Soil organic amendments for climate-smart agriculture

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Citation

Kok, D. D. (2024, September 26). *Soil organic amendments for climate-smart agriculture*. Retrieved from https://hdl.handle.net/1887/4093453

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Dirk-Jan was born on the 26th of February 1993 in 's-Hertogenbosch, the Netherlands. He demonstrated an interest in the natural world already at a young age and could be found collecting rocks and growing plants over the course of his childhood in the Netherlands, Malawi, Malaysia and Senegal. In his teenage years, he became environmentally and politically engaged and was elected a position in student government (2008), won an award for outstanding leadership (2008), was nominated and participated in the Global Young Leaders Conference in Washington D.C. (2010), and became a board member of the student environmental association (2012). However, his greatest high school honour was receiving the President's Award for Outstanding Academic Achievement (2009) - an award signed by a role model of his at the time, the United States President, Barack Obama.

In 2011, Dirk began his studies in Earth Sciences at Utrecht University where he focused on physical geography, specialising in Hydrology. During his Bachelor studies he participated in the Erasmus Exchange Programme and spent six months at the Swiss Federal Institute of Technology in Zurich (2013). Upon his return, he pursued a minor in Archaeology at Leiden University. He graduated from Utrecht University in 2014 with excess ECTS and a thesis on comparing the performance of different satellites in their ability to assess for soil moisture content.

Following his B.Sc. in Earth Sciences, Dirk enrolled in the Master Programme Water Management at the Faculty of Civil Engineering at TU Delft (2014). It is at TU Delft that his attention shifted to the agricultural aspects of water and water management. This is reflected in his participation in the design and execution of a study assessing the susceptibility of small-holder farmers to the effects of climate change in Sudan. At this point, thoroughly engaged in socio-hydrology, his supervisor, Dr. Saket Pande, offered him an internship at the UNESCO World Water Assessment Programme (WWAP) in Perugia, Italy (2016). This internship was followed up with a short consultancy at WWAP to investigate inter-correlations between the indicators for Sustainable Development Goal (SDG) 6. Back in the Netherlands, he acquired a board position at the Leiden Student Swimming and Water Polo Association, Aquamania (2015-2016). Completing his studies under the supervision of Saket Pande, Huub Savenije and Jules van Lier, he graduated from TU Delft with a thesis on the global potential for phosphorus recovery as struvite from wastewater for agricultural reuse (2017). He presented the model underlying his thesis at the Vienna Conference of the European Geoscience Union (2017) and was contracted by the University post-graduation to publish his findings in the scientific journal *Hydrology and Earth System Sciences* (2018).

In 2018, Dirk started his PhD at Leiden University on exploring the impacts of organic amendments on agricultural soils. This PhD was part of a joint research project between Leiden and Wageningen University dubbed the **S**ocial **In**novation for Resour**ce** Efficiency and Nutrient **Re**cycling project (SINCERE). The aim of SINCERE was to link the natural-physical effects of organic amendment application in agriculture to the social factors influencing the implementation of such amendment applications by farmers. A quick literature study revealed that some of the largest knowledge gaps lay in understanding the role of microorganisms in steering and mediating organic amendment impacts. Due to his academic background in earth sciences and water management, Dirk lacked specific knowledge of microbial processes and interactions. However, studying the literature and learning the relevant laboratory procedures, he was able to formulate and develop a methodology to address his research questions. Before starting his experiments in 2019, he took a brief sabbatical to sail across the Atlantic on tall ship the Morgenster as part of the think-tank ‘Quest for Change’. At the institute, he also taught classes and supervised groups for the courses Ecology 2, Environmental Biology 2, and Resilient Cities and Area Studies. He was also closely involved with the PhD Committee (2020, 2021) and the Institute Council (2021). After completing his experiments and having published two of the four research chapters, he left for Napier, New Zealand, publishing the remaining chapters and composing his final thesis there on a part-time basis next to his work as 3 Waters Programme Engineer at Napier City Council (2023). He has since returned to the Netherlands and is now keen to put his acquired skills and knowledge into practice to build a more sustainable future.

PUBLICATIONS

Kok, D. D., Scherer, L., de Vries, W., & van Bodegom, P. M. (2024). MiPrime: A Soil Model for the Microbially Mediated Impacts of Organic Amendments on Measurable Carbon Fractions and Associated Priming Effects. *Accepted with revisions by Soil Biology and Biochemistry*

Kok, D. D., Scherer, L., de Vries, W., & van Bodegom, P. M. (2023). Temporal variability in organic amendment impacts on hydro-physical properties of sandy agricultural soils. *Soil Science Society of America Journal*, *87*(4), 963–984. https://doi.org/10.1002/saj2.20547

Kok, D. D., de Vries, W., Scherer, L., & van Bodegom, P. M. (2023). Contrasting effects of different organic amendments on the microbial responses to extreme temperature changes. *Geoderma*, *439*, 116673. https://doi.org/10.1016/j.geoderma.2023.116673

