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

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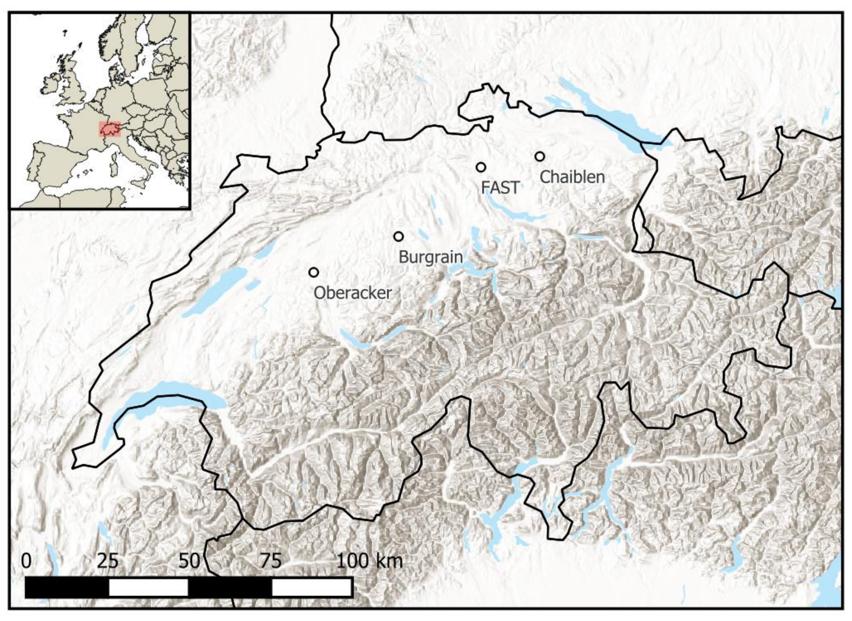
Comparing soil management across sites

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).



Trial	Soil	Management
Oberacker 1994 - present	sandy loam, eutric Cambisol	4: ploughed / no-till x GRUD / Kinsey fertilization
Burgrain 1991 - 2008	sandy clay loam, gleyic Cambisol	3: conventional / integrated / organic
FAST 2009 - present	loam, calcaric Cambisol	16: conv./no-till/ organic/org. red. till x cov. crops x 2 N-levels
Chaiblen 1989 - 2000	clay, gleyic Cambisol	6: 3 crop rotations x intensive / extensive

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 kgDM ha^{-1}. Significance codes represent *p*-values. *: *p*-value < 5%, **: *p*-value < 1%, ***: *p*-value < 0.1%

