

Comparison of Harmonization Methods of Soil Moisture Observations Across Multiple Spatial and Temporal Scales

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SoMMet project

Overall aim: to develop novel and **traceable** methods and establish a **metrological** infrastructure for soil moisture measurements covering **lateral scales** ranging from the decimeter to kilometer

Point-scale sensors **Cosmic-ray neutron sensing (CRNS)** **Satellite-based remote sensing**



SMT100, Bondeno



CRNS FINAPP, Bondeno



Sentinel-1 Copernicus

Specific questions: how to deal with SWC products with different

- Units
- Footprint/scale: horizontal and vertical
- Temporal resolutions



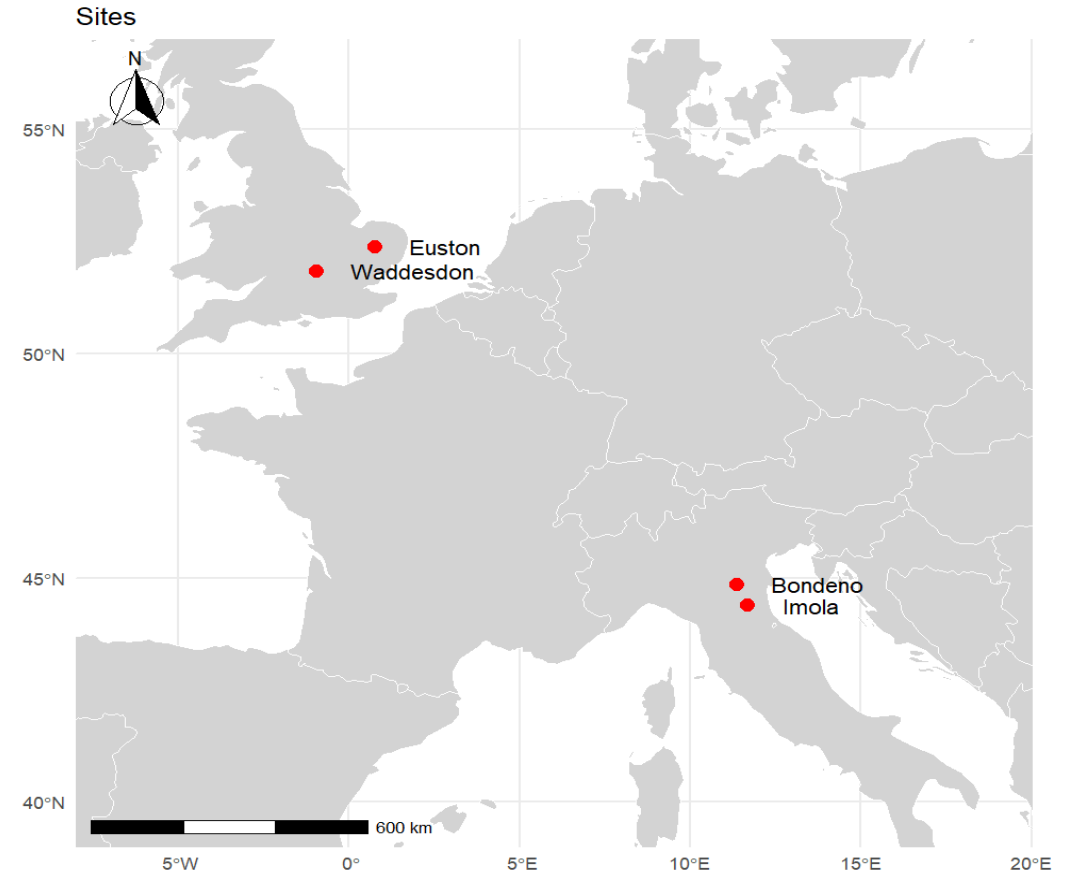
Harmonization and representativeness:
to make different measurements
comparable

