SoilManageR – An R package to derive quantitative soil management indicators

Olivier Heller[1], Fabien Durand-Maniclas[1], Grischa Förderer[1], Raphaël Wittwer[1], Thomas Keller[1,2]
[1] Agroscope, Switzerland; [2] SLU, Sweden

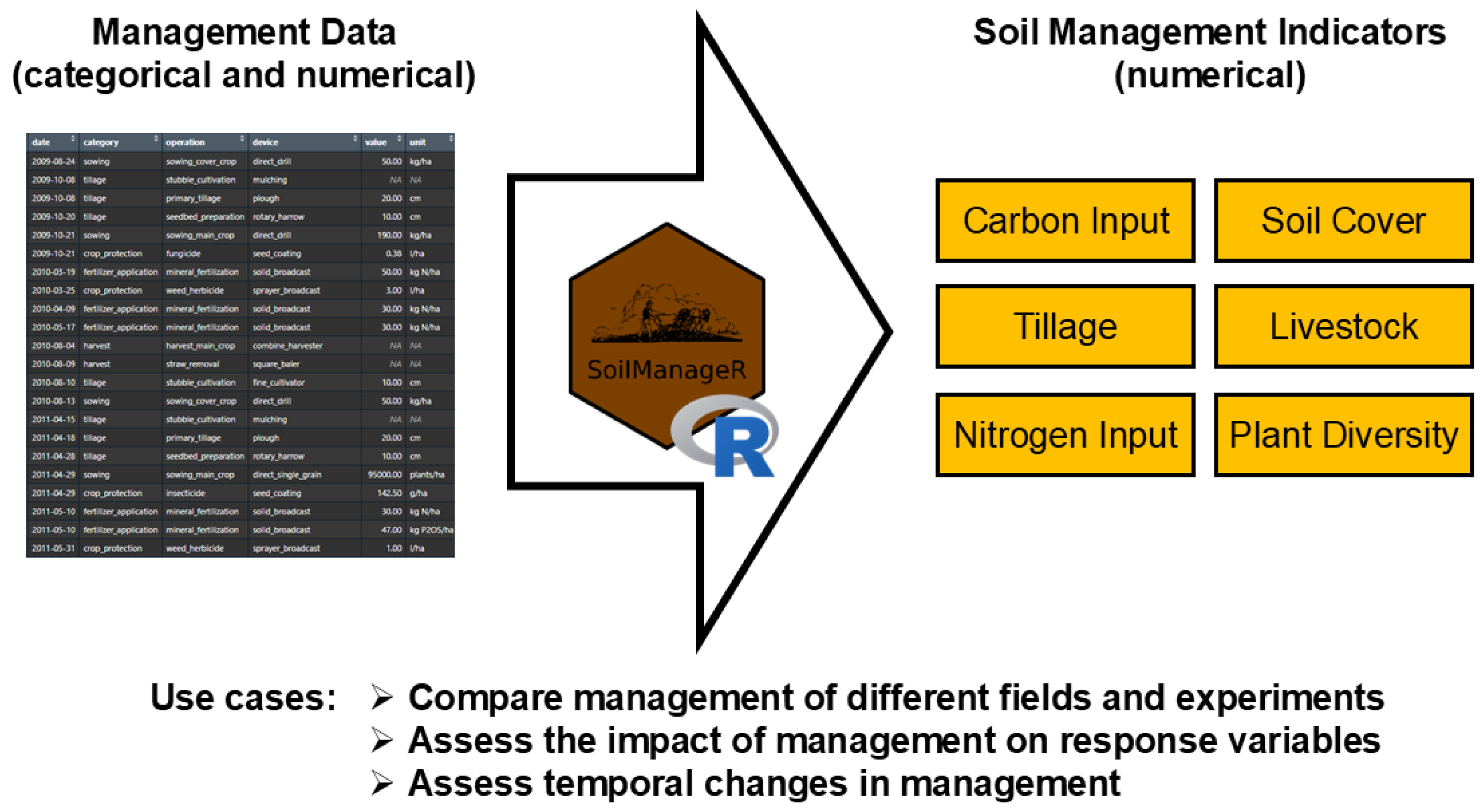

Figure 1: SoilManageR calculates numerical indicators for soil management intensities from soil management information. The management indicators can be used to compare soil management across contexts, space, and time.

