Supplementary Information for

Trade-offs between agronomic yields and sustainability in winter wheat cropping systems under climate change mediated by soil organic matter content

Short title: Time travelling with Triticum

Table A: Management history field 1 50°38’35.1474”N, 4°37’22.0123”E (S1)

Date	Crop / intervention	Dose	Comments/Details
2015	Wheat		
2016	Chicories		
2017	Wheat		
07/08/17	1 pass of harrowing		
24/08/17	Icorporation of Haspargit® and scums		Haspargit®, low-chlorine potassium fertilizer, contains sulfur and calcium
05/03/18	350 kg/ha of Sulfonitrate N26+ 31 SO3(commercial name)	350 kg/h	
06/04/18	350kg/ha Nitrogen (N27 %)	350 kg/h	
15/04/18	CARYX®	1,25 L/ha	Growth Regulator + Fungicide
04/05/18	Tangus Gold	0,5 kg/ha	Fungicide
14/07/18	Canola harvest		
21/08/18	Harrowing		
03/10/18	Tillage		
03/10/18	Plantation escourgeon multi		
06/11/18	HEROLD®	0,5 L /ha	HEROLD®, contact and residual broad-spectrum herbicide based on the leading grass-weed active ingredient flufenacet, for pre- and post-crop emergence application
06/11/18	Chlortoluron	1,2 L/ha	Herbicide
06/11/18	Patriot protect	0,32 L/ha	Patriot® Selective Herbicide
26/02/19	Nitrogen N27 %	250 kg/ha	
28/03/19	KANTIK®	1 L/ha	Fungicide
28/03/19	MEDAX ® TOP	1,2 L/ha	MEDAX® TOP is a growth regulator for cereals
28/03/19	MAGNESIE	2,5 kg/ ha	
02/04/19	SULFAZOTE 22%N (28,6 U)	200 L/ha	
20/04/19	TERPAL ®	1,2L /ha	Terpal® shortens the internodes and strengthens the stem wall, treated cereal crops become more resistant to lodging
20/04/19	INPUT	0,6L /ha	
02/05/19	VELOGY ERA	0,7L / ha	FUNGICIDE
02/05/19	BRAVO	1,2L /ha	FUNGICIDE
02/05/19	MAGNESIE	2,5KG /ha	
02/05/19	Patriot protect	0,2L /ha	Patriot® Selective Herbicide
08/07/19	Harverst escourgeon multi		
24/08/19	Glyfall plus	6L/ha	Total herbicide
02/09/19	Harrowing		
09/09/19	Harrowing		
11/09/19	Sowing seeds (radish, clover, phacelia)	12kg/ha	

2021	Sugar beet/wheat culture		Variety BTS 4860 + KWS Tessilia + Caprianna kws + Bts 3480 (6 boxes of each)
03/04/20	Sugar beet sowing		
21/08/20	Fertilizer 0-5-16+15 CaO+2 MgO+12 EB	1113 kg/ha	
02/09/20	Harrowing		
07/09/20	Harrowing		
07/09/20	Liquid nitrogen	120 l/ha	
07/09/20	Green manure seeding 15kg/ha (base 5kg + early 10kg) brand Lemken		
31/10/20	Fast plow		
06/12/20	Tillage		
23/03/21	7 So3	800 kg/ha	Fertilizer
23/03/21	Nitrogen N27	150 kg/ha	
23/03/21	7 So3	800 kg/ha	Fertilizer
26/03/21	Liquide nitrogen	350 L/ha	
02/04/21	Soil preparation		
04/04/21	Beetix	1,75 L/kg	Herbicide
04/04/21	Centium®	0,05 L/kg	Herbicide
01/05/21	Dianal	0,9 L/ha	
01/05/21	Ethomat	0.3	Herbicide to control annual dicot weeds and annual grass weeds in sugar beet and fodder beet.
01/05/21	Safari®	15 gr/ha	Safari® herbicide for post-emergence control of broadleaf weeds in sugar beets, red beets, chicory, and endive
01/05/21	Goltix® Queen	1 L/ha	Goltix® Queen is a combination of the active ingredient metamitron, and an addition of the active ingredient quinmerac, long-lasting control on regrowth, effectively controlling a broad spectrum of weeds
01/05/21	Vegetop	0,5 L/ha	Additive to enhance herbicide performance.
01/05/21	Magnesia	2,3kg /ha	
07/05/21	Dianal	0,9 L/ha	
07/05/21	Ethomat	0.3	Herbicide to control annual dicot weeds and annual grass weeds in sugar beet and fodder beet.
07/05/21	Goltix® Queen	1 L/ha	Goltix® Queen is a combination of the active ingredient metamitron, and an addition of the active ingredient quinmerac, long-lasting control on regrowth, effectively controlling a broad spectrum of weeds
07/05/21	Vegetop	0,5 L/ha	Additive to enhance herbicide performance.
07/05/21	Magnesia	2,3kg /ha	
11/05/21	Hoeing		
29/05/21	Dianal	0,9 L/ha	

29/05/21	Ethomat	0.3	The product is intended to be used as herbicide to control annual dicot weeds and annual grass weeds in sugar beet and fodder beet.
29/05/21	Beetix	0,6 L/ha L/kg	Herbicide
29/05/21	Tamaris	0,6 L/ha	
29/05/21	Lenazar	150 gr/ha	Selective herbicide against annual dicotyledonous weeds
07/05/21	Vegetop	0,5 L/ha	Additive to enhance herbicide performance.
15/06/21	Centium®	0,05 L/kg	Herbicide
15/06/21	Frontier® Optima	0,5 L/ha	Frontier Optima is a soil herbicide primarily absorbed through the coleoptile of grasses as the seedling penetrates the upper layer of the soil.
15/06/21	Boron	3 L/ha	Fertilizier
15/06/21	Magnesia	2,3kg /ha	Fertilizier
05/08/21	Agora	0,35l /ha	Fungicide
05/08/21	Magnesia	5,9kg /ha	
01/09/21	Bicanta	1 L/ha	Bicanta: product to combat diseases in sugar beet cultivation, combination of two active ingredients 125 g/l of difenoconazole and 125 g/l of azoxystrobin, effective control against all major foliar diseases, including Cercospora, Stemphylium, downy mildew, Ramularia, and rust
01/09/21	Magnesia	5 kg/ha	
16/10/21	Harvest		
15/11/21	Harvest		
2022	Wheat		
18/10/21	Sowing wheat	153 kg/ha	Variety Campesino PMG:44 gr
06/11/21	Thin sowing wheat		
01-03-22	18 SO3	260 kg/ha	
15-03-22	Sulfazote 22%	200 l/ha	
23-03-22	Osmose	0,2 l/ha	
23-03-22	SAVVY®	20 gr/ha	Herbicide, 200g/kg of Metsulfuron-methyl
23-03-22	Sigma® Maxx	1,1 L/ha	Selective post-emergence herbicide in winter wheat, spring wheat, rye, triticale, and spelt against annual grasses and dicotyledons
23-03-22	Magnesia	2 kg/ha	
05-04-22	Nitrogene N27 %	194 kg/ha	Fertilizer
18-04-22	FERTILEADER® Trio		Improves plant resistance to stress, stimulates metabolism, improves plant photosynthesis, contains patented Seactiv® complex (trademark of Timak Agro)
18-04-22	Magnesia	2,3 kg/ha	
18-04-22	Osmose	0,2 l/ha	

