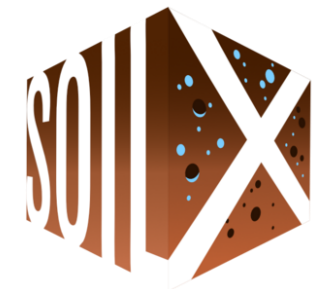




Soil management impacts on soil structural properties in ten European long-term experiments

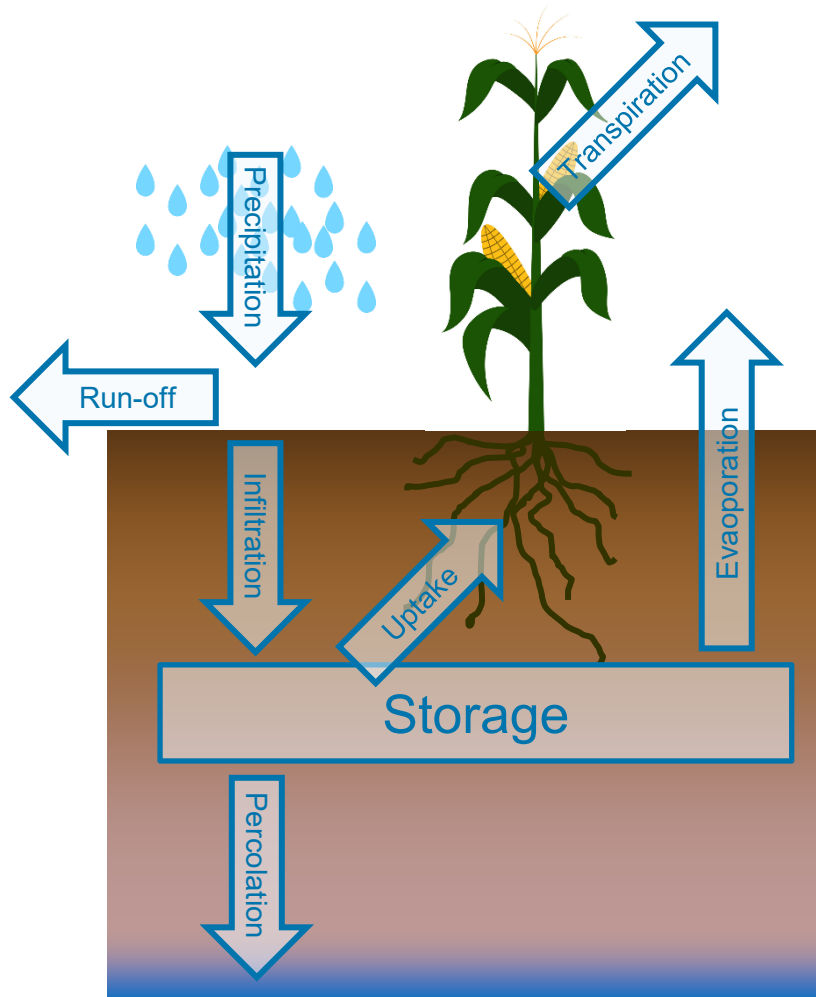
Olivier Heller, Loraine ten Damme, Tommy d'Hose, Elsa M. Arrázola-Vázquez, Lorena Chagas Torres, Pia Euteneuer, Marta Goberna, Miroslav Fér, Nicholas Jarvis, John Koestel, Anna Lindahl, Bano Mehdi-Schulz, Lars J. Munkholm, Ines Santin, & Thomas Keller

September 9th 2025, EUROSIL





Soil management needs to adjust to more frequent extreme weather events



Reduce soil erosion risk during heavy rainfall events



Improve water supply during dry periods



Aim and Hypotheses

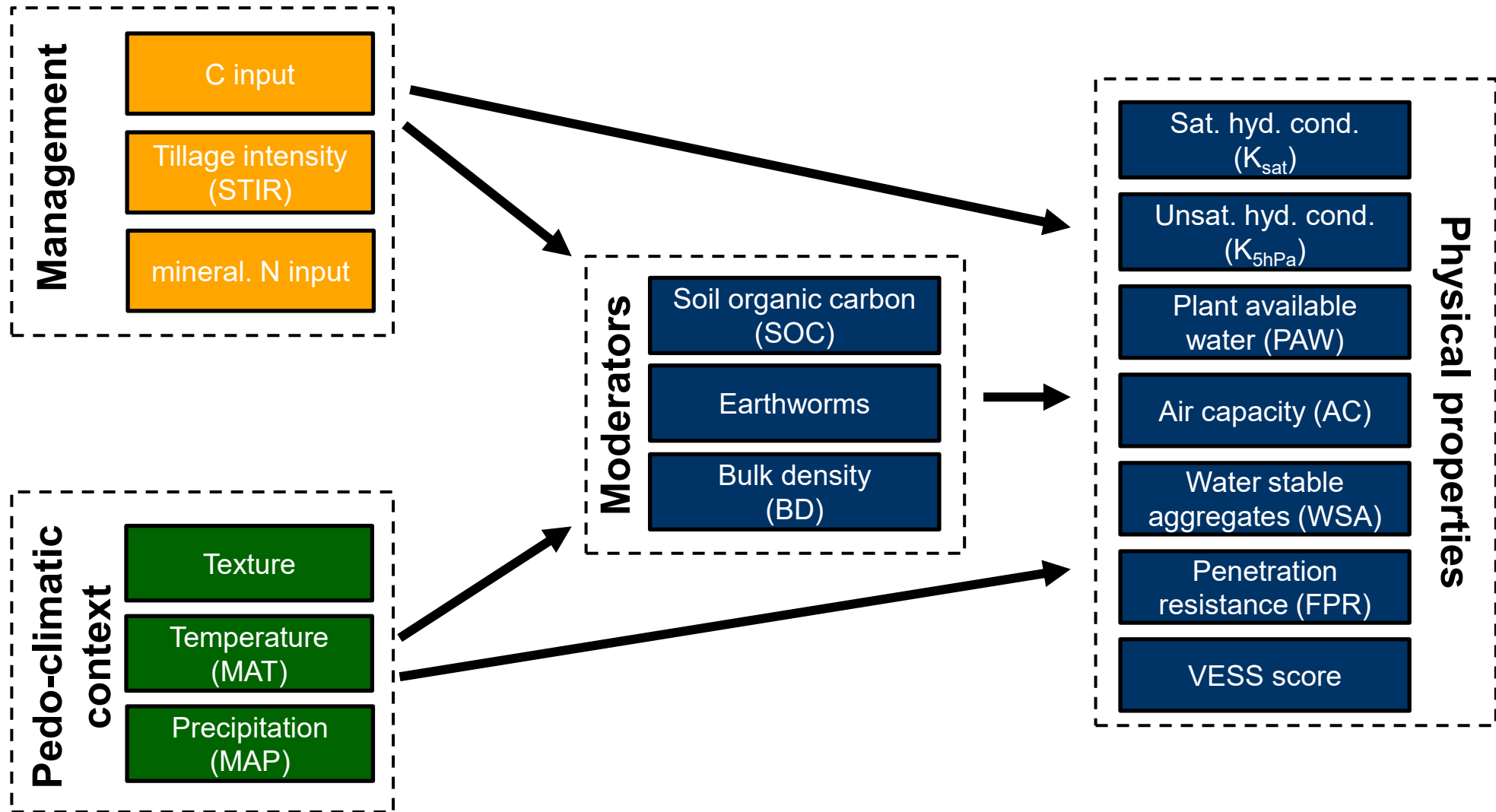
Aim: Quantification of management effects on climate-change adaptation related soil physical properties

Hypotheses:

1. Pedo-climatic conditions, in particular soil texture and climate, are the dominant drivers of soil physical properties, especially in the subsoil.
2. Management influences soil physical properties by modifying *SOC*, *BD*, and *earthworm* abundance.
3. The effects of management on soil functions are mediated through these key properties rather than acting directly.