Kok, D. D., Scherer, L., de Vries, W., Trimbos, K. B., & van Bodegom, P. M. (2022). Relationships of priming effects with organic amendment composition and soil microbial properties. *Geoderma*, *422*, 115951. https://doi.org/10.1016/j.geoderma.2022.115951

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Kok, D. D., Pande, S., Ortigara, A. R. C., Savenije, H., & Uhlenbrook, S. (2018a). Socio-Hydrological Approach to the Evaluation of Global Fertilizer Substitution by Sustainable Struvite Precipitants from Wastewater. *Proceedings of IAHS*, *376*, 83–86. https://doi.org/10.5194/piahs-376-83-2018

Kok, D. D., Pande, S., Ortigara, A., Savenije, H., & Uhlenbrook, S. (2018b). Global phosphorus recovery from wastewater for agricultural reuse. *Hydrology and Earth System Sciences*, *22*, 5781–5799. https://doi.org/10.5194/hess-22-5781-2018

ACKNOWLEDGEMENTS

Completing this thesis has been a journey marked by both triumphs and challenges. Now remains my final challenge: to bring into words my gratitude for all the invaluable contributions made to this work by my supervisors, colleagues, friends, and family. This thesis stands testament to our collective effort. There are many without whom the completion of this work would not have been possible.

First and foremost, Peter, Laura, and Wim. You have been critical to this research, but you've also been much more than that. You have each been an inspiration to me, both personally and professionally. Peter, through your out-of-the-box thinking, commitment to education and research, and your ability to condense my extensive texts in comprehensive manuscripts; Laura, through your diligence, idealism, and your incredibly sharp eye for detail; and Wim, through your talent of always asking me exactly the right questions, you have each demonstrated traits and abilities that I have come to deeply appreciate and admire. Your supervision has taught me lessons in science and in life. I thank you for your many hours of reading, editing, and discussing my texts, and for being an inspiration to me and undoubtedly many other young scientists fortunate enough to have worked with you.

I would also like to thank the **Social Innovation for Nutrient Recycling and Resource Efficiency (SINCERE)** team: Martha Bakker, Gerard Ros, Maaike Happel, Diana Giebels, and Alena Schmidt; the **CML Soil Processes Workgroup**: Nadia Soudzilovskaia, Emilia Hannula, Weilin Huang, Riccardo Mancinelli, and Chenguang Gao; the **CML Remote Sensing Workgroup**: Joris Timmermans, Nuno De Mequita César de Sá, Amie Corbin, Leon Hauser, Anne Uilhoorn, Olivier Burggraaf, Eefje de Goede, and Vivi Wen; indispensable **lab support**: Emilie Didaskalou, Wesley Post, and Gerben Bakker; the **Soup & Yoga gang**: Amie Corbin, Jianhong Zhou, and Bregje Brinkmann; fellow members of **the '20-'22 PhD Committee**: Riccardo Mancinelli, Elizabeth Migoni Alejandre, Brenda Miranda Xicotencatl, and Teun Verhagen; fellow members of the **'21-'22 Institute Council**: Mingming Hu, Franco Donati, Laura Scherer, Weilin Huang, Emilie Didaskalou, and Michiel Veldhuis; the **CML management and other staff**: Martina Vijver, Arnold Tukker, Susanne van den Oever, Sammy Koning, Milan Oostwouder, Ester Philips, Jasper Williams, Paul de Hoog, Krijn Trimbos and others; and the **waters infrastructure team at Napier City Council**: Russell Bond, Phil Kelsen, Syed Andrabi, Gary Schofield, Pious Xavier, Vonnie Archibald, Sue Bailie, Andrew Lebioda, John Kelsey, Paul Davison, Pyo Kim, Anoop Matthews, Patricia van der Westhuizen, and all the rest of you! You have all contributed to my joyous experience as a PhD fellow at CML and in New Zealand.

Last but not least, I would like to thank my partner, family, and friends. Your endless love, encouragement and belief in me have helped me through difficult times while working on this thesis. You are the pillars of my support system, and I could not have done this without you.

Sincerely,

Dirk-Jan Kok

The research in this thesis was financed by the Netherlands Organization for Scientific Research (NWO; grant number NWO-GK-06) and co-financed by the Leiden University CML Impact fund, Province of Gelderland (Provincie Gelderland), Vitens, Agricultural Landscape Collective Achterhoek (Vereniging Agrarisch Landschap Achterhoek), Foundation for Sustainable Agricultural Innovation Haarloseveld and Olden Eibergen (Stichting HOEduurzaam), the Directorate-General for Public Works and Water Management of the Netherlands (Rijkswaterstaat), Dutch Waste Management Association (DWMA), and the Netherlands Society for the Preservation of Nature Monuments (Natuurmonumenten).