18-04-22	Chlormequat	1 L/ha	Growth regulator, can control the vegetative growth of plants (i.e., root and leaf growth), promote the reproductive growth of plants (i.e., flower and fruit growth), and enhance the plant's fruit-setting rate.
27-04-22	Tebecur	2,7 kg/ha	All-round fungicide with efficacy over a period of several weeks, controlling numerous pathogens in various crops, effective on i.a. Fusarium, Alternaria, Septoria nodorum, rusts, Sclerotinia, powdery mildew, leaf spots
27-04-22	Osmose	0,2 l/ha	
27-04-22	Magnesia	2,7 kg/ha	
15-05-22	Nitrogen N38	31 L/ha	Foliar fertilizer
18-05-22	Osmose	0,2 l/ha	
18-05-22	Magnesia	3,6 kg/ha	
18-05-22	REVYTREX®	1,1 L/ha	New cereal fungicide based on Revysol®
18-05-22	COMET ®	0,4 L/ha	Preventive-action fungicide designed to combat foliar diseases in various cereals (eg fight dwarf rust)
29/07/22	Harverst wheat		
05/08/22	Harrowing		
05-08-22	KALCIPHOS P-K (S)	(0-5-15) 1000 kg/ha	
19/08/22	Cattle manure	15t/ha	
24/09/22	Green fertilizer	11,6 kg/ha	
24/09/22	Fast plowing		

Table B: Management history field 2 50°39'12.8668"N, 4°38'10.7664"E (S2)

Date	Crop / intervention	Dose	Comments/Details
2017	Beet culture		
2018	Wheat culture		
2018	Cover crop after harvest (oats, mustard, radish, clover, sunflower, peas).		
2019	Potato culture		
2019-2020	wheat		
20/10/19	Mixed vegetation seeding	145 kg/ha	
02/03/20	Nitrogen N39	175 L/kg	
01/02/20	TMS	80 kg/ha	TMS, mineral CE-fertilizer, regulates microbial flora and organic matter evolution, improves chemical, physical and biological soil fertility.
16/03/20	Sigma® Flex	140 g/ha	Herbicide (not sure about yhe unit looks like g/ha)

16/03/20	Brodway	150 g/ha	Herbicide (not sure about yhe unit looks like g/ha)
16/03/20	Oil	1l/ha	
06/04/20	Cycocel		Cycocel is a plant growth regulator
18/04/20	Nitrogen N39	170 L/ha	
18/04/20	Humic and fulvic acids	1 L/ha	Fertilizer
16/05/20	Tebuzifo	04 L/ha	
16/05/20	TMF	1L/ha	Fertilizer
16/05/20	MgSo4	1,8 kg/ha	Fertilizer
20/05/20	Nitrogen N 27	200 kg/ha	Fertilizer
02/06/20	MgSo4	1,8 kg/ha	Fertilizer
02/06/20	TMF	1L/ha	Fertilizer
02/06/20	Opustear	0,35 l/ha	
02/06/20	Sportitck	0,36 l/ha	
02/06/20	Kestrel	0,36 l/ha	
20/08/20	Cow manure	12000L	Fertilizer
	Cover crop seeding (phacelia, oats, radish, clover)		
	Grazing of cover crops, CRAW Janart trials		
08/03/21	Glypho	1L/ha	Herbicide
23/02/21	TMS	80 kg/ha	Fertilizer
03/03/21	Unreadable	300 kg	
18/03/21	Nitrogen	100L/ha	Fertilizer
18/03/21	Humactiv	3,5 L/ha	Root stimulant
11/05/21	Flax		
11/05/21	Kaei		
11/05/21	TMS	1 L/ha	
11/05/21	MgSo4	3kg/ha	
11/06/21	Rudis®	1 L/ha	Fungicide
11/06/21	TMF	0,4 L/ha	Fertilizer
11/06/21	éthéplum	4 L/ha	
15/06/21	TOPREX	0,3 L/ha	TOPREX, co-formulation of difenoconazole and paclobutrazol, use as plant growth regulator, also as a fungicide against phoma and light leaf spot in winter oilseed rape
15/06/21	Flax		
16/10/21	Wheat Sowing		
05/11/21	Liberator + Flufenacet	0,58 L/ha	Herbicides
05/11/21	Mateno® Duo	0,35 L/ha	Herbicides
26/02/22	TMS	80 kg/ha	Fertilizer
14/03/22	Nitrogen N39	200 L/ha	Fertilizer
05/04/22	Nitrogen N39	175 L/ha	Fertilizer
13/04/22	MgSO4	3,5 kg/ha	Fertilizer
13/04/22	TMF	1 L/ha	Fertilizer

13/04/22	Cycocel	1L /ha	Cycocel is a plant growth regulator
25/04/22	Nitrogen N39	125 L/ha	Fertilizer
22/05/22	Kestrel	1 L/ha	
22/05/22	MGSO4	3kg/ha	Fertilizer
22/05/22	TMF	1L/ha	Fertilizer
01/06/22	Tebuzip ?? Maybe Tebuconazole	0,7 L/ha	
01/06/22	TMF	1L/ha	Fertilizer
01/06/22	Prinus	0,1 ??	
	Wheat	108 Qx/ha	
15/08/22	Horse manure	15 T/ha	Fertilizer
17/09/22	Mixture Scam Selfie		Cover crop

Fig A: Soil monolith sampling

Table C: Details of mineral N fertiliser applied during the Ecotron experiment. The total required amount of nitrogen fertiliser was split into three doses, each of which was applied according to plant growth stage in respective climate. The recommendation was made for each soil type in each CER and based on the guidelines of the Wallon Centre of Agronomic Research (CRA-W) as described in Le Livre Blanc: La fertilisation azotée. The recommendation consists in calculating a forecast N balance for the crop, taking into account the soil nitrogen supplies and the estimated needs of the intended crop. It makes it possible to assess the adequate quantity of fertilizer to bring. Soil nitrogen supplies are determined based on soil characteristics (humus content, remaining mineral nitrogen at the end of winter, mineralization of organic nitrogen in the soil), the phytotechnical history of the plot (crop residues, previous crop) and mineral and previous organic nitrogen fertilizer inputs by the farmer.