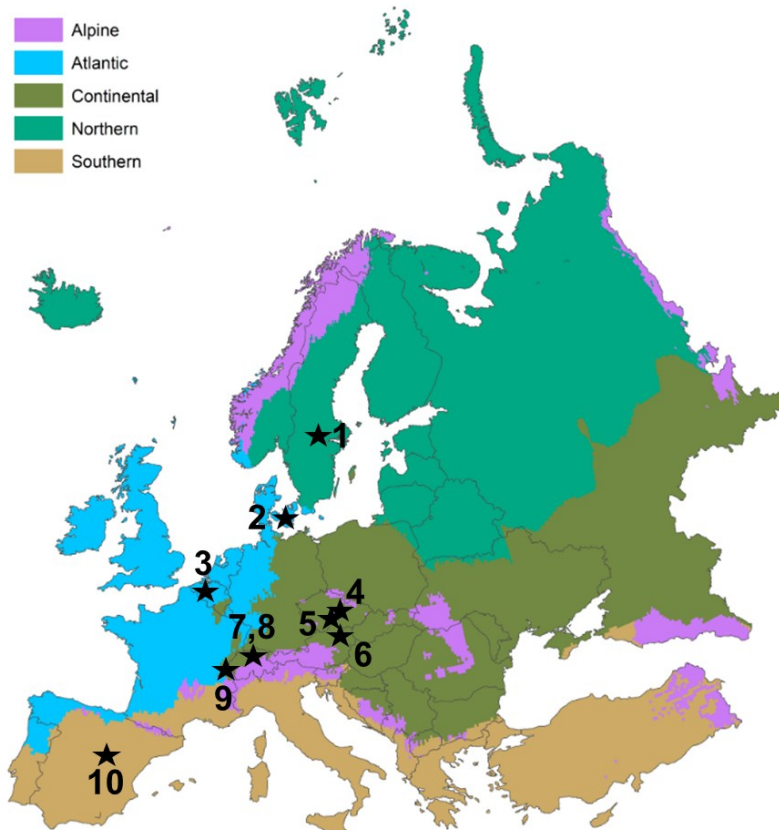


Assumed cause-effect-relations



Sites and methods

🇨🇭 Sampling in ten long-term experiments (LTE)



Map from Metzger (2018), doi.org/10.7488/ds/2416

#	LTE / Country	Factors	Treatments	Blocks
1	Säby (SE)	rotation	2	3
2	CENTS (DK)	tillage, organic matter	2	4
3	BOPACT (BE)	tillage, organic matter	4	4
4	Čáslav (CZ)	organic matter	2	4
5	Lukavec (CZ)	organic matter	2	4
6	Hollabrunn (AT)	tillage	2	3
7	FAST (CH)	tillage	2	4
8	ZOFE (CH)	organic matter	2	4
9	P24A (CH)	organic matter	2	4
10	INIA (ES)	tillage, rotation	4	4

in total 92 plots



Soil sampling



Map from Metzger (2018), doi.org/10.7488/ds/2416



VESS score

Earthworms

Soil organic carbon (SOC)

Bulk density (BD)

Sat. hyd. cond. (K_{sat})

Unsat. hyd. cond. (K_{5hPa})

Plant available water (PAW)

Air capacity (AC)

Water stable aggregates (WSA)

Penetration resistance (FPR)

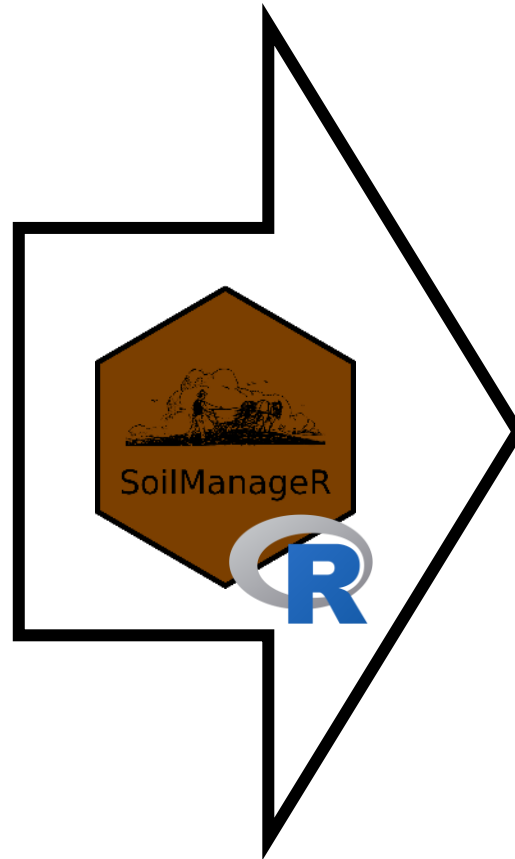
Texture



SoilManageR to calculate management indicators

Management Data (categorical and numerical)

date	category	operation	device	value	unit
2009-08-24	sowing	sowing_cover_crop	direct_drill	50.00	kg/ha
2009-10-08	tillage	stubble_cultivation	mulching	NA	NA
2009-10-08	tillage	primary_tillage	plough	20.00	cm
2009-10-20	tillage	seedbed_preparation	rotary_harrow	10.00	cm
2009-10-21	sowing	sowing_main_crop	direct_drill	190.00	kg/ha
2009-10-21	crop_protection	fungicide	seed_coating	0.38	l/ha
2010-03-19	fertilizer_application	mineral_fertilization	solid_broadcast	50.00	kg N/ha
2010-03-25	crop_protection	weed_herbicide	sprayer_broadcast	3.00	l/ha
2010-04-09	fertilizer_application	mineral_fertilization	solid_broadcast	30.00	kg N/ha
2010-05-17	fertilizer_application	mineral_fertilization	solid_broadcast	30.00	kg N/ha
2010-06-04	harvest	harvest_main_crop	combine_harvester	NA	NA
2010-08-09	harvest	straw_removal	square_baler	NA	NA
2010-08-10	tillage	stubble_cultivation	fine_cultivator	10.00	cm
2010-08-13	sowing	sowing_cover_crop	direct_drill	50.00	kg/ha
2011-04-15	tillage	stubble_cultivation	mulching	NA	NA
2011-04-18	tillage	primary_tillage	plough	20.00	cm
2011-04-28	tillage	seedbed_preparation	rotary_harrow	10.00	cm
2011-04-29	sowing	sowing_main_crop	direct_single_grain	95000.00	plants/ha
2011-04-29	crop_protection	insecticide	seed_coating	142.50	g/ha
2011-05-10	fertilizer_application	mineral_fertilization	solid_broadcast	30.00	kg N/ha
2011-05-10	fertilizer_application	mineral_fertilization	solid_broadcast	47.00	kg P2O5/ha
2011-05-31	crop_protection	weed_herbicide	sprayer_broadcast	1.00	l/ha



Soil Management Indicators (numerical)

- Carbon (C) input
- Tillage intensity (STIR)
- Mineral Nitrogen (N) input

ADAPT - Integrated Analysis 2025

Soil Management effects on Crop Production and Soil Health: Insights from four Swiss Long-term Field Trials

Anna Kessler Seitz^{1,2}, Griecha Förderer^{1,4}, Andreas Chervet¹, Urs Zihlmann¹, Olivier Heller¹, Raphael Wittwer¹, Agroscope, ¹University of Applied Sciences, ²University of Zurich, ³LANAT, Canton of Bern

Comparing soil management across sites. We harmonised and integrally assessed soil management, crop yield and soil health data from four Swiss long-term trials (Figure 1). To compare management intensities across sites, we calculated soil management indicators for tillage intensity (STIR), nitrogen (N) input by mineral fertilizer, carbon (C) input by plants and organic amendments and plant protection intensity with the R package SoilManageR (Heller et al., 2025).