APPENDICES

A Outline of ddPCR Protocol

For the ddPCR quantification of the F:B ratio, microbial DNA was extracted from 250 mg of soil from each sample using a DNeasy PowerSoil Pro DNA Extraction Kit (Qiagen). Samples were diluted with molecular-grade water to ensure DNA concentrations within the range of the detection limit. ddPCR was performed following the manufacturer's standard EvaGreen® protocol for the QX200™ ddPCR™ system (Bio-Rad Laboratories, Hercucles, CA, USA). Bacterial 16S rRNA subunit genes were targeted for amplification using 341 forward (CCTACGGGNGGCWGCAG) and 785 reverse (GACTACHVGGGTATCTAATCC) primers (Klindworth et al., 2013; Thijs et al., 2017). Fungal ITS gene amplification was achieved using ITS1 forward (TCCGTAGGTGAACCTGCGG) and 5.8s reverse (CGC TGC GTT CTT CAT CG) primers (Fierer et al., 2005). 22 µl ddPCR reactions were prepared, each containing 2 µl DNA extract, 0.2 µl 100 nM forward and reverse primer, 10 µl Bio-Rad Evagreen Supermix (Bio-Rad, Hercules, CA, USA) and 9.6 µl Milli-Q. 20 µl of each mixture was transferred into a DG8 Biorad cartridge containing 8 wells and covered with a DG8 rubber gasket. As contamination control, blank 3 µl Milli-Q samples were run in every plate. The ddPCR mixture was emulsified with Bio-Rad generator oil and partitioned in 10.000-20.000 droplets using a Bio-Rad QX-200 droplet generator. 40 µL of each produced droplet mixture was pipetted into a semi-skirted twintec 96-well plate for thermocycling. The plates were sealed with pierceable sealing foil, using the PX1 PCR Plate Sealer (Bio-Rad) and placed in a Bio-Rad T100 Thermal Cycler. DNA amplification was carried out with a 2 °C/s ramp rate for: 5 min at 95 °C for enzyme activation; 40 cycles of 30 s at 95 °C for denaturation, 40 cycles of 1 min at 60°C for annealing/extension, and finally 5 min at 4 °C and 5 min at 90 °C for signal stabilization. After signal stabilization, plates were loaded into the Bio-Rad QX200 Droplet Reader for the identification of fluorescent droplets.

To quantify the number of target copies, we used Bio-Rad's QuantaSoft software version 1.7.4. Droplets were counted as positive or negative by thresholding against the height of their respective fluorescence amplitude. By applying a Poisson distribution model, the concentration of the target and reference DNA sequences and their corresponding 95% confidence intervals were calculated by the software. A threshold was subsequently assigned at the point of greatest separation of the two distributions/bands. Droplets above the threshold were counted as positive events, and below the threshold were counted as negative events. After subtraction of blanks, the enumeration of the positive reactions provided a quantitative estimate of the DNA concentration in the original samples (rDNA copies/µL).

B Colorimetry for Determination of Mineral Nitrogen Concentrations

For the determination of NH_4^+ through the salicylate method (Mulvaney 1996), we prepared: 1a) a complexing solution by dissolving 3.60 g of disodium salt ethylenedinitrilotetraacetic acid disodium salt ($C_{10}H_{14}N_2Na_2O_8{\cdot}2H_2O$) in 60 mL of deionized water; 1b) a salicylate-nitroprusside solution by dissolving 7.8130 g of sodium salicylate ($C_7H_5NaO_3$) and 0.125g of sodium nitroprusside dihydrate ($C_5FeN_6Na_2O{\cdot}2H_2O$) in 100mL of deionized water; 1c) a buffer solution by dissolving 2.0720g of sodium hydroxide (NaOH) and 6.9720g of dibasic potassium phosphate (K_2HPO_4) in a mixture of 28mL of deionized water and 42mL sodium hypochlorite (NaClO). 10 µL of extract and standards were pipetted in 96 cells of a flat bottom polystyrene microplate Subsequently was added: 140 µL of 1M KCl, 15µL of complexing solution (1a), 60µL of the salicylate-nitroprusside solution (1b), and 30 µL of the buffer solution (1c). Between the additions of each solution, the contents of the well plate were vortexed for 15 seconds on a shaker. After a 30-minute reaction time, the absorbance in each cell was measured on an automated spectrophotometer (Tecan Spark 10M) at a wavelength of 667 nm.

For the determination of $NO_3^- + NO_2$ through a reduction-Greiss reaction (Miranda et al. 2001), we prepared: 2a) a reducing solution by dissolving 1.1200g of vanadium chloride (VCl_3) in 140mL of 1N HCl; 2b) a coupling solution by dissolving 0.0900g of *N*-(1-naphthyl)ethylenediamine dichloride ($C_{10}H_7NHCH_2CH_2NH_2{\cdot}2HCl$) in 90mL of deionized water; and 2c) a sulfanilamide solution by dissolving 1.80g of sulfanilamide ($C_6H_8N_2O_2S$) in 20 mL of hydrochloric acid (HCl) 5% solution (v/v). Again, 10µL of extract and standard sample were pipetted in 96 cells of a flat bottom polystyrene microplate/ Subsequently was added: 90µL of 1M KCl, 100µL of reducing solution (1a), 50µL of the coupling solution (1b), and 50µL of the sulfanilamide solution (1c). The contents of the well plate were vortexed for 15 seconds on a shaker between additions. After 30 minutes of reaction time, the absorbance in each cell was measured on an automated spectrophotometer (Tecan Spark 10M) at a wavelength of 540 nm.