Simulated year	**CER**	**Soil**	**End of winter** kg N-NO_3 ha^{-1} 0-25 + 25-50cm		**Total amount of fertiliser needed** kg N ha^{-1}	**1. dose: start stem-elongation** kg N ha^{-1} (ecotron date of application)	**2. dose: 2. node** kg N ha^{-1} (ecotron date of application)	**3. dose: flag leaf** kg N ha^{-1} (ecotron date of application)
2085	3	1	11	10	200	65 (10/02/2085)	65 (04/03/2085)	70 (22/04/2085)
2085	3	2	19	10	150	50 (10/02/2085)	50 (04/03/2085)	50 (22/04/2085)
2085	6	1	11	11	200	65 (10/02/2085)	65 (04/03/2085)	70 (22/04/2085)
2085	6	2	23	18	155	54 (10/02/2085)	50 (04/03/2085)	50 (22/04/2085)
2068	2	1	2	5	205	70 (17/04/2068)	65 (12/05/2068)	70 (23/05/2068)
2068	2	2	5	10	155	55 (17/04/2068)	50 (12/05/2068)	50 (23/05/2068)
2068	5	1	3	10	200	70 (17/04/2068)	65 (12/05/2068)	65 (23/05/2068)
2068	5	2	3	9	160	55 (17/04/2068)	50 (12/05/2068)	55 (23/05/2068)
2013	1	1	3	5	205	70 (12/05/2013)	65 (23/05/2013)	70 (12/06/2013)
2013	1	2	3	<2	155	55 (12/05/2013)	50 (23/05/2013)	50 (12/06/2013)
2013	4	1	2	4	200	70 (12/05/2013)	65 (23/05/2013)	65 (12/06/2013)
2013	4	2	2	<2	160	55 (12/05/2013)	50 (23/05/2013)	55 (12/06/2013)

Table D: Empirical and modelled parameter to quantify agronomic performance and environmental impact

Parameter	Unit and scale of inference	Measurement & method
BBCH plant developmental stage	Unitless, visual assessment of all plants within CERs, bi-weekly	Meier, U. (ed.). (2001). Growth Stages of Mono- and Dicotyledonous Plants. BBCH Monograph. 2nd edition. Federal Biological Research Centre for Agriculture and Forestry, Germany. DOI: 10.5073/20180906-074619.
Plant height	cm, 3 plants per cube, 8 cubes per soil type x climate, monthly	Metric
Leaf area index	Unitless, 3 plants per cube, 4 cubes per soil type x climate, monthly June-August	Scan and image analysis (pixel)
Total root length	mm, 2 plants per cube, 2 cubes per soil type x climate, BBCH 30, 50, 80	Wash, scan, image analysis Seethepalli, A., Dhakal, K., Griffiths, M., Guo, H., Freschet, G. T., York, L. M. (2021). RhizoVision Explorer: Open-source software for root image analysis and measurement standardization. AoB PLANTS, plab056, https://doi.org/10.1093/aobpla/plab056.
Maximum quantum efficiency PSII	Fv/Fm, 3 leaves per cube, 8 cubes per soil type x climate, weekly for sufficiently large leaf surface area	HandyP+, Hansatech Instruments, UK Vlaović J., Balen J., Grgić K., Žagar D., Galić V. & Šimić D., 2020. An Overview of Chlorophyll Fluorescence Measurement Process, Meters and Methods. In: 2020 International Conference on Smart Systems and Technologies (SST). Presented at the 2020 International Conference on Smart Systems and Technologies (SST), 245–250. doi: 10.1109/SST49455.2020.9264091.
Foliar silicon	mg kg-1, 3 leaves per cube, 4 cubes per soil type x climate, BBCH 30, 50, 80	Inductively coupled plasma optical emission spectroscopy (ICP-OES), Core Facility Hohenheim (CFH), University of Stuttgart, Germany
Foliar proline	µg g-1, 3 leaves per cube, 4 cubes per soil	Acid-ninhydrin quantification. Bates, L.S., Waldren, R.P. & Teare, I.D. Rapid determination of free proline for

	type x climate, BBCH 30, 50, 80	water-stress studies. Plant Soil 39, 205–207 (1973). https://doi.org/10.1007/BF00018060.
Take-all index	%, visual assessment, 3 plants per cube, 4 cubes per soil type x climate, BBCH 40-50	Cook, RJ (2003) Take-all of wheat. Physiological and Molecular Plant Pathology 62(2):73-86. https://doi.org/10.1016/S0885-5765(03)00042-0. BBA (1999). F. 01 Deutscher Vorschlag für eine EPPO-Richtlinie zur Prüfung der Wirksamkeit von Saatgutbehandlungsmitteln gegen luft- und bodenbürtige Krankheitserreger an Getreide. Biologischen Bundesanstalt für Land- und Forstwirtschaft, Braunschweig, Germany
NO_3 aq.	mg L-1, interstitial soil pore water extracts using rhizons at 8-12cm depth, 0-8 cubes per soil type x climate if water extraction possible, weekly	LAQUAtwin NO3-11C, Horiba Ltd., Kyoto, Japan Folegatti, M.V., Blanco, F.F., Boaretto, R.M. and Boaretto, A.E. (2005) Calibration of cardy-ion meters to measure nutrient concentrations in soil solution and in plant sap. Sci. Agric. 62(1): 8-11. https://doi.org/10.1590/S0103-90162005000100002
Glucose equivalent	mg ml-1, interstitial soil pore water extracts using rhizons at 8-12cm depth, 0-8 cubes per soil type x climate if water extraction possible, weekly	Yemm EW, Williams AJ (1954). The estimation of carbohydrates in plant extracts by anthrone. Biochem J. 57(3):508-14. https://doi.org/0.1042/bj0570508.
Microbial biomass carbon	CO_2-C mg g-1, BBCH 30, 50, 80	MicroResp, James Hutton Institute, UK Campbell, CD, Chapman, SJ, Cameron, CM, Davidson, MS, Potts JM (2003) A rapid microtiter plate method to measure carbon dioxide evolved from carbon substrate amendments so as to determine the physiological profiles of soil microbial communities by using whole soil. Appl. Environ. Microbiol., 69 (6): 3593-3599.
Grain yield	t ha-1 at 14% grain moisture, harvest, 4 undisturbed cubes per soil type x climate,	Weight and water content