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	

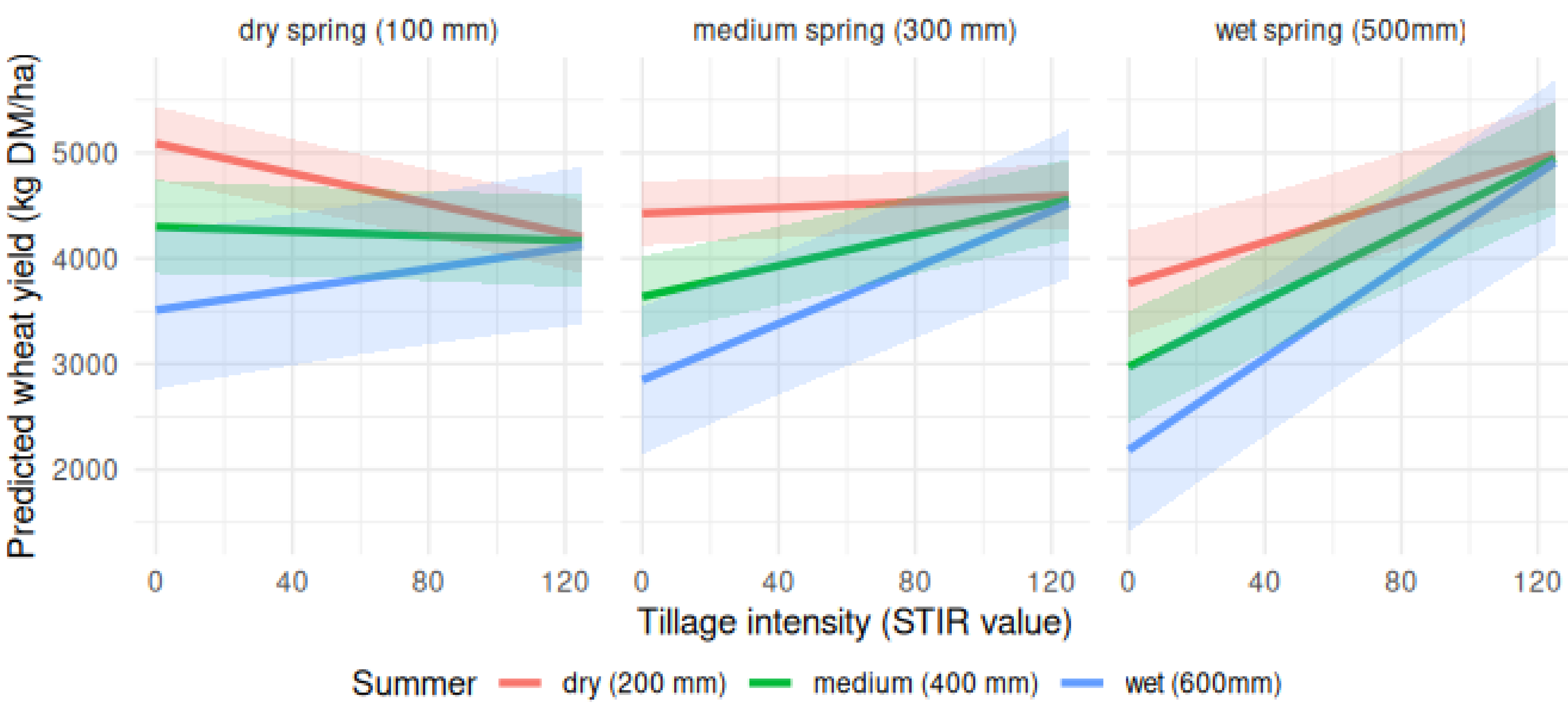


Figure 2: Prediction of wheat yield with varying tillage intensity and summer precipitation based on the model presented in Table 1. The shaded areas represent confidence intervals of the prediction. All parameters, except the ones shown in the graph, are set to the median value in our dataset.