—————→

$(10^{-1} - 10^1) \text{ m}$ $(10^2 - 10^3) \text{ m}$ $(10^3 - 10^4) \text{ m}$

Sites and Products

- Data collected at four sites in Northern Italy and Southern UK
- Daily SSM (1km res) by CGLS from 2016 to Oct 2024
- CRNS with radius of ~ 125 m
- Static TDR observations for the depth = 5 cm
- Longer time-series for UK site



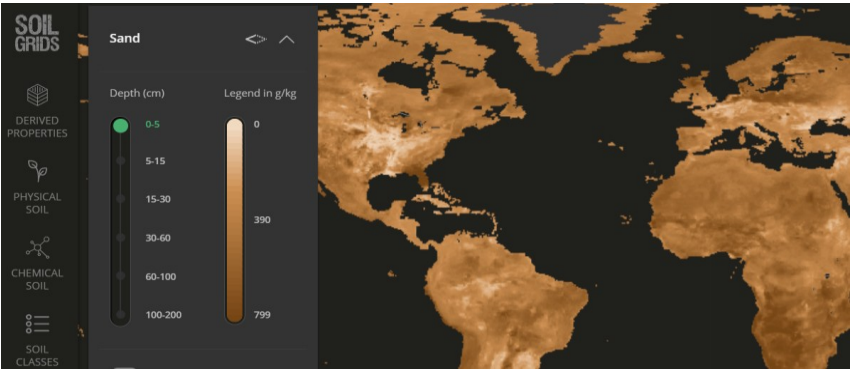
A Simple Approach

- Complexity
- ↓
- Units
 - Time
 - Depth
 - Lateral space

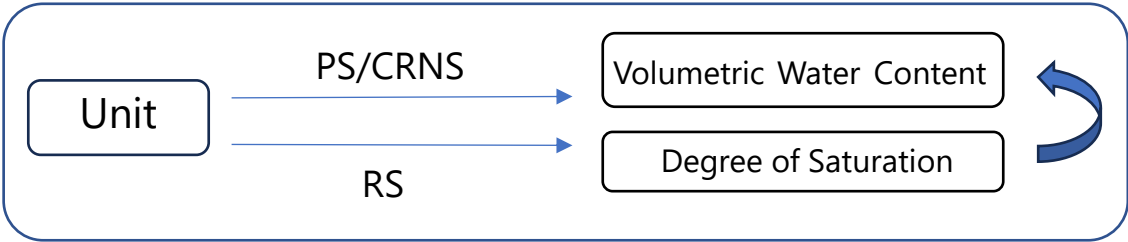
Web interface for European hydraulic pedotransfer functions (euptfv2)

DOI: <https://doi.org/10.34977/euptfv2.01>
Authors: Szabó, Brigitta; Gyurkó, Dávid; Weynants, Melanie and Weber, Tobias K. D.
Publisher: Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research
Version: v2.0.0
Release date: 31 July 2019