Soil N leaching	kg N ha-1 yr-1, cumulative	DNDC (DeNitrification-DeComposition) model, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire Durham, USA https://www.dndc.sr.unh.edu/
Soil CO_2-emission	CO_2-C kg ha-1 yr-1, cumulative	DNDC (DeNitrification-DeComposition) model, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire Durham, USA https://www.dndc.sr.unh.edu/
Soil N_2O-emission	N_2O-N kg ha-1 yr-1, cumulative	DNDC (DeNitrification-DeComposition) model, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire Durham, USA https://www.dndc.sr.unh.edu/

Fig B: Correlation between empirical and modelled parameter estimates, polygons indicate grouping by soil type. To validate the accuracy of the modelled parameters from the DNDC model, the results were compared against measured values using the coefficient of determination (R^2). The correlation was excellent for the DNDC estimate of CO_2-emission and the standardised basal soil microbial respiration assessed with the MicroResp kit (R^2=0.99), using n=20 empirical observation (panel A), because n=4 values of 2068.S1 were detected as outliers (panel E). The soil CO_2-emissions predicted with the DNDC model also correlated well with the microbial biomass estimated in March using MicroResp (panel C). While no empirical data directly on denitrification was gathered during the Ecotron experiment, the DNDC estimate of soil N_2O-emission correlated well with the metabolic quotient (qCO_2), probably reflecting that microbes that actively denitrify (under anaerobic conditions) also engage in respiration, leading to CO_2 emissions (R^2=0.6) (panel B). The correlation between the measured nitrate in aqueous solution and the predicted soil N-leaching was good (R^2=0.71) if 2013.S1 was not taken into account. Similarly, a moderate correlation (R^2=0.53) was observed for the root exudation predicted by the DNDC model and the measured values of glucose equivalent, if 2013.S1 was excluded (R^2=0.53). This could be due to the cold winter in 2013 where surface soil was temporarily frozen (Fig.3B, 3D). The data distribution suggests that the NO_3 in aqueous solution in 2013.S1 was actually higher than what was measured, which could also be related to the freezing conditions, the high sand content of S1, and/or to the fast turnover of NO_3 in soil where it is quickly taken up by plants and microbes (panel D). For root exudation, in DNDC root exudates are represented as a portion of the root-derived carbon where the model considers both root growth and root turnover, while the empirical measurement performed here only gives an estimate of low-molecular weight sugars measured as glucose equivalents which may explain discrepancies. The data distribution suggests that both the DNDC model and the measurements underestimated root exudation in 2013.S1 (panel F), which similarly to NO_3 could be due to the high reactivity of these molecules in the soil. Overall, the modelled and measured parameter were well aligned for gaseous emissions of CO_2 and N_2O (R^2=0.98, R^2=0.6), and moderately well aligned for nitrate and glucose equivalents (R^2=0.71, R^2=0.53) with 2013.S1 not fitting the distribution, possibly due to the technical limitations of the empirical measurements. Polygons in panels group the data points of each soil together.