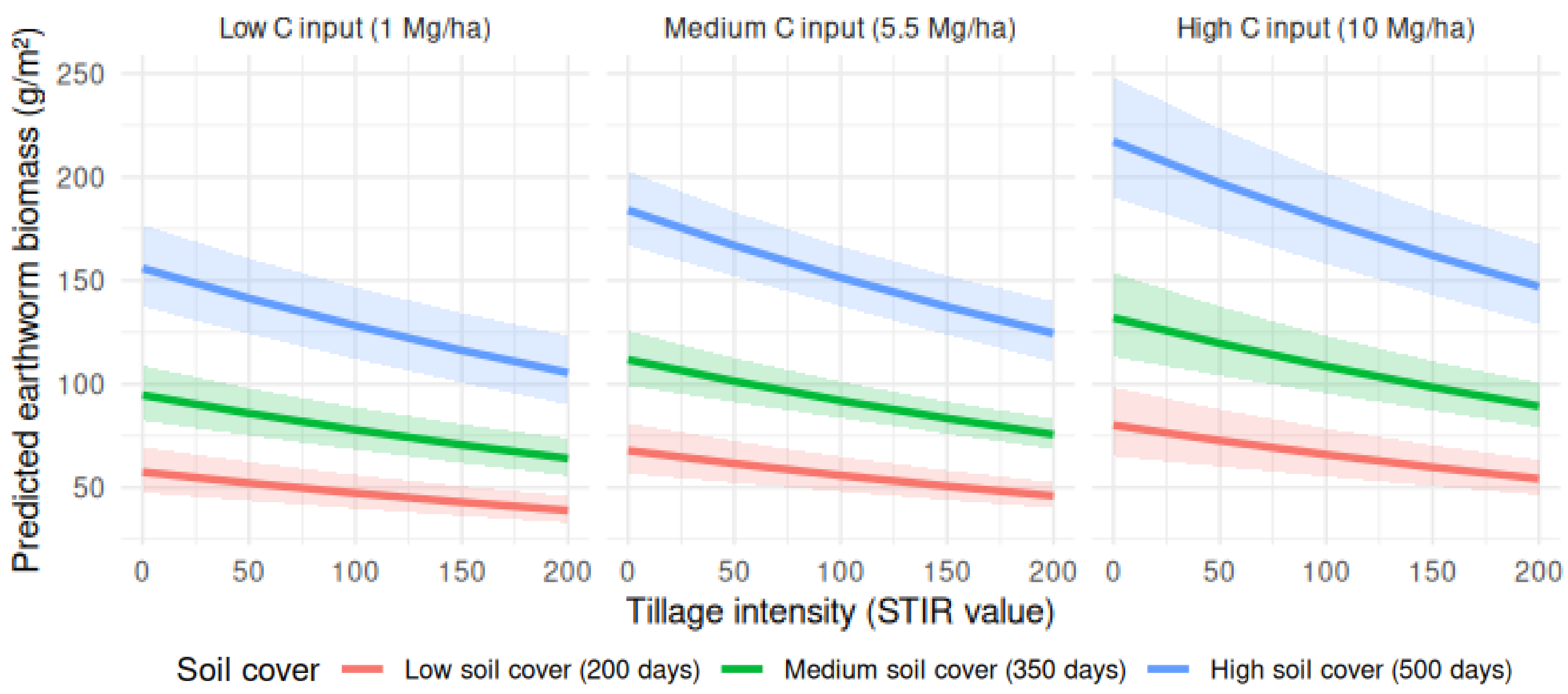


Figure 3: Prediction of earthworm biomass with varying soil cover (days with > 30% cover), tillage intensity and C input, based on the model presented in Table 2. The shaded areas represent confidence intervals of the prediction. Values for soil cover, tillage intensity, and C input were attenuated with a half-life time of one year. The maximum soil cover value that can be attained was thus ~ 526 days.

Habitat for earthworms

We assessed earthworm biomass (n = 318) as a soil health metric that is quickly reacting to changes in soil management. For this analysis, we attenuated (weighted) the indicator values by time with an exponential decay function with a half-life time of 1 year. We found that earthworm biomass was higher when the plot had higher soil cover (days with > 30% soil cover) (rel. importance = 72%), lower tillage intensity (21%) and higher C input (8%) prior to sampling.

Table 2: Estimates of the fixed effects of the mixed-effect model for the log-transformed earthworm biomass (g m^{-2}). Significance codes represent *p*-values. **.**: *p*-value < 10%, ***: *p*-value < 0.1%

Term	Estimate Std. Error	Significance
Intercept	1.34 ± 0.12	***
Attenuated soil cover (days)	1.44E-03 ± 2.4e-04	***
Attenuated tillage intensity (STIR value)	-8.48E-04 ± 2.14e-04	***
Attenuated C input (kg ha^{-1})	1.60E-05 ± 8.3e-06	.

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.

References:
Heller, O., Chervet, A., Durand-Maniclas, F., Guillaume, T., Häfner, F., Müller, M., Wittwer, R. and Keller, T. (2025), SoilManageR—An R Package for Deriving Soil Management Indicators to Harmonise Agricultural Practice Assessments. *Eur J Soil Sci, 76*: e70102. doi: 10.1111/ejss.70102

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