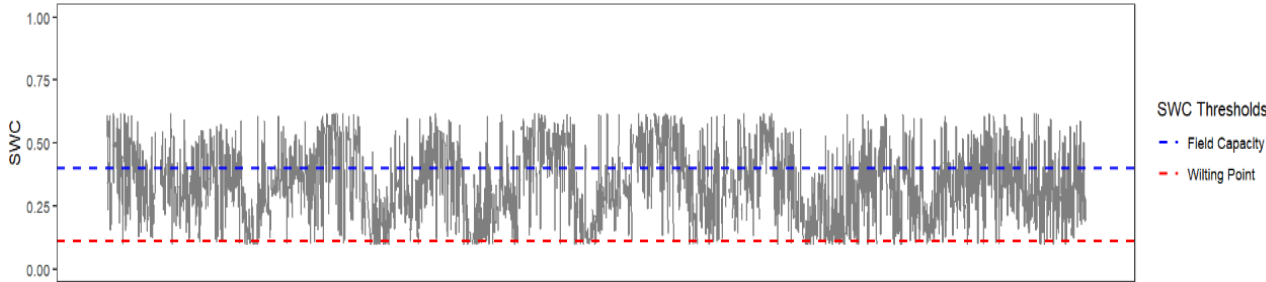
- Field Capacity
- Wilting Point



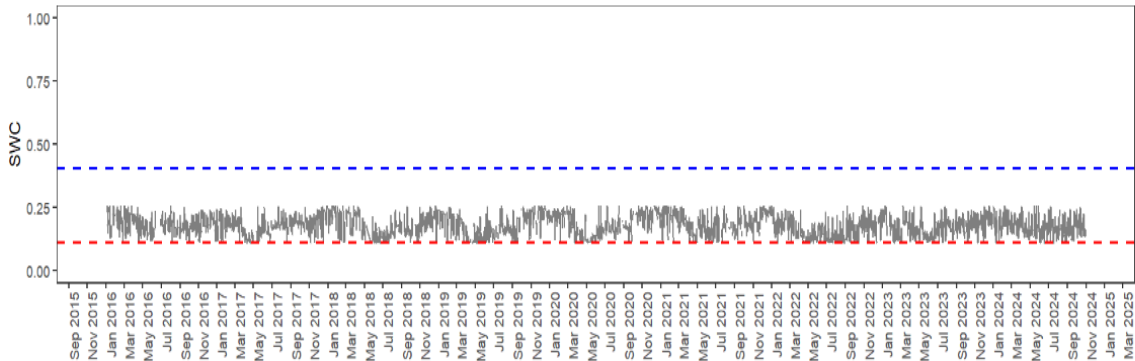
Units



Euston, RS time series and SWC thresholds
Unit conversion with formula, percentage in range: 60.69 %



Unit conversion with matching mean and variance, percentage in range: 94.42 %



Method 1:

$$\Phi = 1 - \frac{\rho_{bd}}{2.65} \quad (\text{Saxton \& Rawls, 2006})$$

$$\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r} \quad (\text{van Genuchten, 1980})$$

Assumptions:

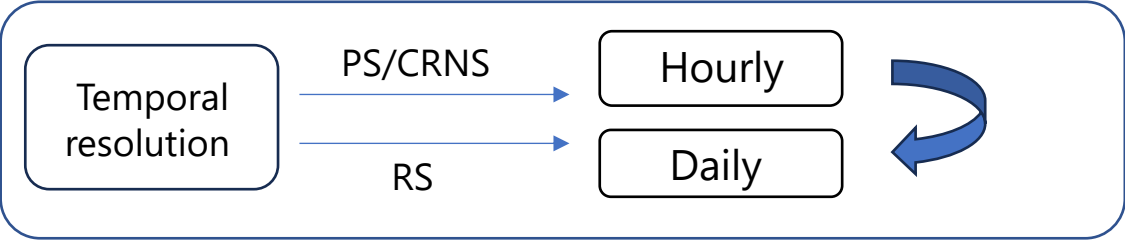
- Residual SM in VWC = min CRNS hourly
- Saturated SM in VWC = porosity or max CRNS hourly

Method 2:

Matching mean and variance of RS dataset to CRNS. (Massari, 2015)

Site	Method	Bias	RMSD	ubRMSD	Percentage RS
All sites (mean)	1	0.107	0.195	0.155	56.4
	2	-0.004	0.088	0.087	77

