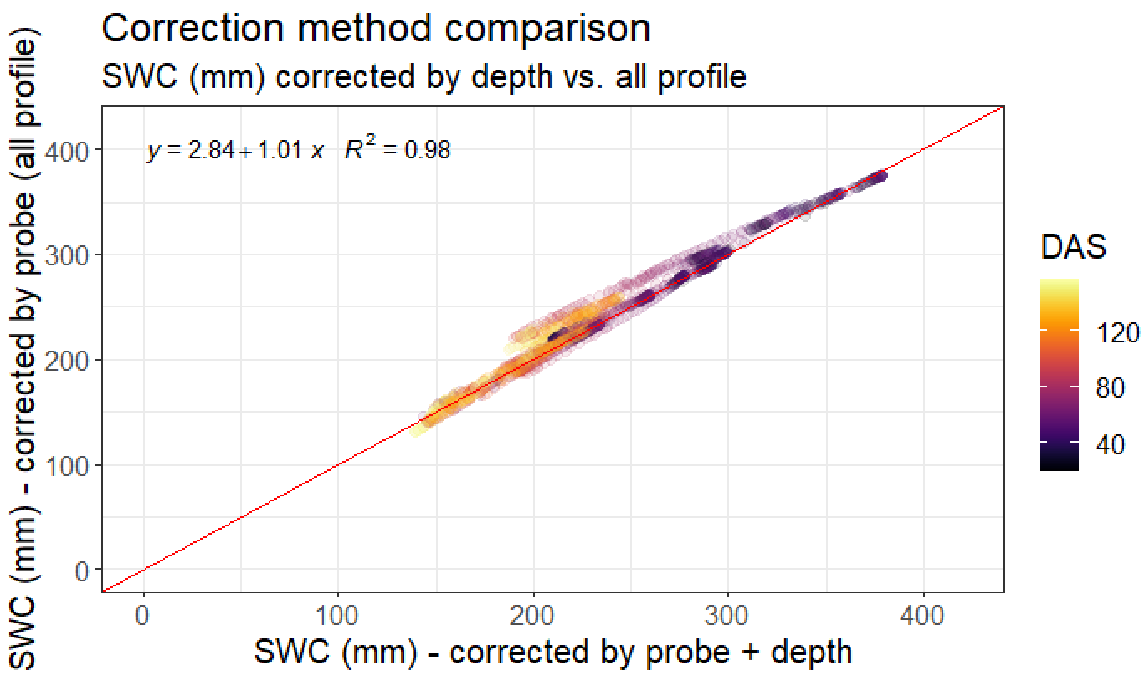


Figure 8. Correction method comparison. 'DAS' colours represent 'day after sowing', from 40 to 176, representing the measurement dates with neutron probe from which the correction factors were estimated.

Despite the existing inaccuracy, satisfactory robustness exists in respect to the estimated correction factors (i.e. the correction factors varied less than 0.1 in absolute terms for each *probe* × *depth* combination), probes uncertainty is predicted to be lower than 10% for most cases, and corrected data may be considered to be enough assertive for SWC spatial and temporal monitoring (Figure 9).