C Amendment Characteristics and MRVs

Table C1. Pearson correlation coefficients for peak microbial biomass and abundance for different OA components. The highest correlation coefficient per MRV is emboldened.

Component			Biom-C (CF)	FB DNA (ddPCR)	F-DNA	B-DNA	F:B	C-min.		N-min			
								Rate	Cumul.	Rate	Cumul.	CUE	qCO_2
Stoichiometr.	C:N	C_{TOT}: N_{TOT}	-0.2	-0.19	-0.22	-0.17	-0.05	-0.19	0.26	-0.18	-0.58*	-0.38	0.15
		C_{IS}:N_{IS}	-0.22	-0.19	-0.25	-0.16	-0.06	-0.22	0.24	-0.21	-0.58*	-0.05	0.13
		C_{AH}:N_{AH}	-0.15	-0.21	-0.15	-0.2	-0.01	-0.11	0.3	-0.11	-0.55*	-0.32	0.18
		C_{HW}: N_{HW}	-0.19	-0.2	-0.19	-0.19	-0.02	-0.19	0.24	-0.16	-0.54*	0.15	0.14
		C_{DO}: N_{DO}	0.21	0.36	0.2	0.35	0.13	0.22	0.63**	0.22	0.05	-0.07	0.3
Energetic	N	N_{TOT}	0.60**	0.49*	0.53*	0.43	0.26	0.59*	0.73***	0.53*	0.84***	-0.33	0.26
		N_{IS}	0.70**	0.60**	0.74***	0.52*	0.36	0.81***	0.76***	0.72***	0.87***	-0.26	0.37
		N_{AH}	0.26	0.19	0.05	0.18	0.02	0.08	0.48*	0.08	0.53*	0.15	0.04
		N_{HW}	0.48*	0.46	0.48*	0.41	0.29	0.4	0.46	0.45	0.88***	0.38	0.14
		N_{DO}	0.66**	0.50*	0.79***	0.41	**0.43**	0.78***	0.56*	0.75***	**0.90*****	-0.07	0.32
	C	C_{TOT}	0.3	0.22	0.21	0.19	0.13	0.32	0.83***	0.25	0.1	-0.44	0.35
		C_{IS}	0.4	0.4	0.36	0.36	0.19	0.47*	**0.85*****	0.39	0.21	-0.44	0.41
		C_{AH}	0.06	-0.15	-0.12	-0.15	-0.02	-0.01	0.62**	-0.06	-0.13	-0.44	0.18
		C_{HW}	0.3	0.25	0.35	0.2	0.3	0.24	0.51*	0.33	0.47	0.32	0.21
		C_{DO}	0.66**	0.58*	**0.81*****	0.50*	**0.43**	0.79***	0.55*	**0.76*****	0.86***	-0.07	0.33
	C_x:C_{TOT}	C_{IS}: C_{TOT}	0.45	0.54*	0.46	0.50*	0.26	0.45	0.72***	0.46	0.50*	0.37	0.33
		C_{AH}: C_{TOT}	0.13	-0.06	-0.05	-0.07	0.02	0.02	0.64**	0	0.09	-0.37	0.16
		C_{HW}: C_{TOT}	0.23	0.3	0.32	0.27	0.29	0.11	0.23	0.28	0.60**	0.41	0.07
		C_{DO}: C_{TOT}	0.56*	0.57*	0.73***	0.49*	0.42	0.62**	0.38	0.66**	0.87***	0.16	0.23
	C_{DO}:C_x	C_{DO}: C_{IS}	0.57*	0.55*	0.72***	0.47*	0.42	0.62**	0.42	0.66**	**0.90*****	0.15	0.24
		C_{DO}: C_{AH}	0.51*	0.57*	0.71***	0.50*	0.41	0.59*	0.29	0.64**	0.82***	0.2	0.21
		C_{DO}: C_{HW}	**0.71****	**0.71*****	0.78***	**0.64****	0.35	**0.86*****	0.70**	**0.76*****	0.81***	-0.35	0.39