Temporal Matching



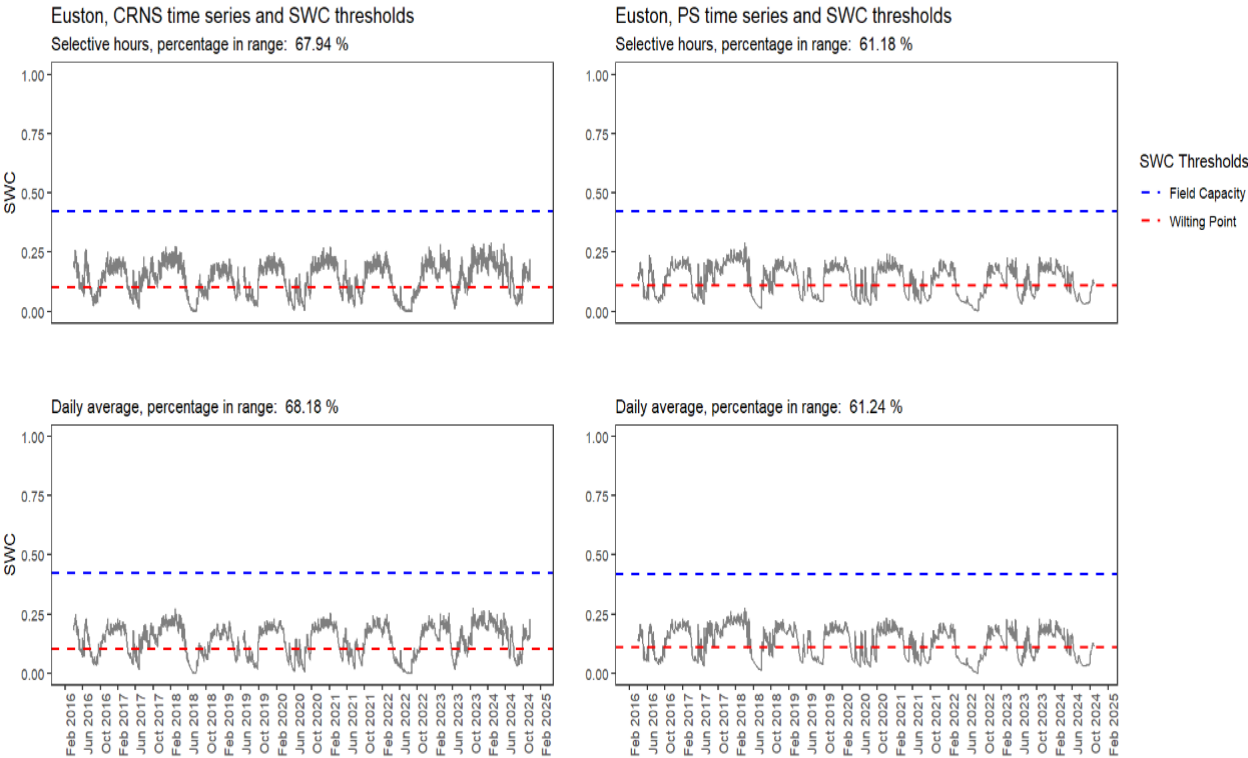
Method 1:

Considering the hours of passage of Sentinel 1 over the site.

- Italian sites at 5 A.M. and 5 P.M.
- UK sites at 6 A.M. and 6 P.M.

Method 2:

Daily average.



Site	Method	Bias	Correlation (R)	RMSD	ubRMSD	Percentage CRNS	Percentage PS
All sites (mean)	1	0.04	0.547	0.086	0.072	74.4	65.7
	2	0.037	0.56	0.081	0.066	75	65.4

Almost equal results by 2 methods

Depth

Depth

PS

Sensors are placed at different depths.

RS

Captures uppermost layer of soil.

CRNS

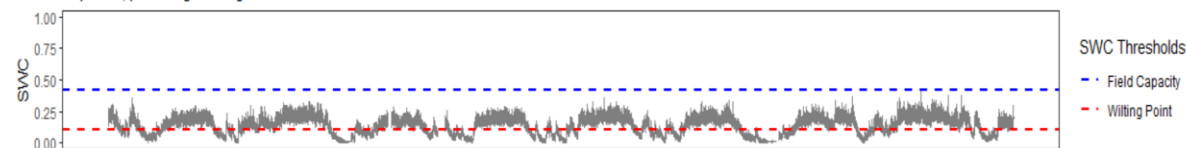
Depth is not specified, it is a range. Studies show it is more sensitive to shallower depths.