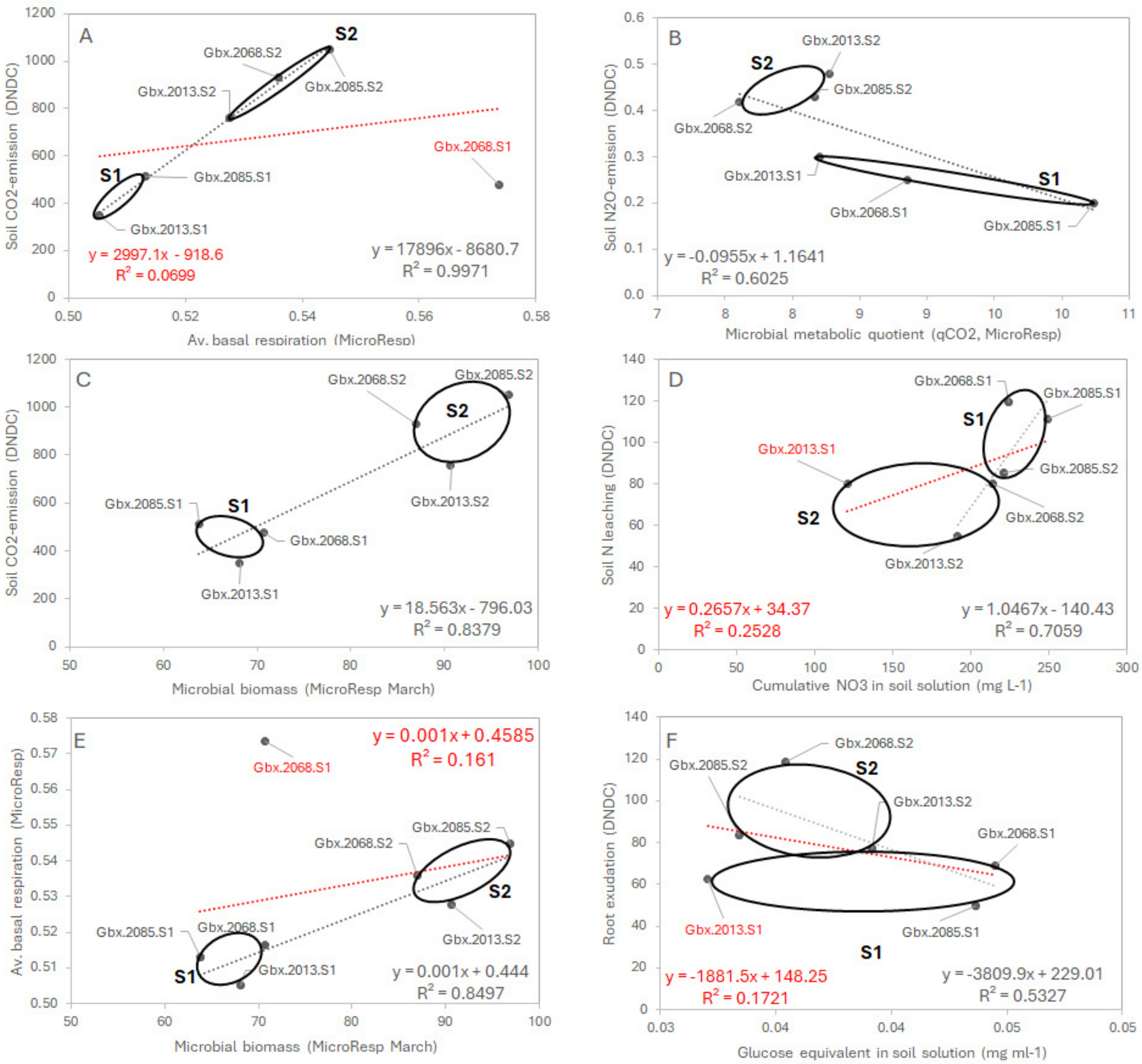
A
S1
S2
Gbx.2068.S2
Gbx.2013.S2
Gbx.2085.S2
Gbx.2068.S1
Gbx.2085.S1
Gbx.2013.S1
y = 2997.1x - 918.6
R² = 0.0699
y = 17896x - 8680.7
R² = 0.9971
Soil CO2-emission (DNDC)
Av. basal respiration (MicroResp)
B
S2
S1
Gbx.2013.S2
Gbx.2085.S2
Gbx.2068.S2
Gbx.2013.S1
Gbx.2068.S1
Gbx.2085.S1
y = -0.0955x + 1.1641
R² = 0.6025
Soil N2O-emission (DNDC)
Microbial metabolic quotient (qCO2, MicroResp)
C
S1
S2
Gbx.2068.S2
Gbx.2085.S2
Gbx.2013.S2
Gbx.2085.S1
Gbx.2068.S1
Gbx.2013.S1
y = 18.563x - 796.03
R² = 0.8379
Soil CO2-emission (DNDC)
Microbial biomass (MicroResp March)
D
S1
S2
Gbx.2068.S1
Gbx.2085.S1
Gbx.2013.S1
Gbx.2085.S2
Gbx.2068.S2
Gbx.2013.S2
y = 0.2657x + 34.37
R² = 0.2528
y = 1.0467x - 140.43
R² = 0.7059
Soil N leaching (DNDC)
Cumulative NO3 in soil solution (mg L-1)
E
Gbx.2068.S1
y = 0.001x + 0.4585
R² = 0.161
Gbx.2085.S2
Gbx.2068.S2
S2
Gbx.2013.S2
Gbx.2085.S1
Gbx.2068.S1
Gbx.2013.S1
S1
y = 0.001x + 0.444
R² = 0.8497
Av. basal respiration (MicroResp)
Microbial biomass (MicroResp March)
F
Gbx.2068.S2
Gbx.2085.S2
S2
Gbx.2013.S2
Gbx.2068.S1
Gbx.2013.S1
Gbx.2085.S1
S1
y = -1881.5x + 148.25
R² = 0.1721
y = -3809.9x + 229.01
R² = 0.5327
Root exudation (DNDC)
Glucose equivalent in soil solution (mg ml-1)

Table E: Loadings for the main vector of each modality (Year.Soil)

	2013.S1	2013.S2	2068.S1	2068.S2	2085.S1	2085.S2
Basal.CO2.02.05				-0.8399		1.55331
Basal.CO2.30.05	-0.7269	-0.8814		1.23257		
Basal.CO2.03.07				-0.8972	1.25774	
Basal.CO2.07.08			-0.0394			
Foliar.proline_BBCH80			0.14672			
Foliar.silicon_BBCH50						1.36197
Glucose.equivalent.27.02	0.82706		-0.1687			
Glucose.equivalent.14.03	-0.6393					
Glucose.equivalent.02.05	0.67934			-0.7745		
Glucose.equivalent.21.05		-0.896				
Glucose.equivalent.03.07			-0.0938			
Glucose.equivalent.19.07	-0.7882	-1.0001				
Glucose.equivalent.25.08			-0.1407			
Leaf.area.index.March	-0.864	-0.8922				1.31855
Leaf.area.index.April		-1.0344	0.09927			1.53179
Leaf.area.index.May		-1.141				
Leaf.area.index.June		-1.1419				
Maximum.quantum.efficiency.PSII.23.03				-0.7742	1.17837	1.12584
Maximum.quantum.efficiency.PSII.07.04				0.82972		-1.2996
Maximum.quantum.efficiency.PSII.19.04			-0.1273			
Maximum.quantum.efficiency.PSII.10.05				-0.9076		
Maximum.quantum.efficiency.PSII.08.06		-0.9777				
Maximum.quantum.efficiency.PSII.21.06	-0.8253	-1.2397				
Maximum.quantum.efficiency.PSII.05.07				0.89958		
Microbial.biomass.carbon_BBCH30			-0.1362			
Microbial.biomass.carbon_BBCH50			0.03226	0.72059		
NO3.aq.14.03					-1.3856	
NO3.aq.15.05	0.75471			-0.8281		
NO3.aq.12.06					1.53893	
NO3.aq.03.07		-0.9794				
NO3.aq.19.07	-0.7774					
NO3.aq.07.08					1.16468	
Plant.height.March					1.4301	1.14948
Plant.height.April					1.43003	1.14928
Plant.height.May					1.43006	1.14936
Plant.height.June					1.43012	1.14976
Take.all.index	-0.722					
Total.root.length_BBCH30			-0.0929		1.13926	

Fig C: Edge evidence plot showing the evidence for inclusion or exclusion. The blue edges represent edges with posterior evidence for presence, the red edges evidence for absence, and the gray edges have insufficient evidence to conclude either way. The Bayes factor used was $BF_{10}>15$.