Figure 1: Location, soil, and management of the investigated LTEs

Crop production: 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. For example, the effect of tillage intensity was positive in relatively wet years, whereas the benefit from increased tillage was reduced or even negative in years with a dry spring (Mar-May) and summer (Jun-Aug).

Table 1: Estimates of the fixed effects of the mixed model for wheat yield in kgM² kg⁻¹. Significant codes represent p-values: * p-value < 5%, ** p-value < 1%, *** p-value < 0.1%.

Term	Estimate	Std. Error	Significance
Intercept	718.726	1.12	***
Mineral N input (kg ha ⁻¹)	21.3	0.1	***
Tillage intensity (STIR)	-0.24	0.01	***
Plant protection intensity (pesticides)	0.02	0.01	**
Summer precipitation (mm)	-0.002	0.0001	***
Spring precipitation (mm)	0.0001	0.0001	*

Table 2: Estimates of the fixed effects of the mixed model for the logarithmic earthworm biomass (g m⁻²). Significant codes represent p-values: * p-value < 5%, ** p-value < 1%, *** p-value < 0.1%.

Term	Estimate	Std. Error	Significance
Intercept	1.44E-03	2.4E-04	***
Mineral N input (kg ha ⁻¹)	8.4E-04	2.1E-04	***
Mineral N input (kg ha ⁻¹) ²	-1.6E-07	3.3E-08	***

Conclusions and Outlook

- The approach of using numerical management indicators to elucidate site-specific management effects on crop production and soil health is promising.
- Integration of more sites and management combinations from experiments and on-farm studies will allow advanced evidence synthesis (e.g. non-linear responses, causal inference).
- We aim to identify site-adapted ranges of sustainable soil management.

Summary: Wheat yields depend mainly on nitrogen input, crop protection and tillage, with strong weather interactions. Earthworm biomass increased with higher soil cover, reduced tillage and greater carbon input. Numerical indicators thus help reveal site-specific management effects on production and soil health.

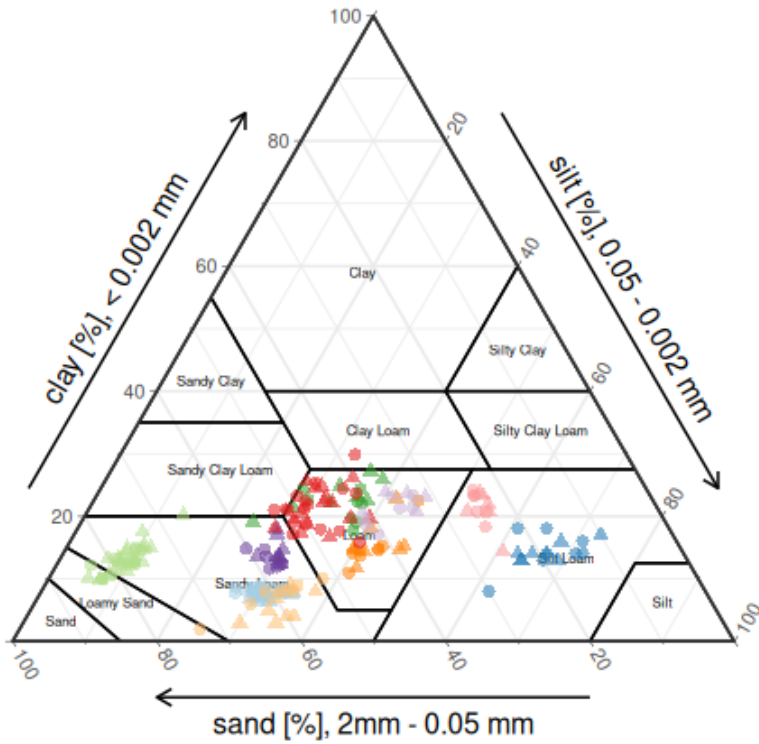
Agroscope - Good food, healthy environment

Poster #1058 in GT 06
Ground Floor (Wed-Thu)

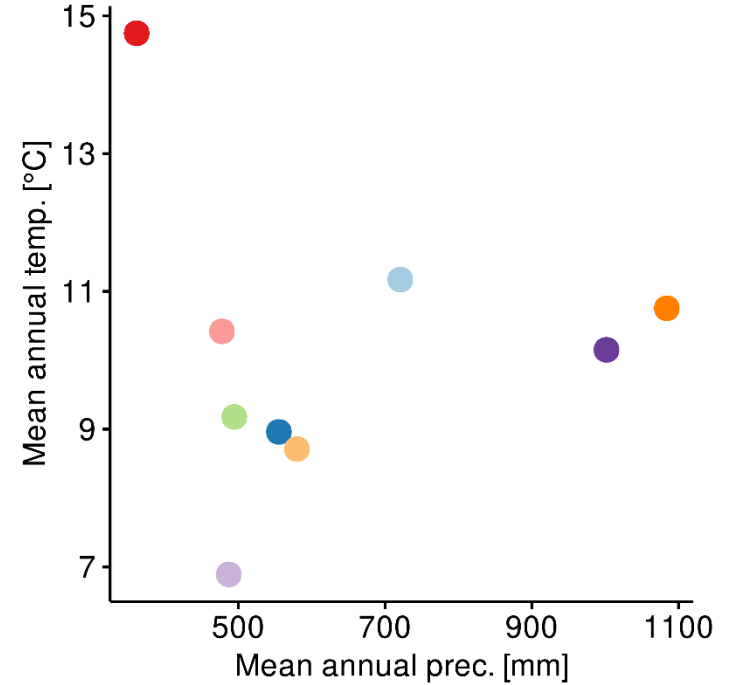
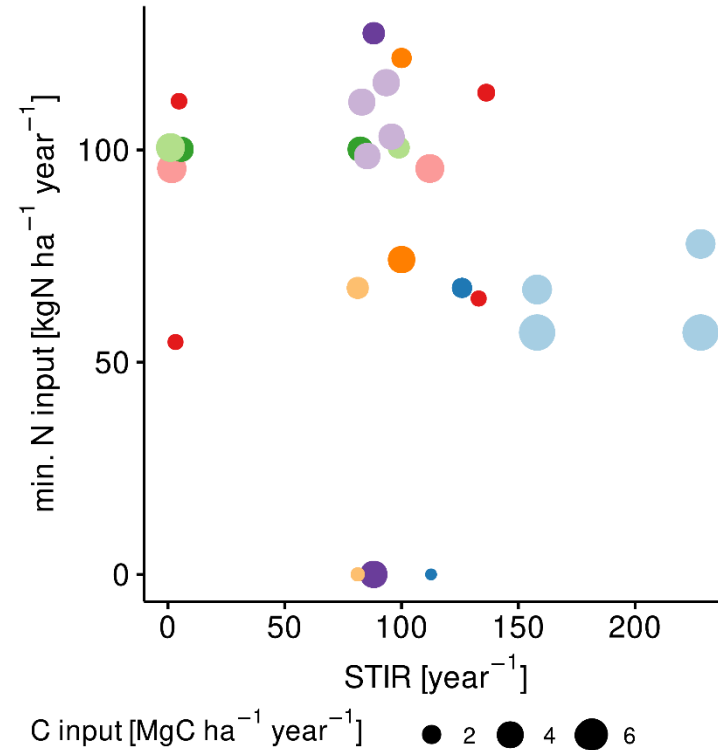
Heller et al., (2025), SoilManageR—An R Package for Deriving Soil Management Indicators to Harmonise Agricultural Practice Assessments. Eur J Soil Sci, 76: e70102. <https://doi.org/10.1111/ejss.70102>