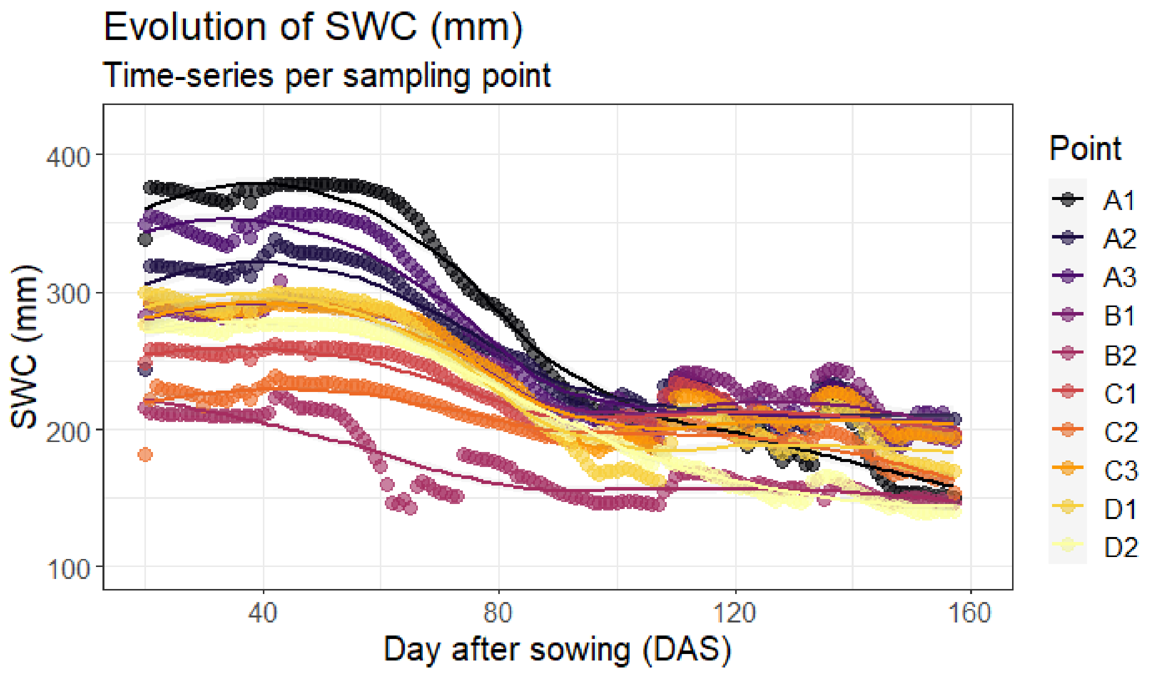


Figure 9. Temporal evolution of total SWC per probe site.

5. Spatial distribution of water inflows

The spatial distribution of water inflows was roughly derived from two data inputs (i.e. daily rainfall data and daily probe measurements of SWC after correction). Daily lateral inflows were derived through a simplified water balance, neglecting both runoff and crop water extraction from the calculation.

Every (daily) time-step that total SCW varies above precipitation input, the difference between SCW variation and precipitation input was assumed to be caused by lateral inflow. It is clear that such a raw calculation still neglects the important contribution of surface runoff and crop water uptake to the water balance, and consequently to the water inflow estimation, however it may serve as the baseline for establishing relative differences in terms of lateral inflows among different sites (Figure 10 and 11). Simulating daily runoff and crop water uptake are determinant for improving the estimates of lateral inflows from rainfall and probes data.