D Graphs of the Temporal Response of Investigated Microbial Response Variables

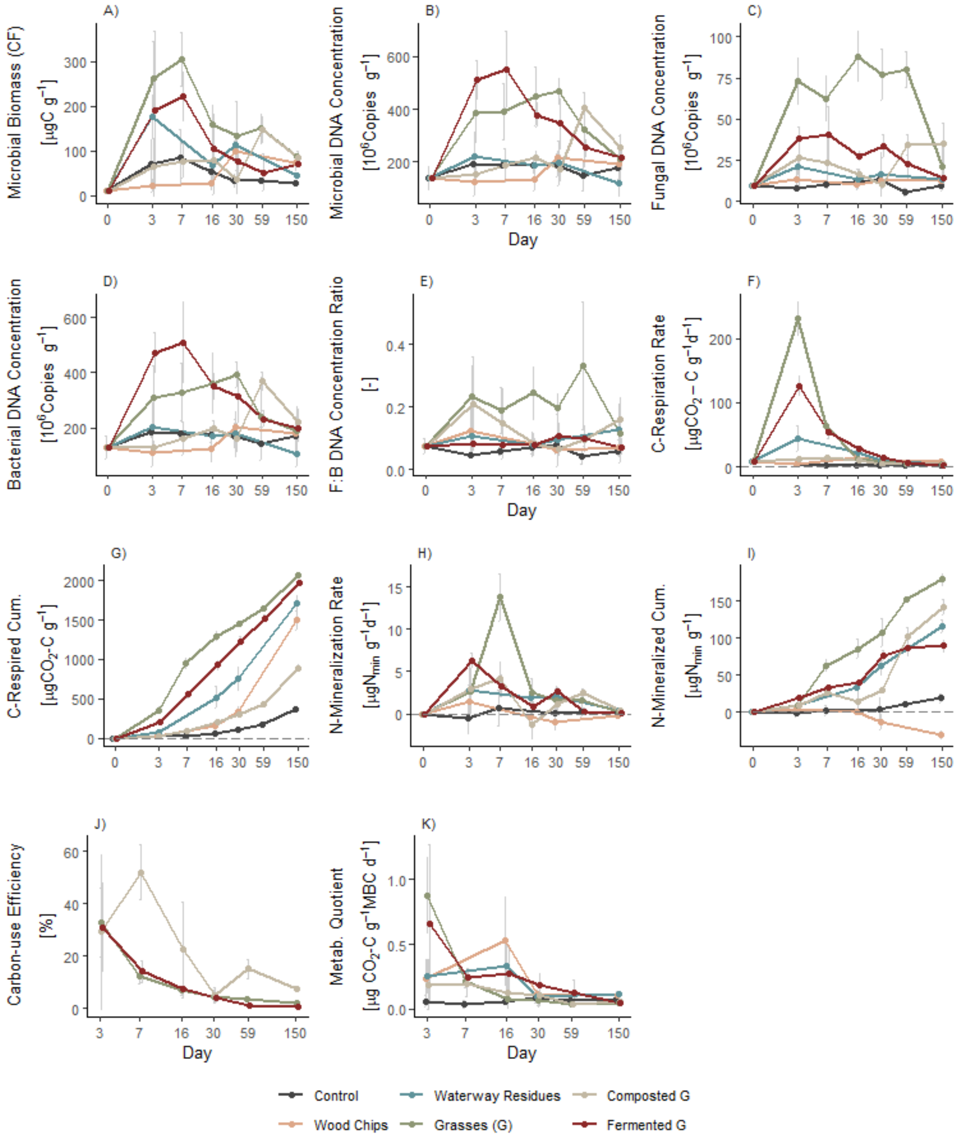

Figure D1. Temporal response of MRVs to OA application. n=3 for each mean data point with standard error as error bars.

E Complete Correlation Matrix for Microbial Response Variables and Priming Effects

Table E1. Pearson correlation matrix for different combinations of MRVs. Correlations based on MRV data from all sampling days.

	Priming Cum.	Priming Rate	Metab. Quot	CUE	N_{min} Cum	N_{min} Rate	CO_2 Cum.	CO_2 Rate	F:B	Biomass CF	F+B DNA	Fungal DNA
Bacterial - DNA	0.01	0.69***	0.41***	0.21	0.25*	-0.03	0.17	0.41***	0.56***	0.70***	0.99***	0.70***
Fungal - DNA	-0.03	0.38**	0.30**	0.21	0.45***	0.11	0.34***	0.41***	0.78***	0.67***	0.78***	
F+B - DNA	0	0.69***	0.40***	0.2	0.29**	0.02	0.21*	0.44***	0.59***	0.72***		
Biomass - CF.	-0.09	0.73***	0.65***	0.51***	0.19	0.07	0.1	0.56***	0.51***			
F:B	0.04	0.2	0.32**	0.38**	0.38***	-0.16	0.24*	0.22*				
CO_2 - Rate	-0.26	0.72***	0.67***	0.39**	-0.17	0.25*	-0.14					
CO_2 - Cum.	0.88***	-0.09	-0.14	-0.52***	0.74***	-0.07						
N_{min} - Rate	-0.31*	0.16	-0.1	-0.07	-0.05							
N_{min} - Cum	0.56***	-0.16	-0.15	-0.35**								
CUE	-0.39**	0.34*	0.65***									
Metab. Quotient	-0.15	0.75***										
Priming - Rate	-0.02											