Soil texture, management indicators and climate



Long-term experiment

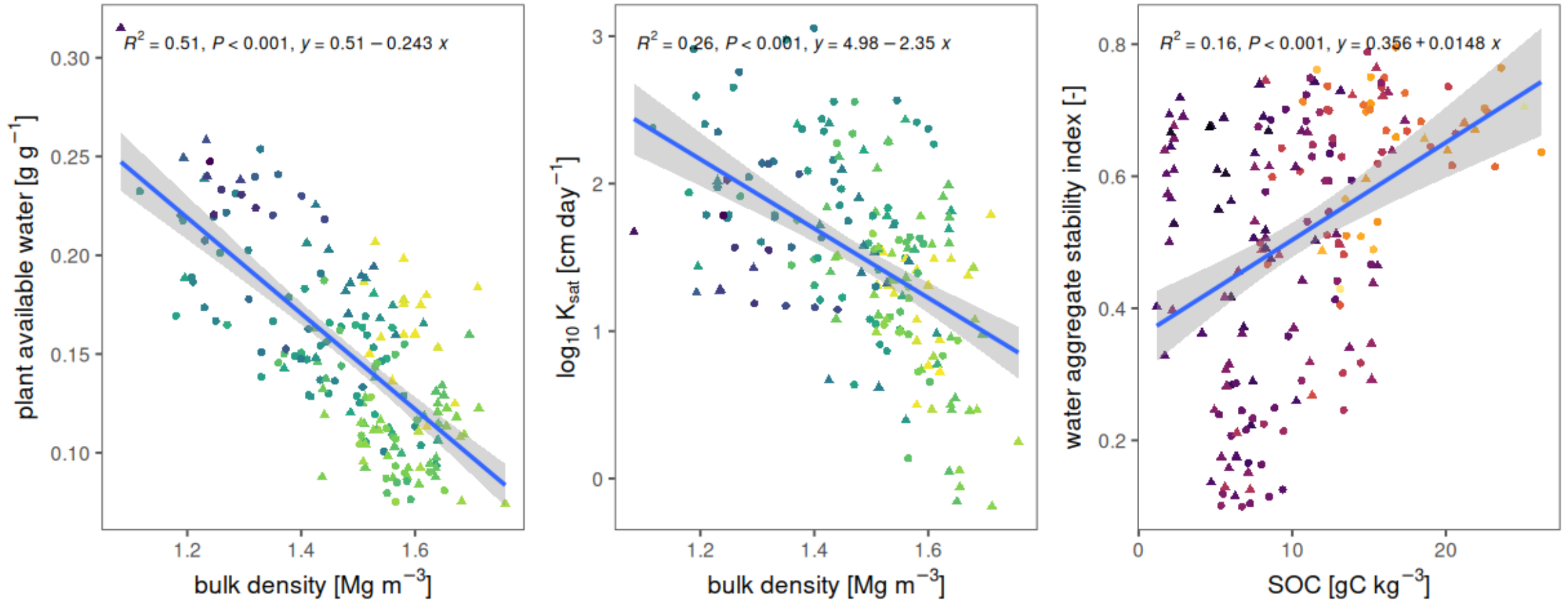


- BOPA (BE)
- CENT (DK)
- HOLL (AT)
- LUKA (CZ)
- SAEB (SE)
- CASL (CZ)
- FAST (CH)
- INIA (ES)
- P24A (CH)
- ZOFE (CH)

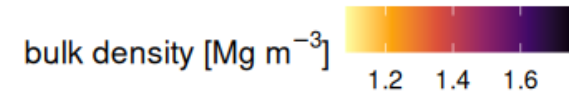
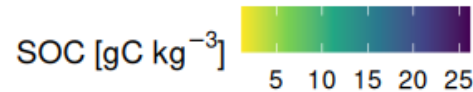
Correlation of soil physical properties



Soil physical properties are correlated with BD and/or SOC



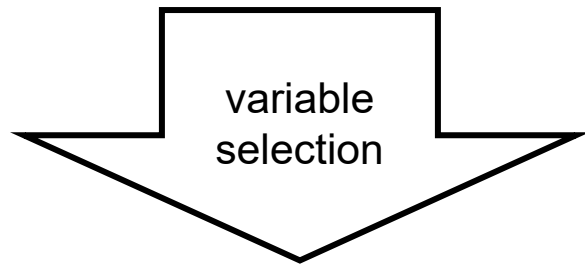
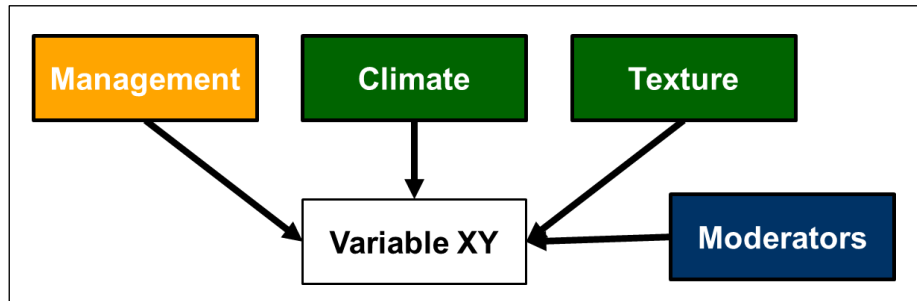
Soil depth • topsoil ▲ subsoil