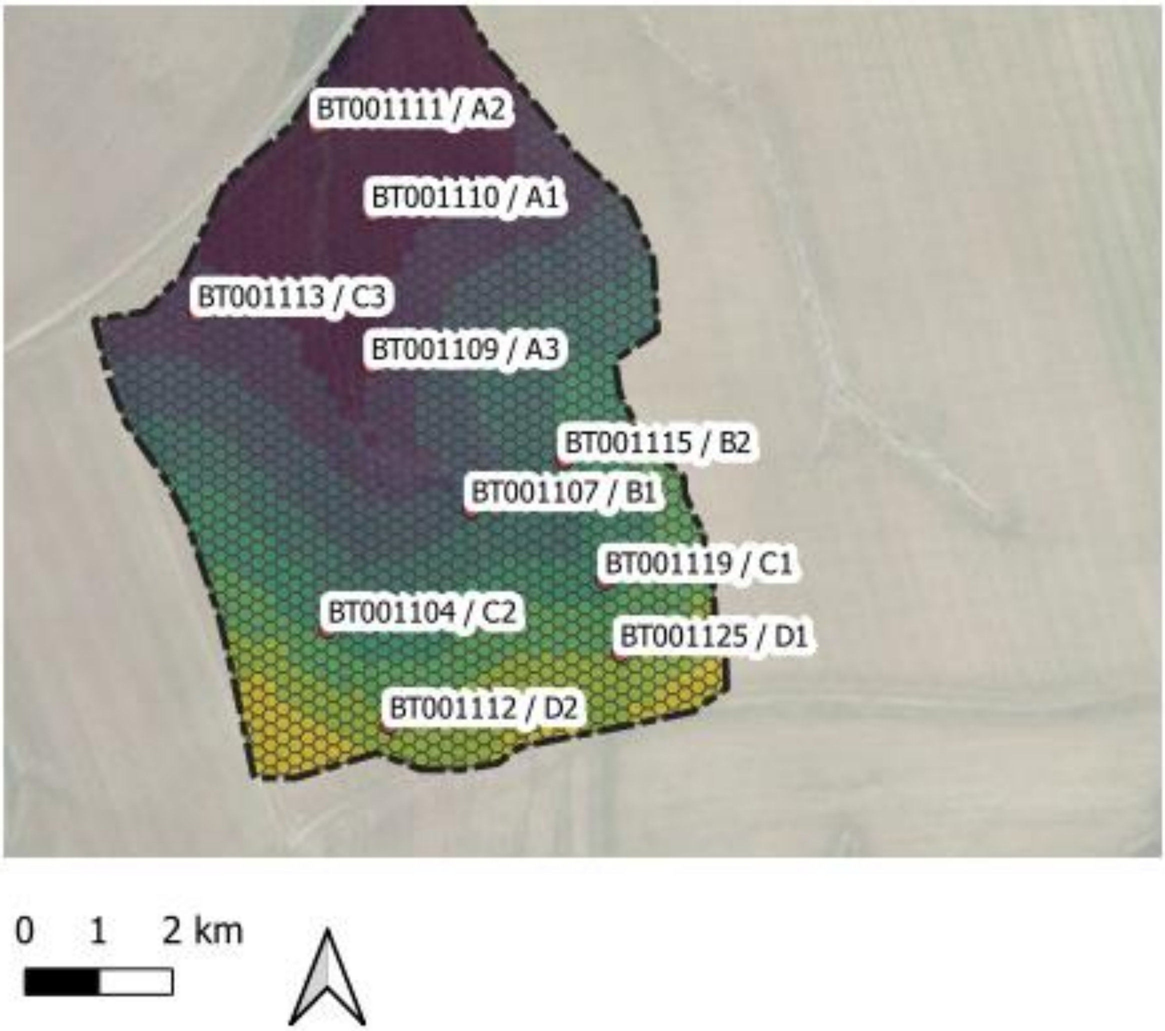


Figure 10. Spatial location of capacitance probes.