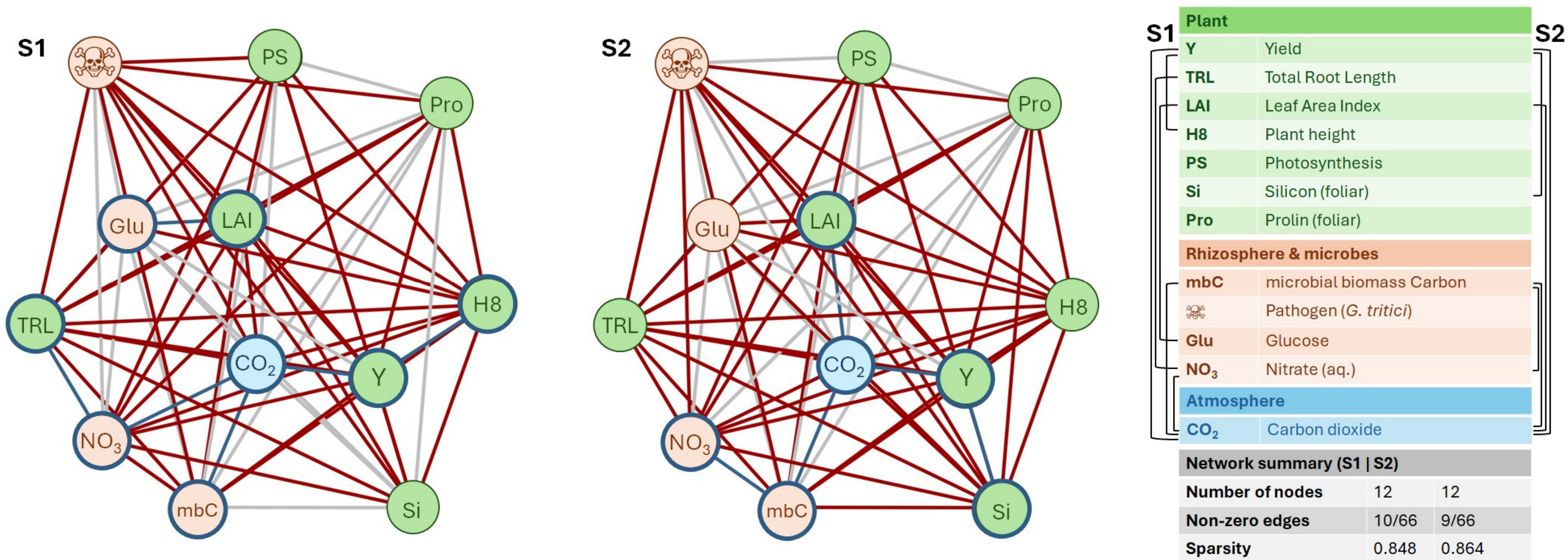

Table F: Edge evidence probability tables for S1

S1	Glucose	Pathogen	Foliar proline	mbC	TRL	LAI	CO2	PS	NO3	H8	Foliar silicon	Grain yield
Glucose	0.000	0.750	0.560	0.240	0.000	1.000	0.850	0.310	0.080	0.000	0.390	0.150
Pathogen		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.210	0.000	0.000	0.000
Foliar proline			0.000	0.290	0.000	0.000	0.200	0.240	0.020	0.000	0.080	0.040
mbC				0.000	0.000	0.000	0.940	0.240	0.000	0.000	0.080	0.000
TRL					0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
LAI						0.000	0.000	0.000	0.000	0.000	0.000	0.000
CO2							0.000	0.750	1.000	0.000	0.500	1.000
PS								0.000	0.000	0.000	0.000	0.000
NO3									0.000	0.000	0.000	0.000
H8										0.000	0.000	1.000
Foliar silicon											0.000	0.030
Grain yield												0.000

Table G: Edge evidence probability tables for S2

S2	Glucose	Pathogen	Foliar proline	mbC	TRL	LAI	CO2	PS	NO3	H8	Foliar silicon	Grain yield
Glucose	0.000	0.320	0.510	0.230	1.000	0.000	0.720	0.740	0.480	0.000	0.000	0.250
Pathogen		0.000	0.000	0.000	0.000	0.000	0.110	0.090	0.000	0.000	0.000	0.000
Foliar proline			0.000	0.220	0.000	0.000	0.380	0.390	0.070	0.000	0.050	0.000
mbC				0.000	0.000	0.000	1.000	0.120	1.000	0.000	0.000	0.000
TRL					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LAI						0.000	1.000	0.000	0.000	0.000	0.000	0.000
CO2							0.000	0.420	0.000	0.000	0.000	1.000
PS								0.000	0.060	0.000	0.000	0.000
NO3									0.000	0.000	0.000	0.000
H8										0.000	0.000	0.000
Foliar silicon											0.000	1.000
Grain yield												0.000