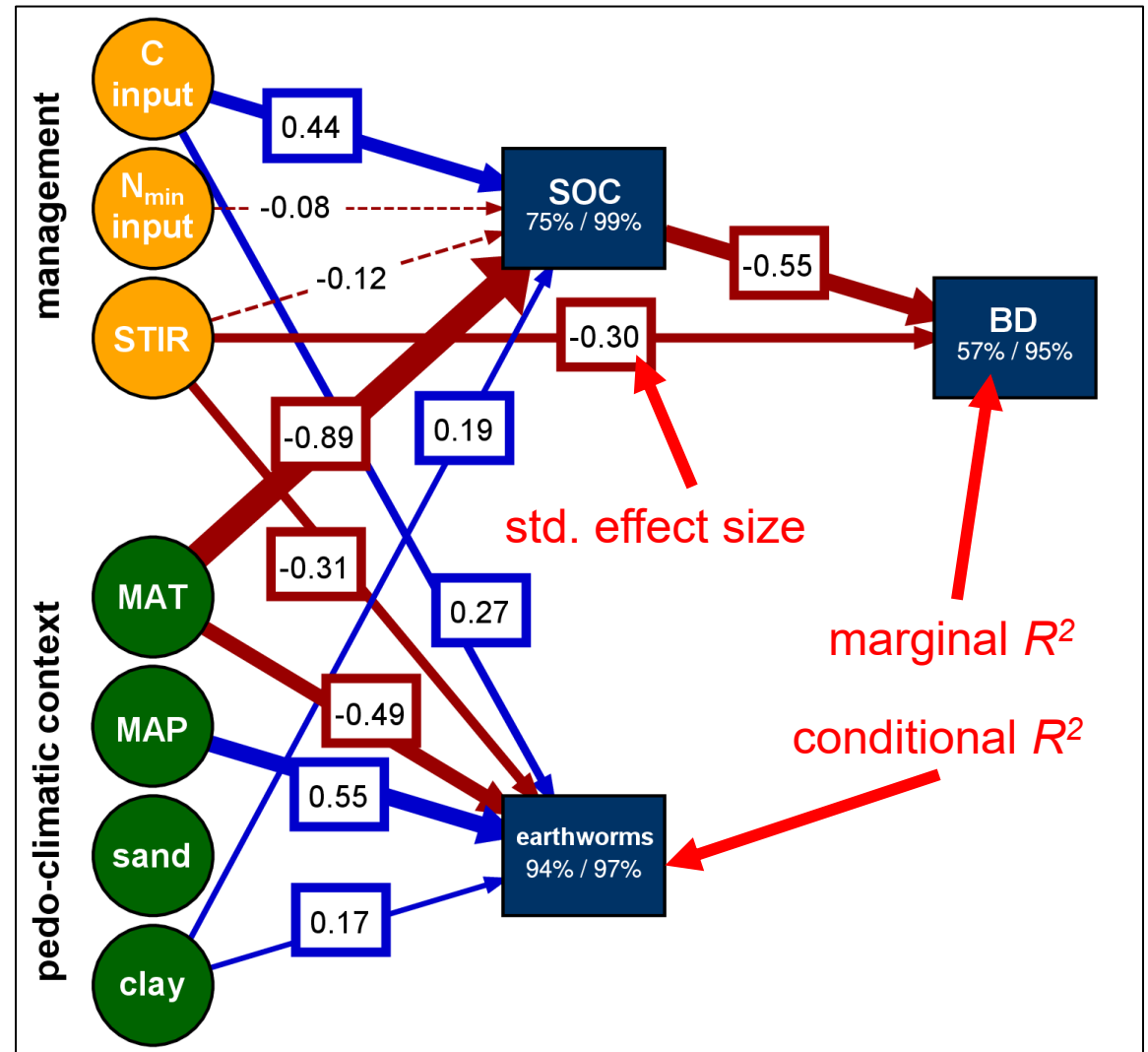
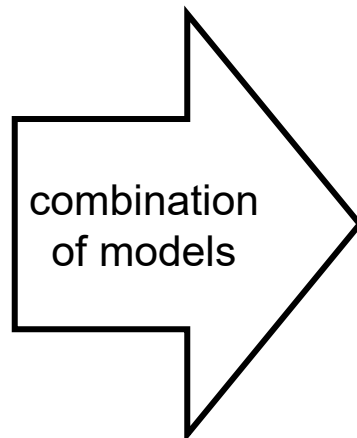
Disentangling direct and indirect effects



Variable selection and path analysis

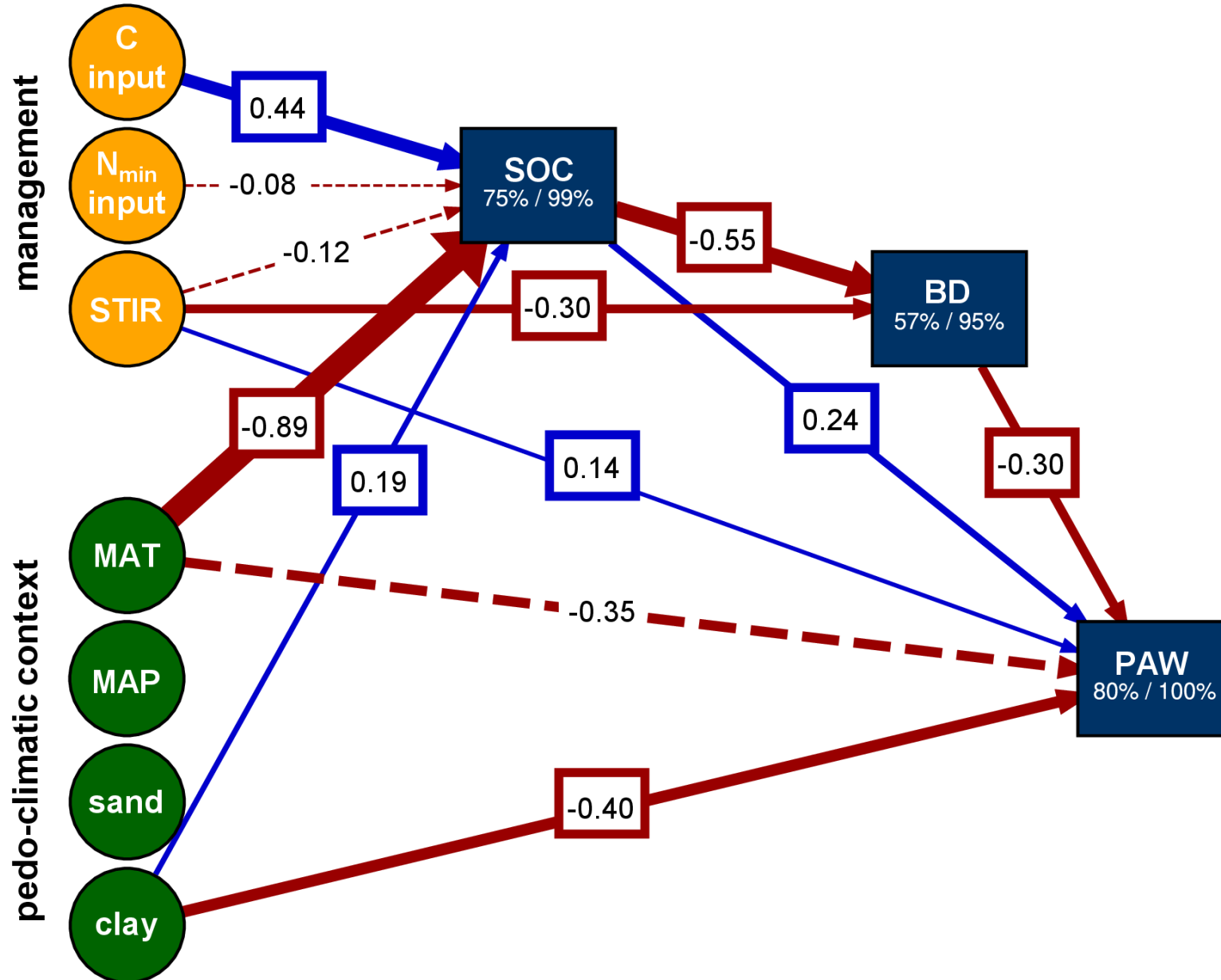


$$\text{SOC} \sim \text{C input} + \text{STIR} + \text{min N input} + \text{MAT} + \text{clay} + (1 | \text{LTE})$$