F Graphs of Notable Relationships Among Microbial Response Variables

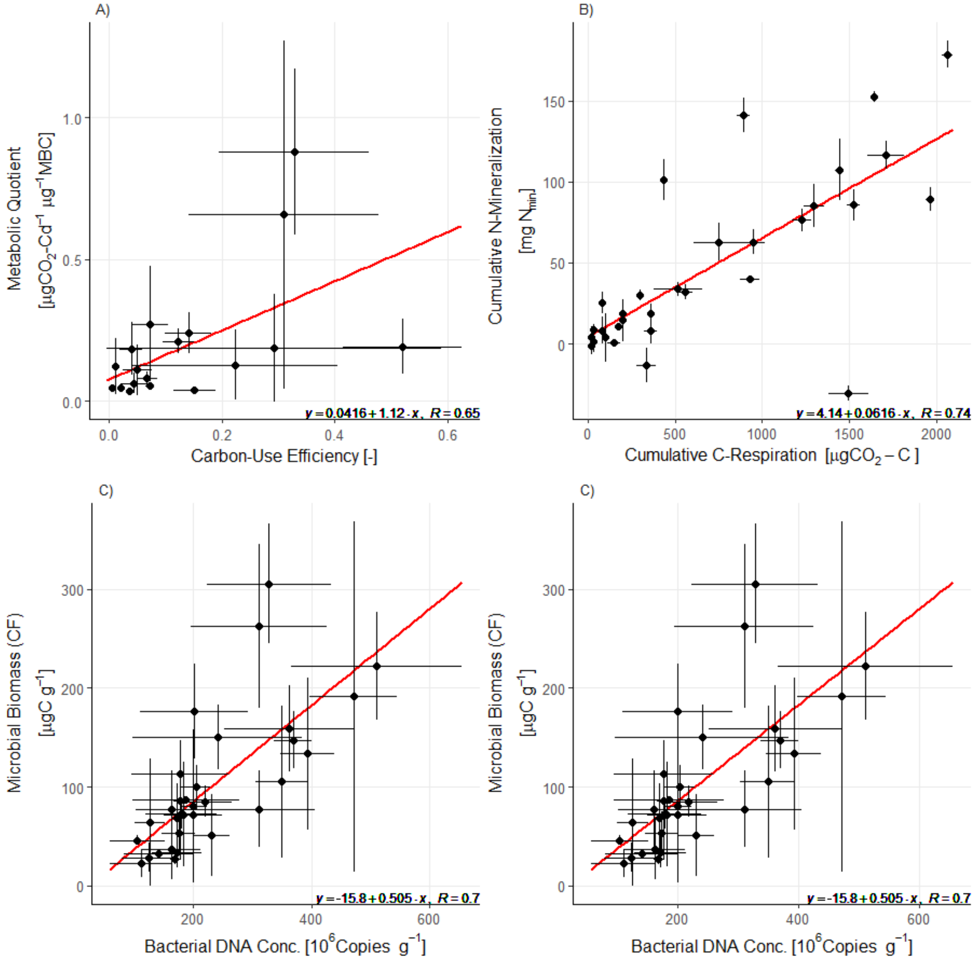

Figure F1. Regression plots for strongest significant correlations amongst MRVs across treatments and sampling days ($R>0.7$, $p<0.001$): CUE versus metabolic quotient (A), Cumulative nitrogen mineralization and carbon respiration (B), bacterial DNA concentrations by ddPCR versus microbial biomass by CF (C), and the sum of fungal and bacterial DNA concentrations by ddPCR versus microbial biomass by CF (D). Excludes relationships amongst MRVs that are mathematically related to each other. n=3 for each mean data point with standard error as error bars.

G Images of plant samples from the roadside mown grasses amendment.


Figure G1. Growing chamber prior to cutting.

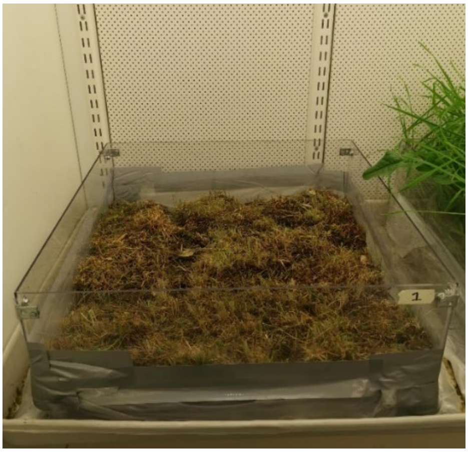
Figure G2. Growing chamber post cutting.