Quantifying soil management

Enhanced soil cover, adequate organic matter supply, reduced tillage intensity, and diverse crop rotations are recognized measures for improving soil health. Quantifying these aspects is challenging because of the diversity of soil management practices. We developed SoilManageR, an R-package, which calculates numerical soil management indicators from nominal management information typically available from long-term field experiments (LTEs), on-farm studies, or soil monitoring schemes (Table 1). Here, we illustrate the use of SoilManageR with a two examples from ongoing studies.

Table 1: Indicators that are included in V1.0 of SoilManageR

Indicator	Components	Input	Sources
Tillage intensity	STIR value	tillage type, date, speed*, depth*, area*	USDA-NRCS (2023)
Soil cover	Plant cover Residue cover	crop type, sowing date, harvest date, cover crop termination date, tillage	Büchi et al. (2016) Mosimann & Rüttimann (2006) Steiner et al. (1999, 2000)
Carbon input	Crop input Cover crop input Organic amendments	crop type, yield*, cover crop duration, cover crop biomass*, amendment type and amount, dry matter content*, C content*	Bolinder et al. (2005)** Keel et al. (2017) Seitz et al. (2022) Sinaj et al. (2017)
Nitrogen fertilization	Mineral fertilization Organic amendments	input type, dry matter conent*, N content*	Sinaj et al. (2017)
Rotational diversity	Shannon Index Plant diversity index	Crop species, cover crop species	Spellerberg & Fedor (2003) Tiemann et al. (2015)

* optional input, default values are available,; ** and other publications that further developed the approach of Bolinder et al. (2005)

Combining data from different experiments

We used SoilManageR to calculate soil management indicators for 26 treatments across four LTEs from Switzerland. Wheat yields (n = 613) were driven by mineral N input (rel. importance = 23%), crop protection intensity (15%), and tillage intensity (15%). However, the effect of management intensity was depending on the weather conditions of the cropping year (Figure 2, Table 2). For example, the effect of tillage intensity was positive in wet years, but the benefit from increased tillage intensity was reduced or negative in drier years.

Table 2: Estimates of the fixed effects of the mixed model for wheat yield in kgDM ha^{-1}. Significance codes represent *p*-values. *: *p*-value < 5%, **: *p*-value < 1%, ***: *p*-value < 0.1%. n = 613, R_2^M = 43%, R_2^C = 83%

Term	Estimate Std. Error	Significance
Intercept	7783 ± 2941	*
Mineral N input (kg ha^{-1})	21.2 ± 3	***
- interaction with spring precipitation	-0.045 ± 0.011	***
Tillage intensity (STIR)	-17.3 ± 4.5	***
- interaction with summer precipitation	0.03 ± 0.01	*
- interaction with spring precipitation	0.042 ± 0.01	***
Plant protection intensity (applications)	1296 ± 307	***
- interaction with spring precipitation	1.21 ± 0.37	**
- interaction with summer temperature	-79.4 ± 16.2	***
Summer precipitation (mm)	-3.9 ± 1.9	*
Summer temperature (°C)	-126 ± 140	
Spring precipitation (mm)	-2 ± 1.8	