Approach:

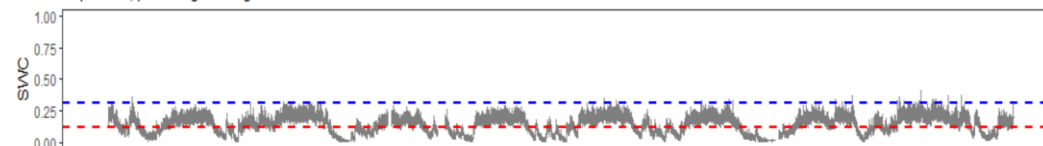
To find FC and WP for 3 depth ranges and see which one covers more CRNS points.

Euston, CRNS time series and SWC thresholds

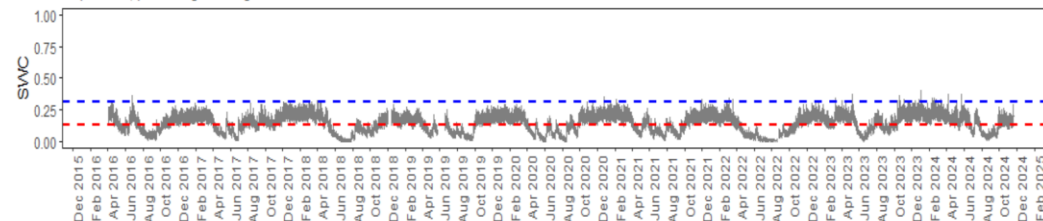
Depth 0-5, percentage in range: 68.55 %



Depth 0-15, percentage in range: 65.89 %