Figure G3. Plant sample 1


Figure G4. Plant sample 2

Figure G5. Plant sample 3

Figure G6. Plant sample 4

Figure G7. Plant sample 5

Figure G8. Plant sample 6

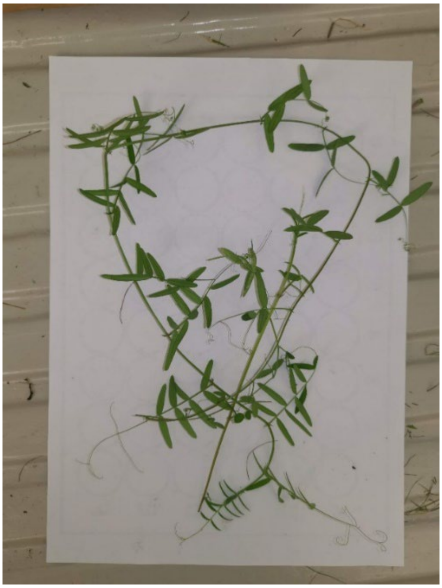

Figure G9. Plant sample 7

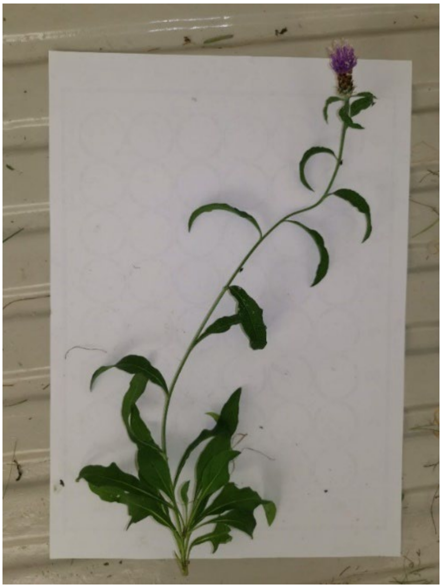

Figure G10. Plant sample 8

H Chemical properties of organic amendments applied.

Table H1. Organic amendment chemical properties as per Kok *et al.* (2022).

Property		**Units**	**Unprocessed Grasses**	**Compost Grasses**	**Bokashi Grasses**
C:N	C_{TOT}: N_{TOT}	[mg mg^{-1}]	11.4 ± 0.7	10.1 ± 0.2	13.3 ± 0.7
	C_{IS}:N_{IS}	[mg mg^{-1}]	11.1 ± 0.9	13.8 ± 1.9	16.8 ± 0.3
	C_{AH}:N_{AH}	[mg mg^{-1}]	12.7 ± 5.7	4.9 ± 1.4	7.8 ± 1.5
	C_{HW}: N_{HW}	[mg mg^{-1}]	9.0 ± 1.1	8.5 ± 0.7	6.9 ± 0.2
	C_{DO}: N_{DO}	[mg mg^{-1}]	7.9 ± 0.7	8.7 ± 0.6	9.7 ± 0.6
N	N_{TOT}	[mg g^{-1}]	32.4 ± 1.5	25.1 ± 0.4	28 ± 1.2
	N_{IS}	[mg g^{-1}]	26.3 ± 1.8	14.7 ± 1.9	17.2 ± 0.2
	N_{AH}	[mg g^{-1}]	6.1 ± 2.3	10.4 ± 2	10.9 ± 1.2
	N_{HW}	[mg g^{-1}]	3.3 ± 0.4	4 ± 0.3	2.5 ± 0
	N_{DO}	[mg g^{-1}]	5.4 ± 0.2	2.9 ± 0.2	1.9 ± 0.1
C	C_{TOT}	[mg g^{-1}]	370.4 ± 14.5	254 ± 3.8	373.2 ± 12.4
	C_{IS}	[mg g^{-1}]	292.7 ± 12.3	203.4 ± 10	288.8 ± 4.5
	C_{AH}	[mg g^{-1}]	77.7 ± 19	50.5 ± 10.7	84.4 ± 13.2
	C_{HW}	[mg g^{-1}]	30.1 ± 1.6	33.5 ± 1.9	16.9 ± 0.3
	C_{DO}	[mg g^{-1}]	42.9 ± 3	25.3 ± 0.7	18 ± 0.7
C_x:C_{TOT}	C_{IS}: C_{TOT}	[µg mg^{-1}]	790.2 ± 45.3	801 ± 41.1	773.8 ± 28.3
	C_{AH}: C_{TOT}	[µg mg^{-1}]	209.8 ± 51.9	199 ± 42.2	226.2 ± 36
	C_{HW}: C_{TOT}	[µg mg^{-1}]	81.1 ± 4.7	131.8 ± 6.8	45.3 ± 1.7
	C_{DO}: C_{TOT}	[µg mg^{-1}]	115.7 ± 9.4	99.4 ± 3.1	48.2 ± 2.4
C_{DO}:C_x	C_{DO}: C_{IS}	[µg mg^{-1}]	146.5 ± 12.1	124.1 ± 7	62.3 ± 2.6
	C_{DO}: C_{AH}	[µg mg^{-1}]	551.5 ± 140.3	499.7 ± 106.6	213 ± 34.2
	C_{DO}: C_{HW}	[mg mg^{-1}]	1426.2 ± 126.2	754.2 ± 47.9	1062.8 ± 44.2