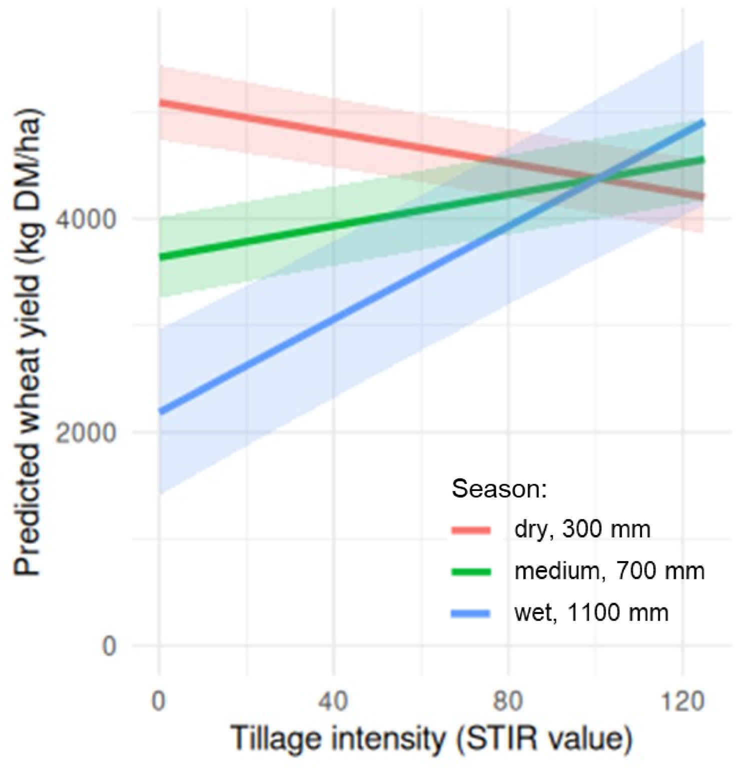

Figure 2: Prediction of wheat yield with varying tillage intensity and precipitation based on the model presented in Table 2.

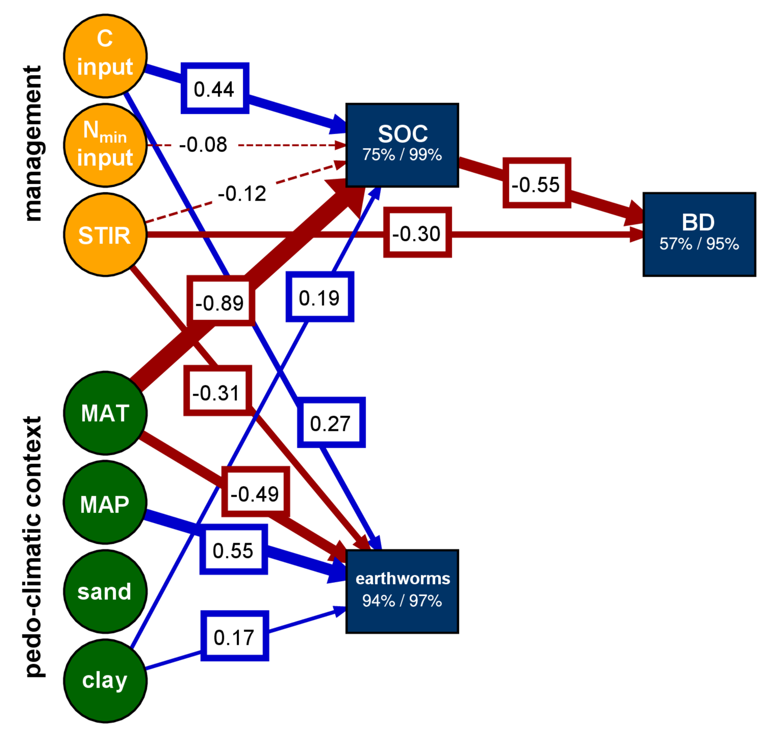

Figure 3: Piecewise Structural Equation Model representing direct and indirect effect of soil management and pedo-climatic context on selected soil properties.

Identification of direct and indirect effects

In the SoilX Project pedo-climatic and management drivers were integrated in piecewise Structural Equation Models to elucidate their direct and indirect effects on soil properties (Figure 3). Furthermore, the use of soil management indicators allowed to quantify the relative importance of different drivers (Figure 4).