Depth 0-30, percentage in range: 60.81 %

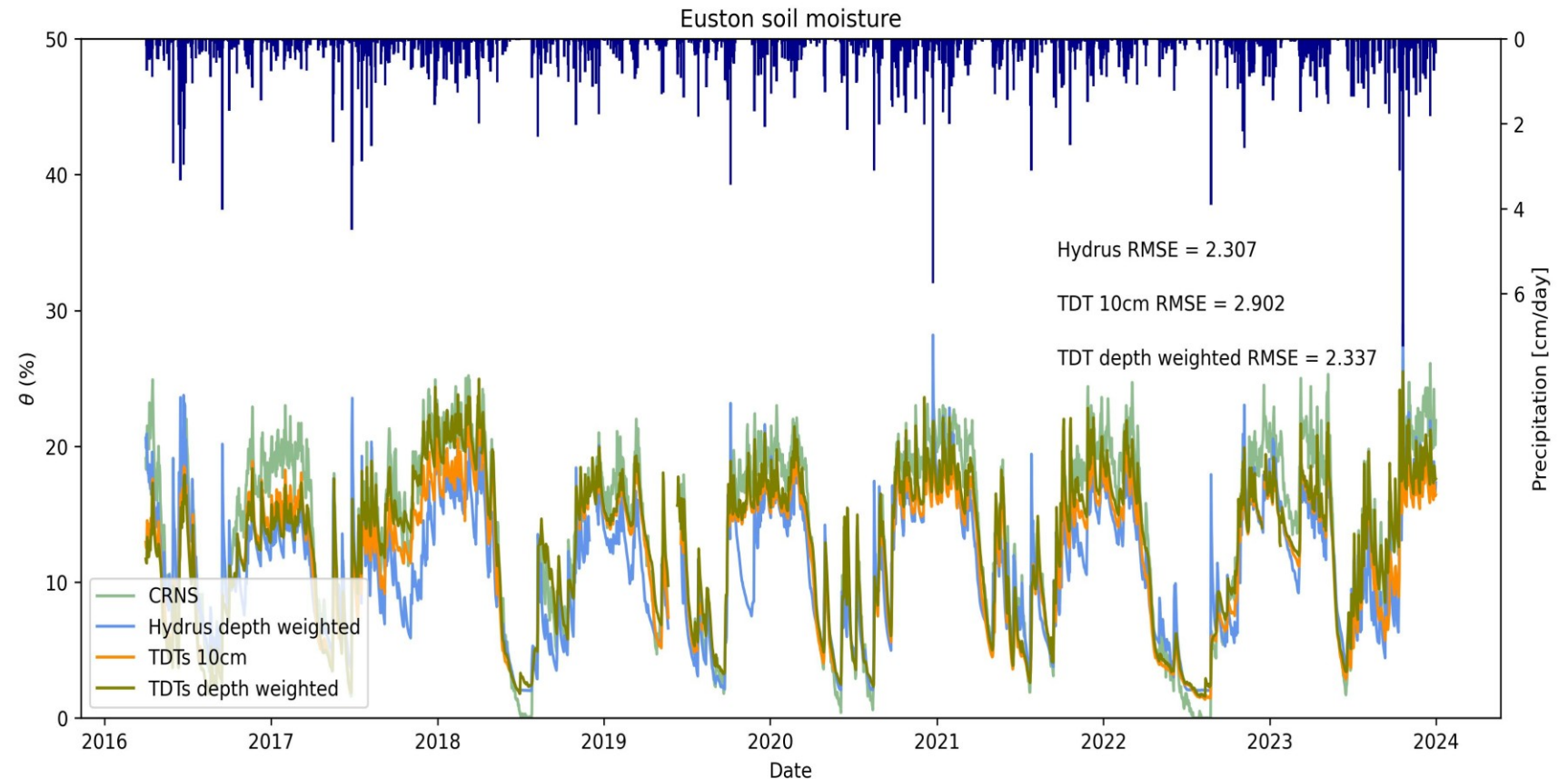


Site	Depth range	Percentage CRNS
All sites (mean)	0-5 cm	73.8
	0-15 cm	57.7
	0-30 cm	51.9

- Range 0-5 cm covered more CRNS points.
- Impossible to have statistical metrics.
- Needs further detailed analysis.