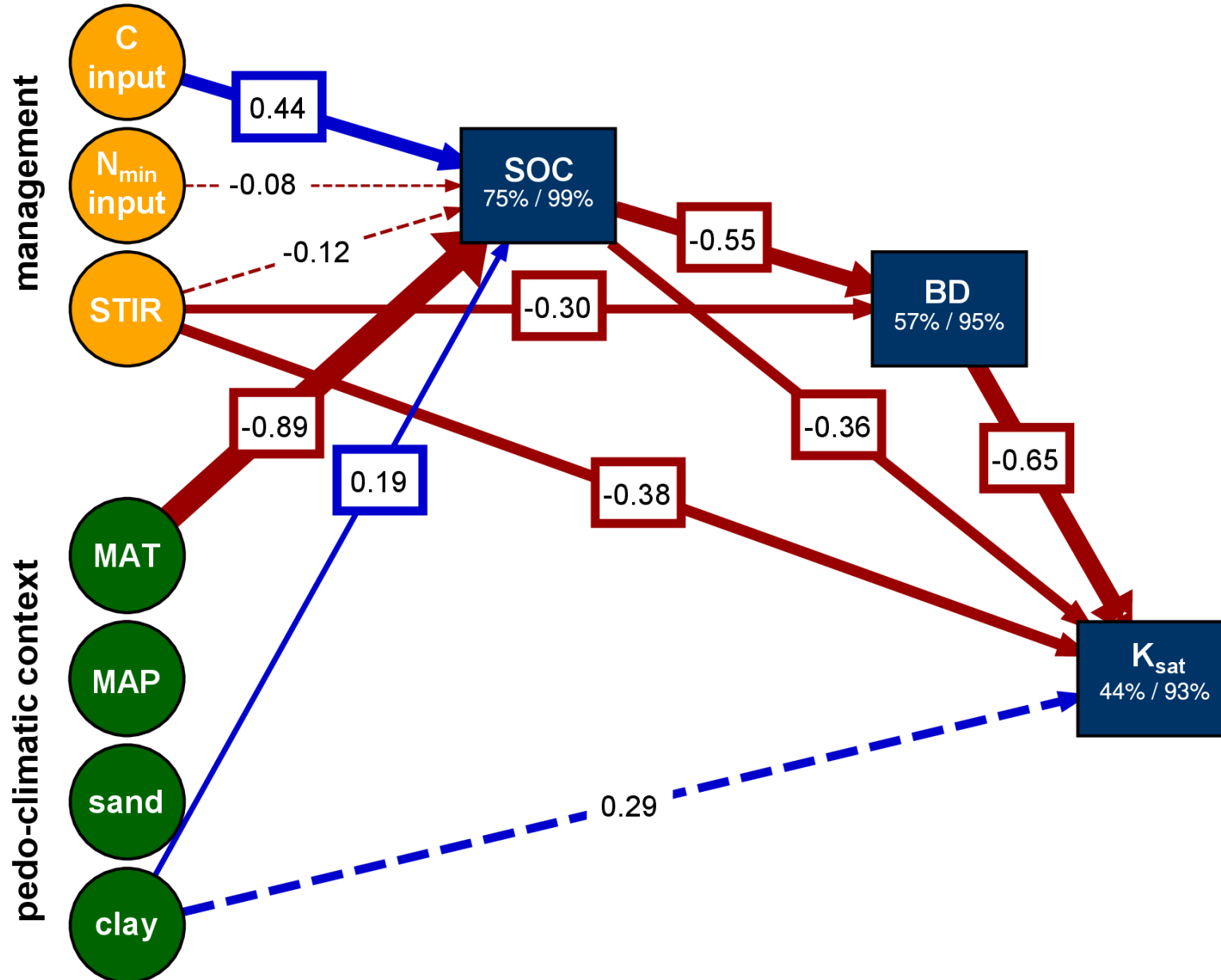


Drivers of plant available water (PAW)



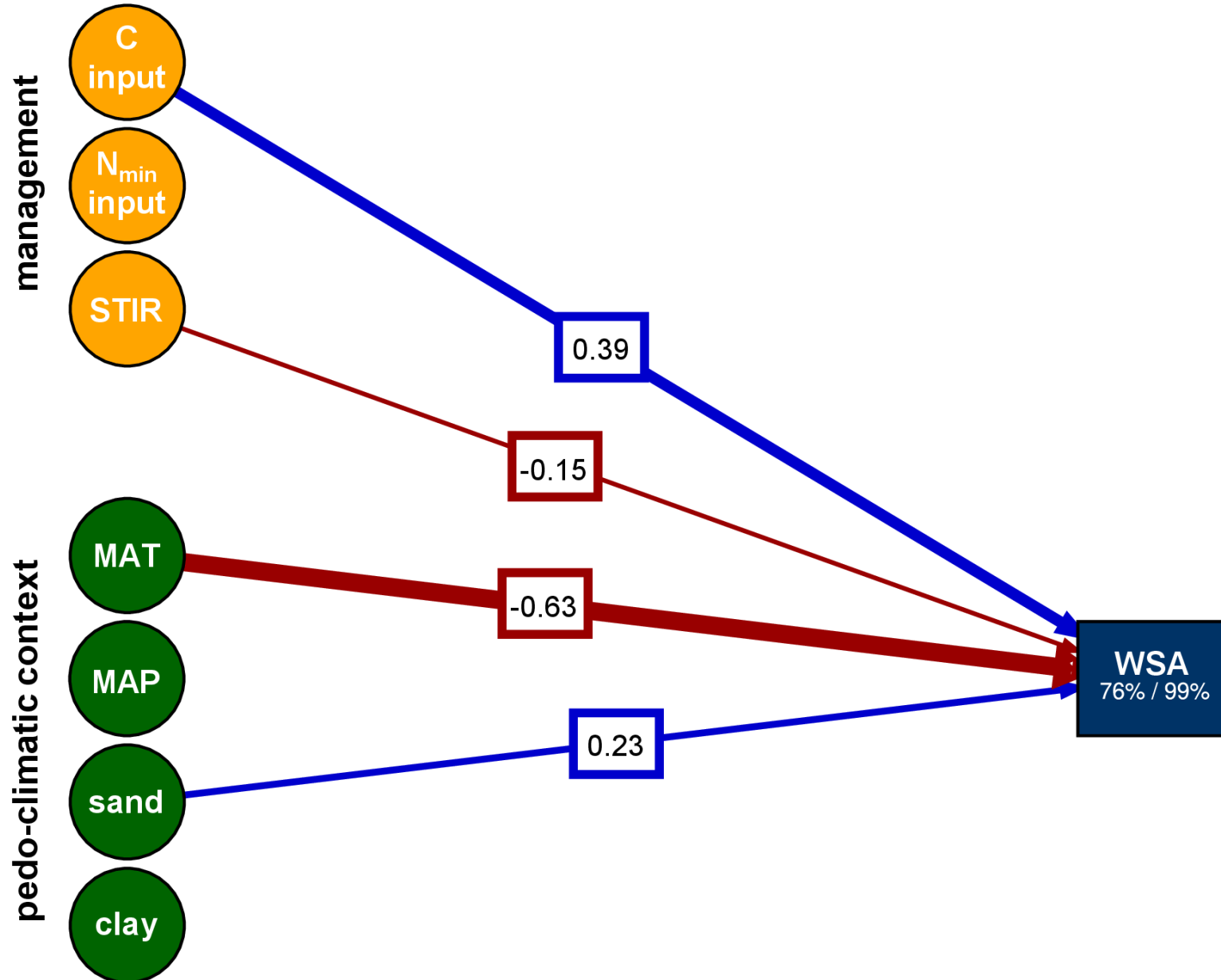


Drivers of saturated hydraulic conductivity (K_{sat})