Fig D: Centrality plot

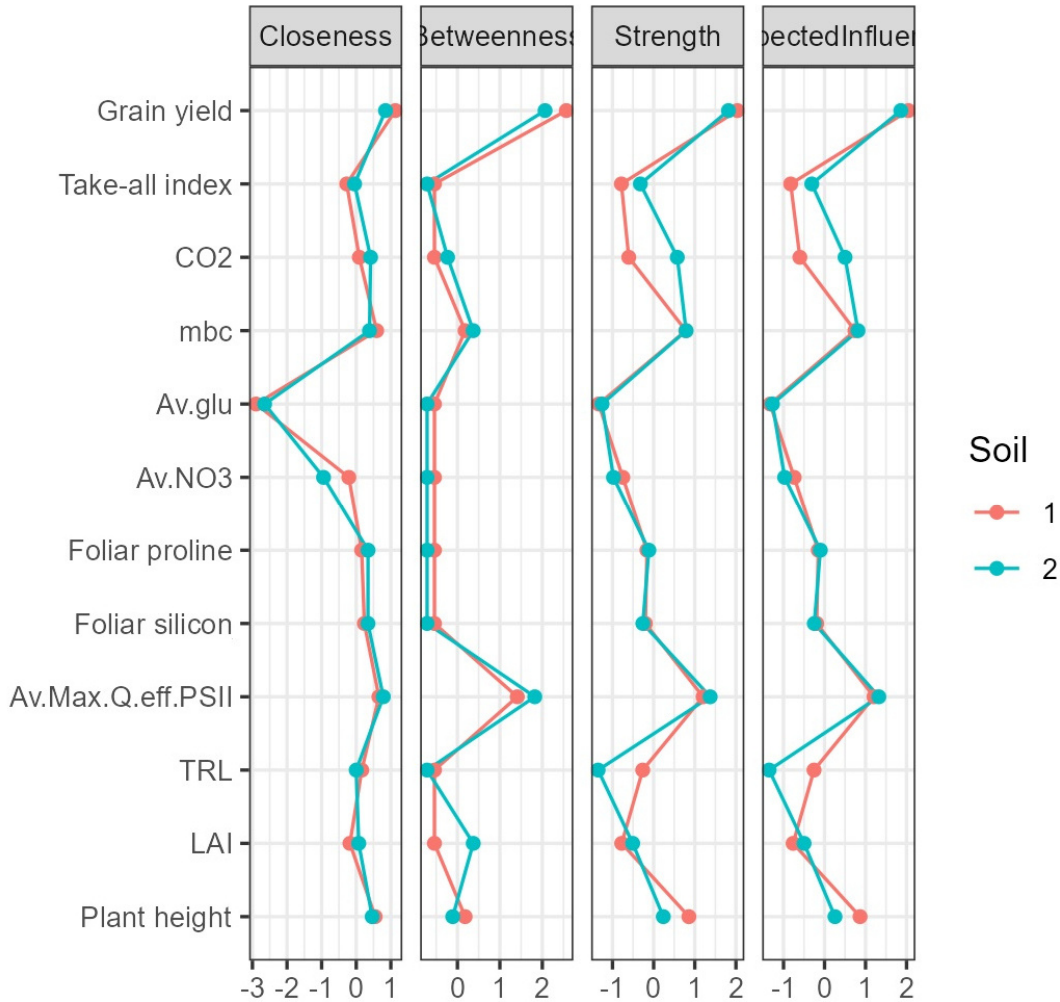

Table H: Centrality measures per variable

	S1				S2			
Variable	Betweenness	Closeness	Strength	Expected influence	Betweenness	Closeness	Strength	Expected influence
H8	0.181	0.547	0.857	0.866	-0.111	0.461	0.235	0.254
LAI	-0.542	-0.182	-0.776	-0.766	0.373	0.072	-0.509	-0.499
TRL	-0.542	0.160	-0.266	-0.256	-0.715	0.000	-1.350	-1.351
PS	1.410	0.656	1.203	1.206	1.823	0.782	1.374	1.325
Foliar silicon	-0.542	0.234	-0.200	-0.191	-0.715	0.339	-0.262	-0.249
Foliar proline	-0.542	0.157	-0.162	-0.153	-0.715	0.342	-0.117	-0.102
Av.NO3	-0.542	-0.214	-0.750	-0.741	-0.715	-0.945	-0.977	-0.973
Av.glu	-0.542	-2.894	-1.335	-1.326	-0.715	-2.647	-1.254	-1.270
mbc	0.181	0.589	0.783	0.741	0.373	0.383	0.789	0.816
CO2	-0.542	0.090	-0.605	-0.602	-0.232	0.415	0.575	0.500
Pathogen	-0.542	-0.275	-0.784	-0.825	-0.715	-0.048	-0.323	-0.311
Grain yield	2.567	1.131	2.036	2.045	2.065	0.846	1.819	1.860

Fig E: Basal and exudate-induced soil respiration (CO_2) measured in situ. Basal and exudate-induced respiration were measured at five time points during the course of the experiment using a modified protocol for the MicroResp kit (Campell et al., 2003): At each time point, soils were used at their original soil moisture and incubated inside the CERs at given temperatures (Fig. 3C, 3D). Basal respiration here refers to the CO_2-emitted from unamended soils (no water, no substrate), while exudate-induced respiration refers to soils amended with samples of interstitial soil pore water extracted from each cube prior to incubation (addition of 25µl per deep-well). Each modality (soil*year*time) was studied with four biological replicates (cubes), each of which had eight technical replicates on MicroResp plates. All soils were sampled at 0-15cm depth and sieved to 2mm prior to incubation. Incubations lasted 6h and absorbance was measured at 570nm. Dots in graph represent biological reps and rectangles mean per modality. Asterisks indicate significant differences between means according to ANOVA with p>0.05., p≤ 0.05*, p≤ 0.01**, p≤ 0.001 and letters indicate grouping based on TukeyHSD test.

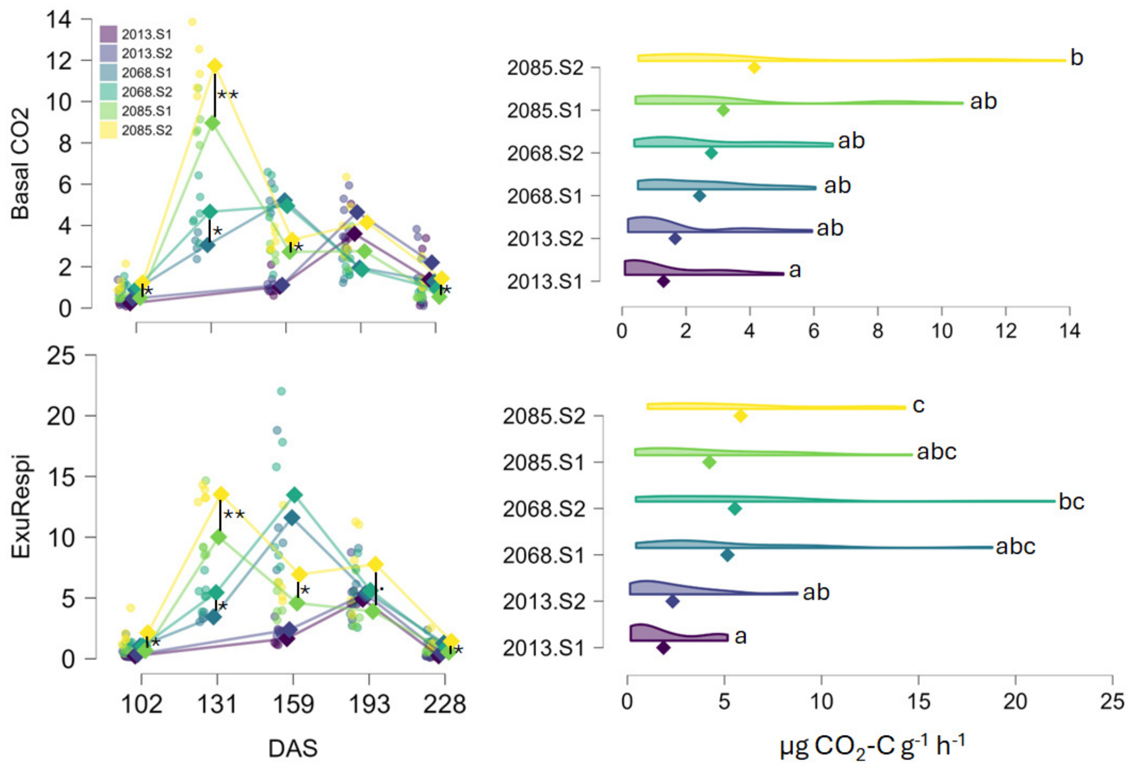

Fig F: Metabolic quotient (qCO_2) and multiple substrate-induced respiration (MSIR) measured under standardised laboratory conditions. Metabolic quotient (qCO_2) and multiple substrate-induced respiration (MSIR) were measured at BBCH 30, 50, 80 under standardised conditions as described in (Campell et al., 2003). The metabolic quotient qCO_2 is the ratio of basal and glucose-induced respiration and is inversely correlated with microbial carbon use efficency, which in it's simplest form is approximated as microbial growth divided by respiration (Manzoni et al., 2012). The substrates used to determine multiple substrate-induced respiration (MSIR) are: ketoglutaric acid, oxalic acid, xylan, glucose, glucosamine, alanine and aminobutyric acid. Soils were samples at two depths (0-10cm and 10-20cm). Dots in graph represent biological reps per modality combined over depths and BBCH stages (n=24) and asteriks indicate significant differences between soil types according to ANOVA with p>0.05., p≤ 0.05*, p≤ 0.01**, p≤ 0.001.