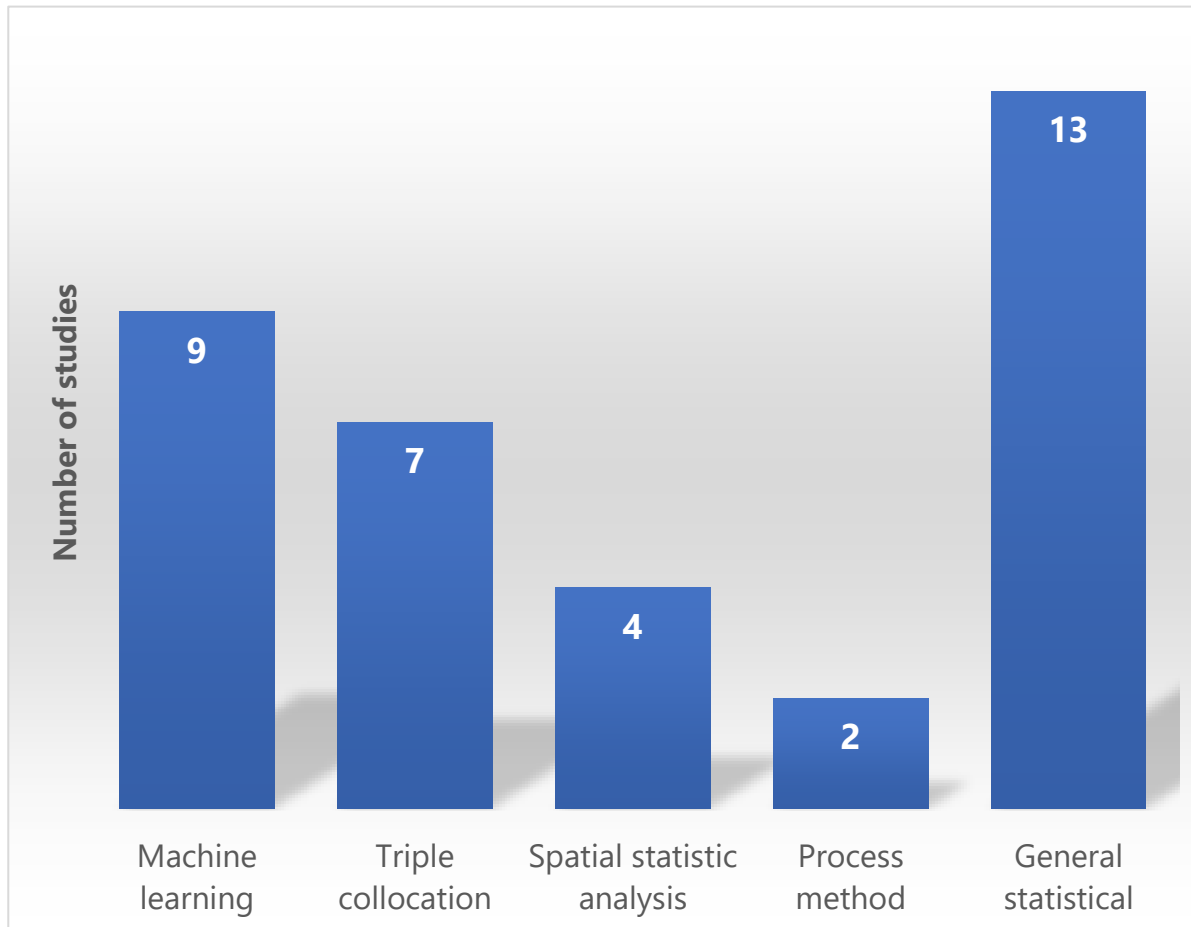
Current vertical space research: HYDRUS 1

- Hydrus-1D model is a simulation tool for one-dimensional water movement in unsaturated zone.
- Input for SM is PS data
- Reasonable agreement between Hydrus, CRNS and TDRs



Further work – Lateral space harmonization

- 35 relevant articles retrieved



- General statistical (13)
 - Arithmetic mean
 - Least-squares regression
 - Least absolute shrinkage and selection operator regression
 - Ridge regression
- Machine learning (9)
 - Deep learning models (DL)
 - Random forest (RF)
 - K-nearest neighbours (KNN)
- Triple collocation (7)
 - Extended triple collocation (ETC)
 - Multiplicative triple collocation (MTC)
- Spatial statistic (4)
 - Kriging
 - Bayesian spatial statistics
 - Variogram analysis
- Process-based models (2)
 - Land surface models
 - HYDRUS-1D
 - Joint UK Land Environment Simulator (JULES)

Further work – Lateral space harmonization

- Qualitative review of pros and cons

Method	Advantages	Disadvantages
General statistical	Simple to apply Regression models quite common for scaling soil moisture data	Don't take spatial autocorrelation into account Assumptions of linearity may be violated
Machine learning	Predictions often better than the other methods mentioned here Can be good for complex, non-linear problems and are robust to outliers	Accurate predictions often require many observations Black-box approach hides mechanisms on how models work
Triple collocation	No reference dataset is required Scaling factors can be derived to rescale datasets to a common data space	TC assumptions may be violated Doesn't perform as well when datasets differ significantly in spatial and temporal resolution
Spatial statistics	Can take spatial autocorrelation into account	Assumptions of stationarity may be violated with heterogeneity
Process-based models	Can be used with auxillary information to capture spatiotemporal variability Can be used to make predictions where sample observations are absent Can capture complex interactions	Reliant on weighting functions - different weighting functions can produce quite different results Can be complicated Unlikely to be consistent across fine and coarse scales (Villarreyes et al., 2014)

Acknowledgement



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We value your insights and look forward to discussing this topic further:

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