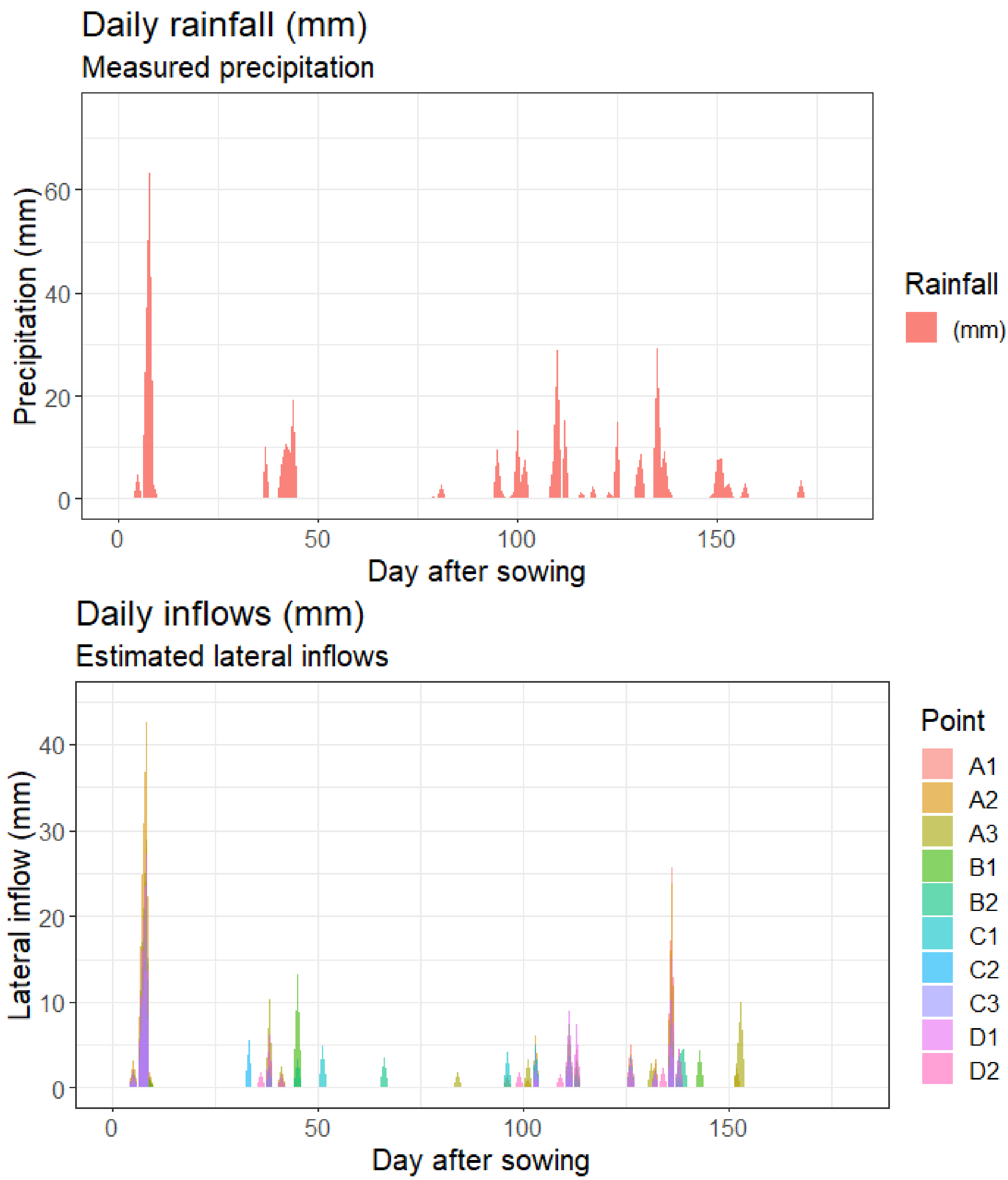


Figure 11. Water inflows (from crop emergence to maturity) per point site: daily rainfall (upper plot) and lateral inflows (bottom plot).

6. Final remarks

This document aims primarily to support users in the use of the 'SWC database' that is shared within the context of SHui WP2.1.

The SWC database provides daily values of SWC, measured at nine different depths and for 10 different point sites within the same field. Points can be mapped through GIS by using the shape files attached to this report. The SWC database was generated after correction of capacitance probes data, as explained in chapter three and four. The users must be aware of the existing limitations in respect to water inflow estimates, not just in terms of precipitation uncertainty (chapter one) but also in terms of lateral flows (chapter 5, please consider it as food for thought).

Please do not hesitate in contacting me in case you have any questions or would like to have further information: roquettetenreiro@gmail.com

7. Supplementary material

7.1 Soil data

Dataset	Parameter	Units	A1	A2	A3	B1	B2	C1	C2	C3	D1	D2
Soil	ECa	dS/m	0.45	0.55	0.45	0.20	0.20	0.20	0.20	0.20	0.35	0.40
	Clay content	*%*	50	50	50	38	38	38	38	38	50	50
	Sand content	*%*	15	15	15	22	22	22	22	22	15	15
	Texture class	*USDA system*	**Clay**			**Clay-loam**					**Clay**	
	Bulk density	*g/cm3*	1.76	1.68	1.78	1.88	1.78	1.8	1.8	1.78	1.81	1.81
	BD mean (std. dev)	*g/cm3*	1.77 (0.05)			1.81 (0.04)					1.77 (0.05)	
	K_SAT	*mm/day*	4.8-50	4.8-50	4.8-50	6.2-65	6.2-65	6.2-65	6.2-65	6.2-65	4.8-50	4.8-50
	N layers	*#*	1	1	1	1	1	1	1	1	1	1
	depth	*cm*	140	140	140	140	140	140	140	140	140	140
	Hydrologic group	-	**Group D**	**Group D**	**Group D**	**Group D**	**Group D**	**Group D**	**Group D**	**Group D**	**Group D**	**Group D**
	CN	-	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00
	θPWP	*%*	29.00	29.00	29.00	22.00	22.00	22.00	22.00	22.00	29.00	29.00
	θFC	*%*	41.00	41.00	41.00	35.00	35.00	35.00	35.00	35.00	41.00	41.00
	θSAT	*%*	46.00	46.00	46.00	40.00	40.00	40.00	40.00	40.00	46.00	46.00

7.2 Management data

Management	Sowing date	*date*	13-Dec
	Harvest date	*date*	8-Jun
	Sowing rate [mean]	*kg/ha*	200