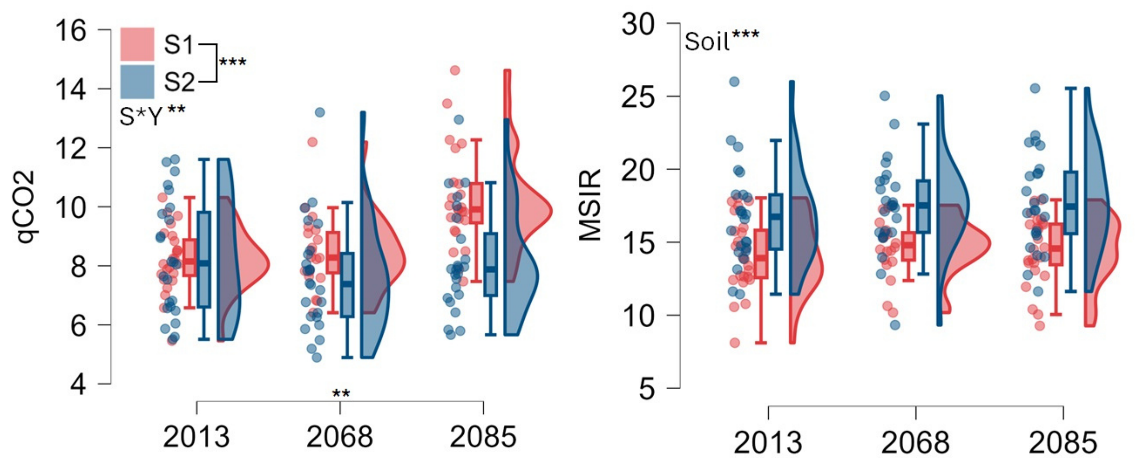

Fig G: Conceptual framework of carbon and nitrogen pools and fluxes in the two soil types S1 and S2

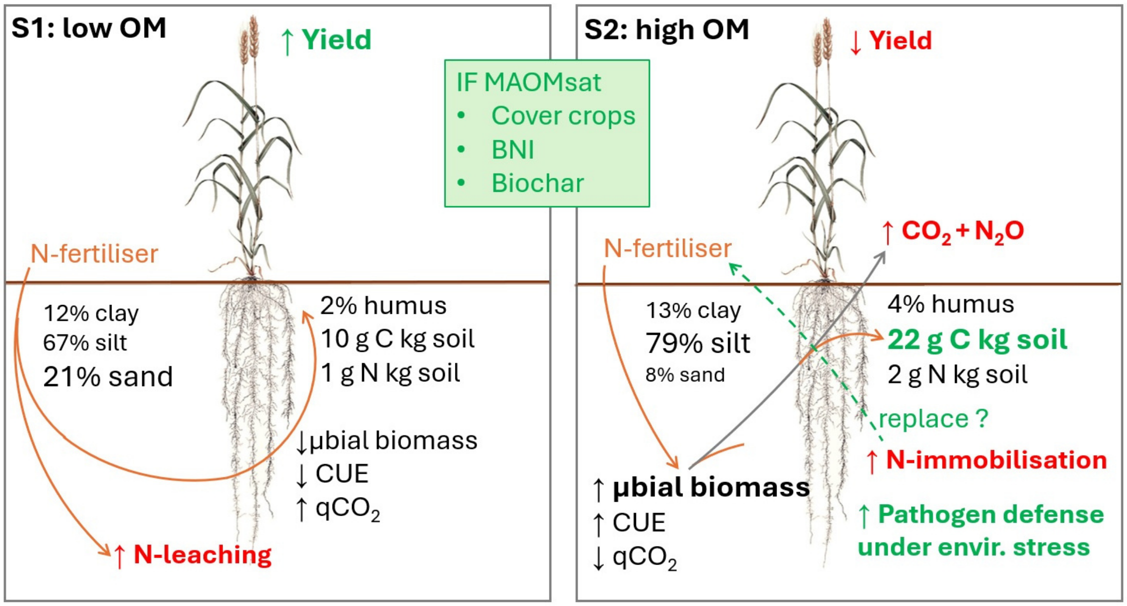

Fig H: Relative abundance of known fungal pathogens in the two soils S1 (low OM) and S2 (high OM) in the three climates 2013, 2068 and 2085 at the three sampling time points according to plant growth stage in respective modality (stem elongation, flowering and ripening). Molecular microbial analysis was performed as described in Waibel et al. (2025) and ITS2 marker genes were manually assigned to known pathogens in NCBI Blast ("ZOTU10920", # Ustilago tritici (92.62%),"ZOTU3982",#Blumeriagraminisfsptritici(100%), "ZOTU5249",#Urocystisagropyri(100%), "ZOTU61",#Fusariumculmorum(100%), "ZOTU33",#Fusariumredolens(100%), "ZOTU6014",#Fusariumsolani(100%), "ZOTU2956",#Fusariumsolani(<99%), "ZOTU5952",#Fusariumsolani(<99.5%), "ZOTU10178",#Fusariumbrachygibbosum(100%), "ZOTU5859",#Phaeosphaeriaelongata(98.35%), "ZOTU4851",#Torulafici(100%), "ZOTU7753",#Phaeosphaeriasp(96.67%), "ZOTU5909",#Bipolarissorokiniana(100%), "ZOTU2694",#Rhizoctoniasolani(100%), "ZOTU5353", "ZOTU1466", "ZOTU2712", "ZOTU4522", "ZOTU1228", "ZOTU2001", "ZOTU466"#Gaeumannomycesgraminis(100%))