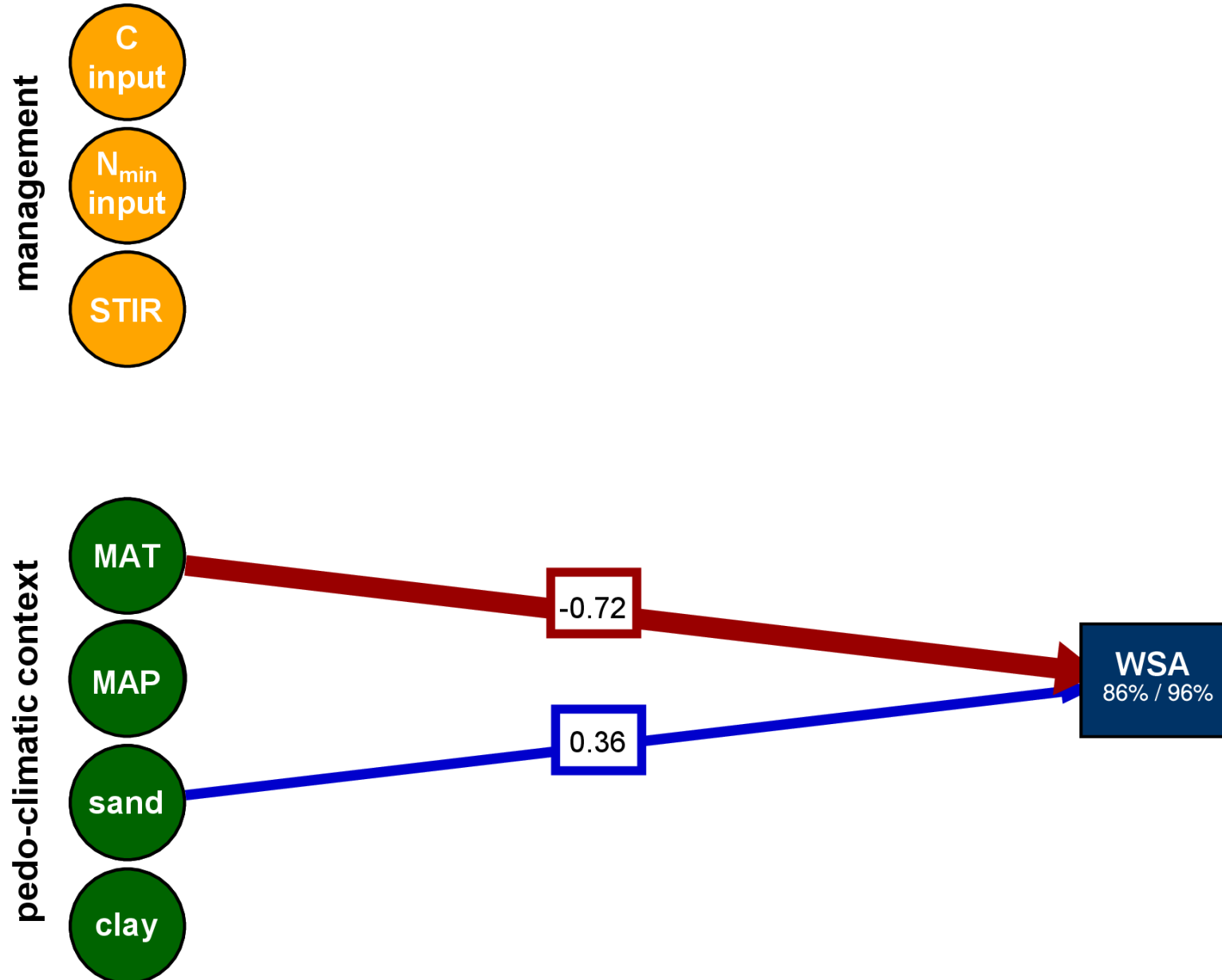


Drivers of aggregate stability (WSA)





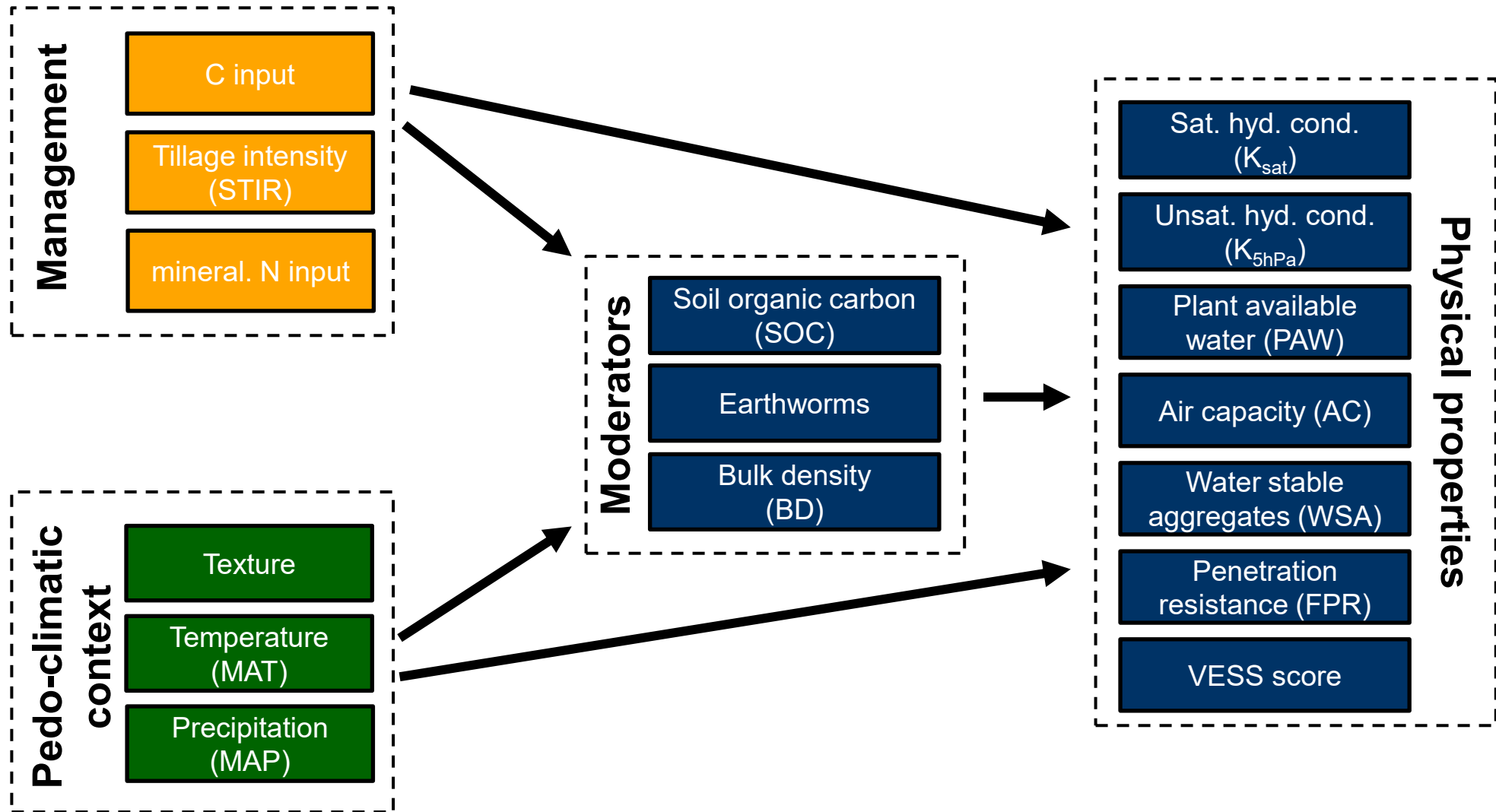
Drivers of aggregate stability (WSA) in the subsoil