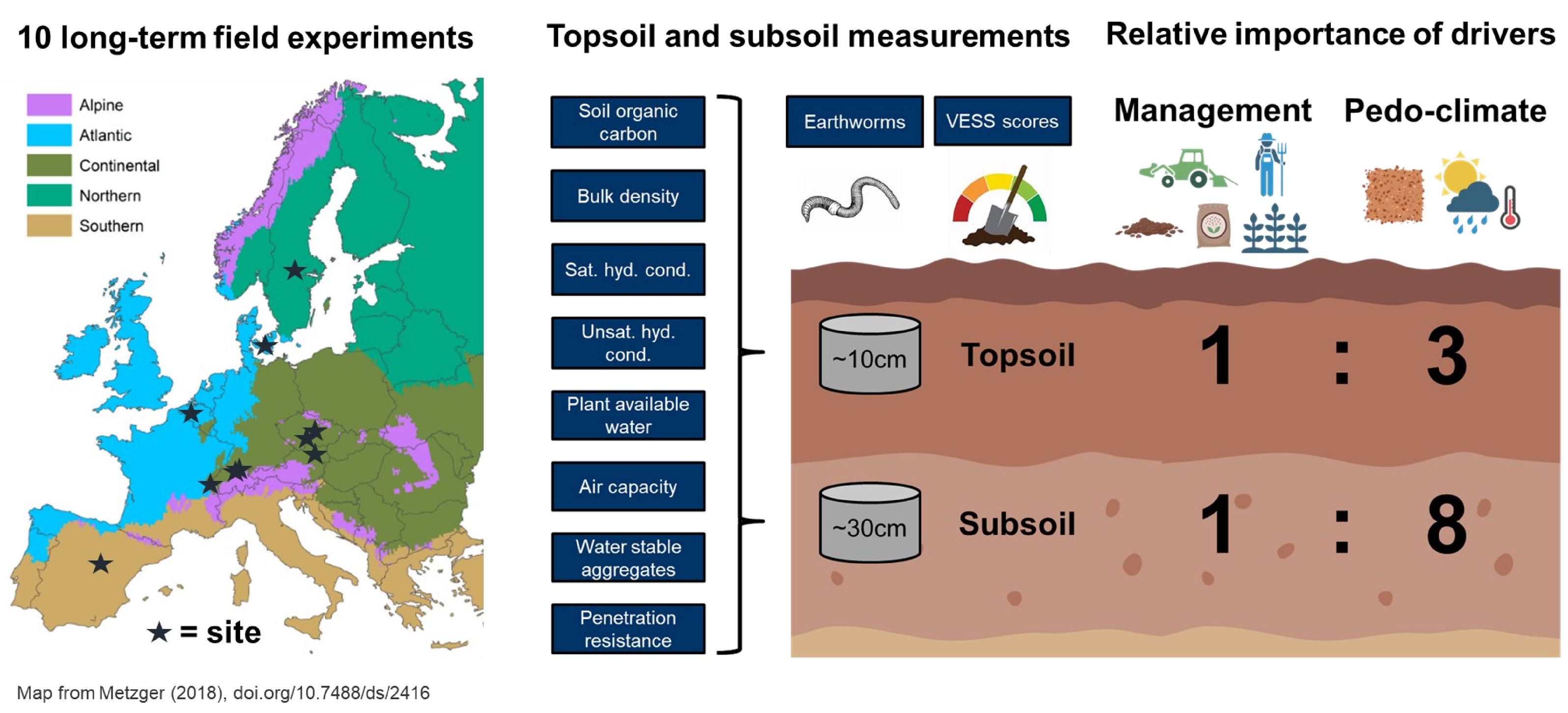

Figure 4: The Pedo-climatic context, carbon input and tillage intensity co-determined the physical properties of soils across ten European long-term field experiments that were assessed in the EJP SOIL SoilX Project.

Outlook

- The R package is open-source and available on CRAN
- More indicators are planned (e.g. plant protection intensity, or N fixation by leguminous crops,)

Reference:
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