Summary and Conclusions

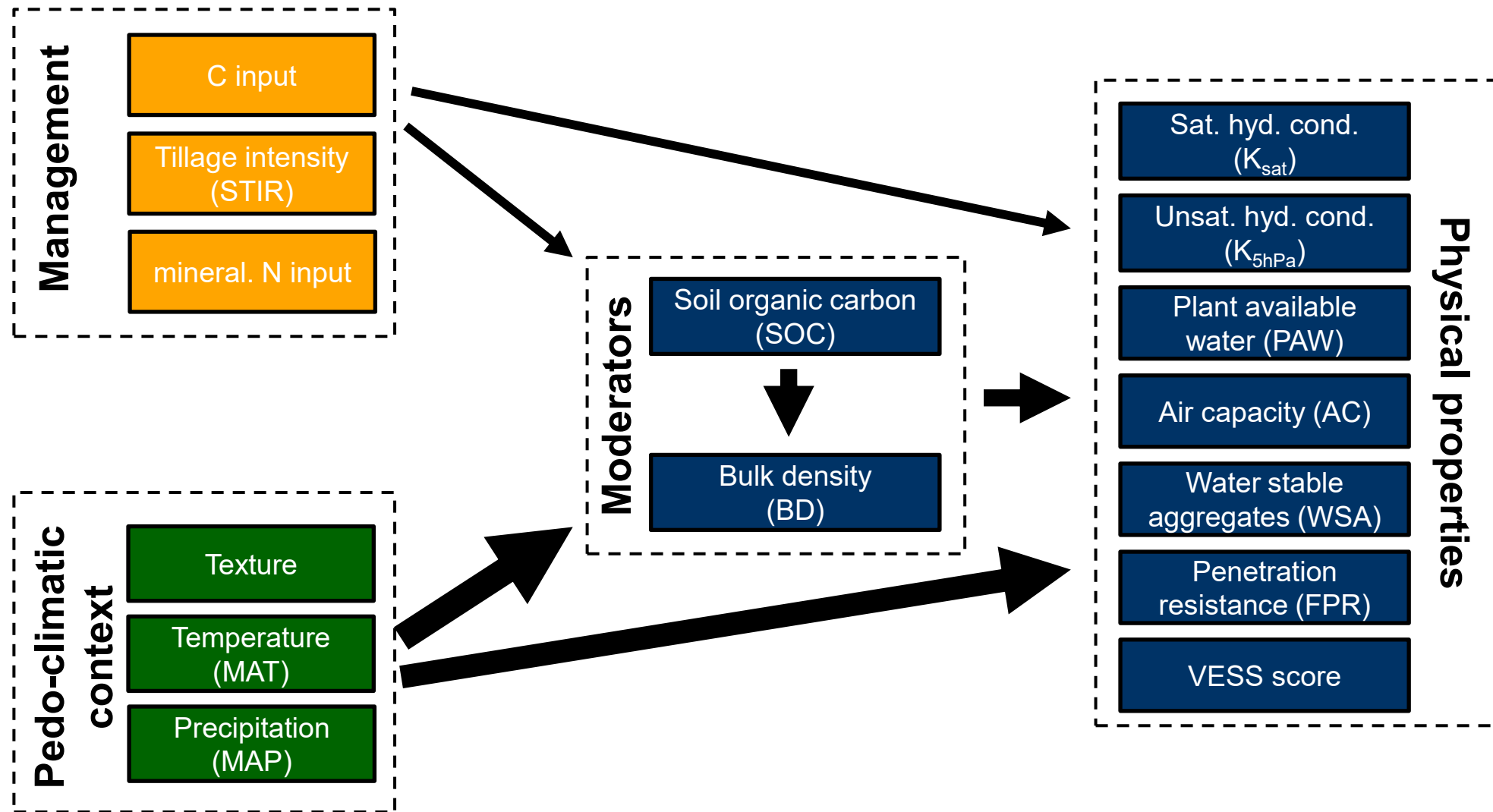


Assumed cause-effect-relations



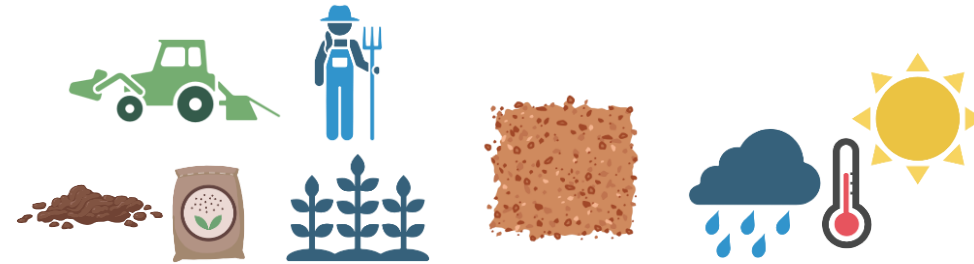
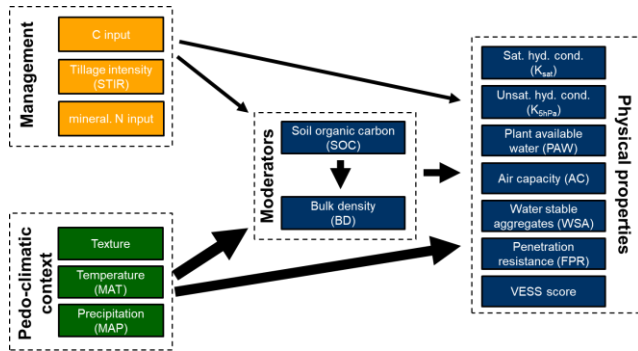


Pedo-climatic context dominates management

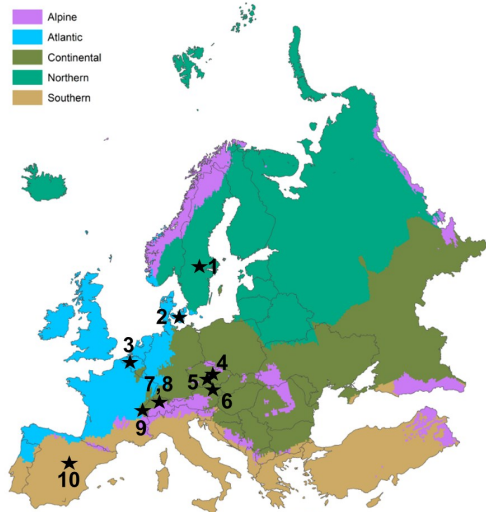




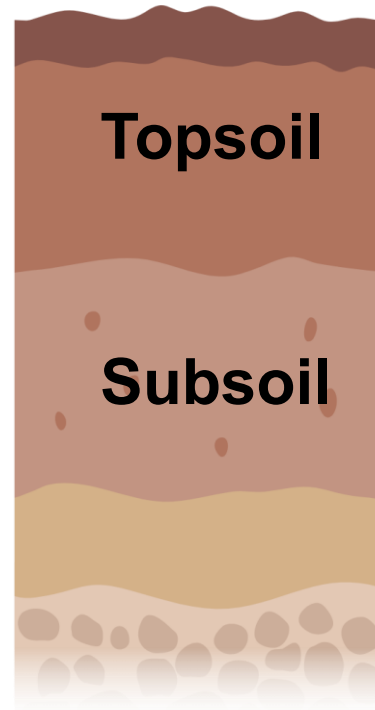
Management effects are much stronger in the topsoil



Management Soil Climate



Map from Metzger (2018), doi.org/10.7488/ds/2416



1 : 1/2 : 2

1 : 1 1/2 : 6 1/2



Conclusion

Management vs. pedo-climatic context

- Pedo-climate dominates management effects on the continental scale by 2½ :1 in the topsoil and 8:1 in the subsoil.
- Downscaling needed for better recommendations (smaller climatic gradient)

Management effect on soil functions

- **Water regulation** enhanced by SOC and low soil density, but tillage can reduce infiltration
 - +3% PAW per +1% SOC
 - +6% PAW per +1% SOC (if BD effects are considered)
 - Loss of continuous biopores by tillage
- **Erosion prevention** increased with C input and tillage reduction
- Habitat for **Earthworms** improved by higher C input and tillage reduction



Acknowledgments

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- Holzkämper, Annelie

LTEs and measurements

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- Volpe, Valerio
- Wittwer, Raphaël