I Outline of the wet-chemical extraction procedure

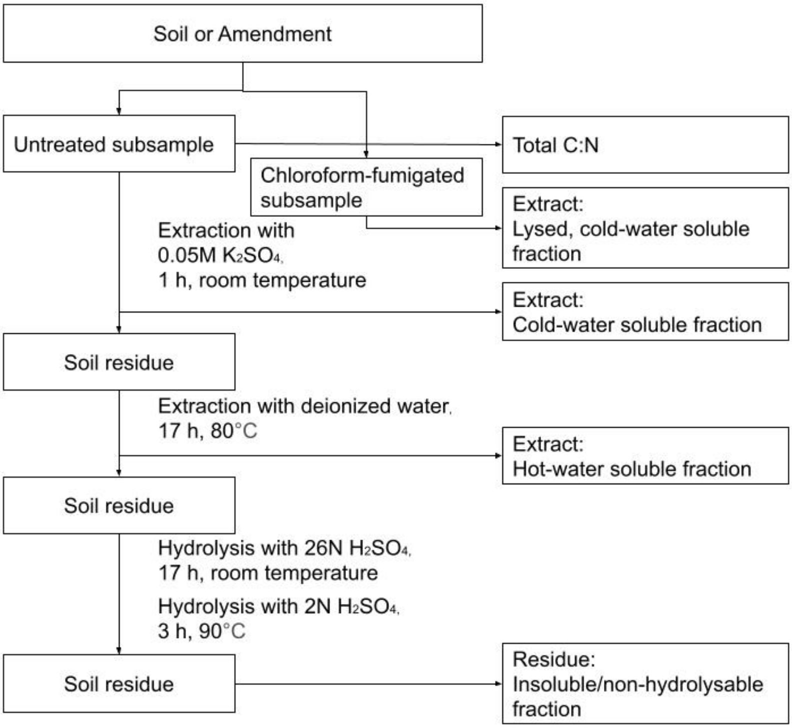

Figure I1. Outline of the wet-chemical extraction procedure.

J Plotted observed means, standard error, and pairwise comparison results for all data.

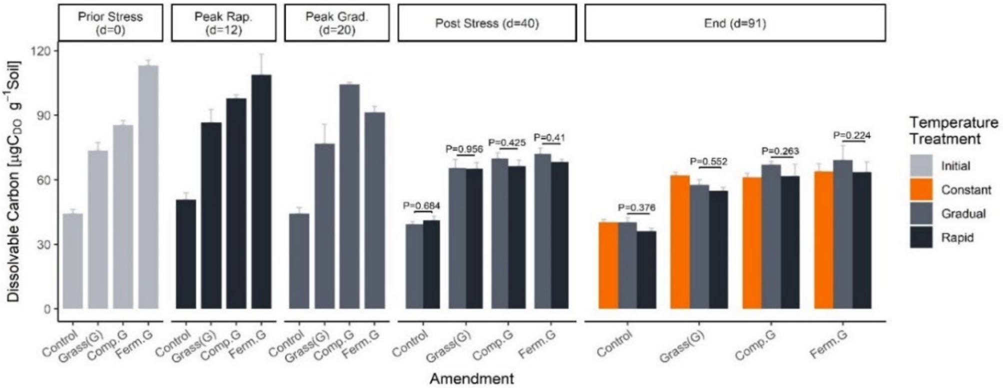

Figure J1. Dissolvable carbon: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

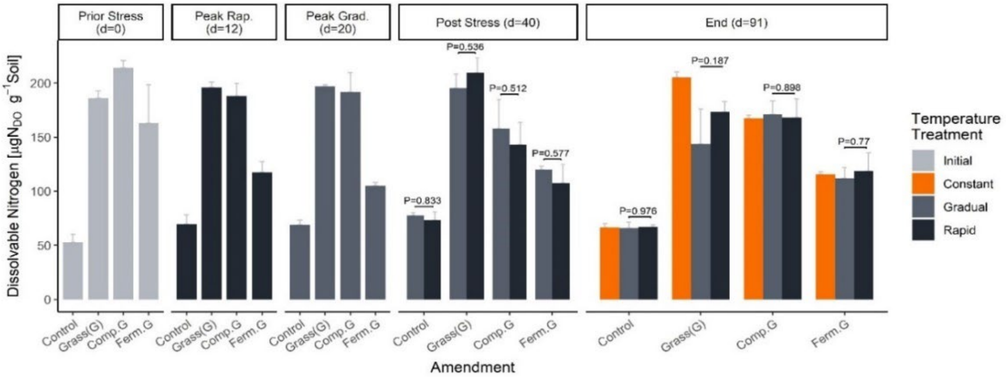

Figure J2. Dissolvable nitrogen: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

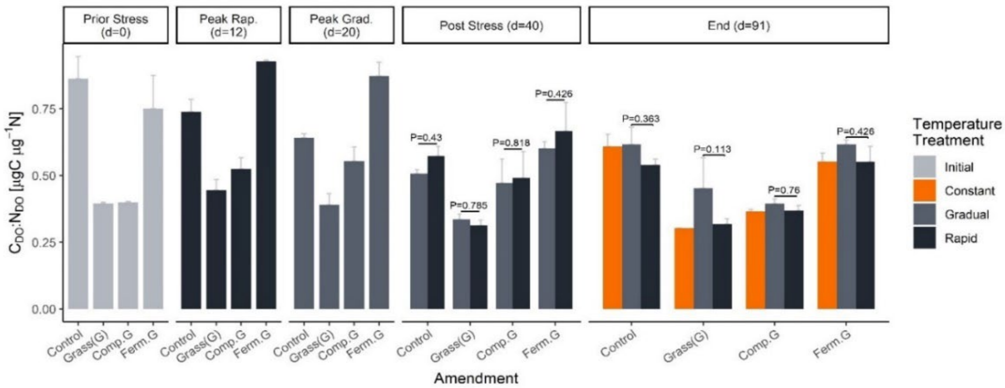

Figure J3. Dissolvable carbon to nitrogen ratio: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

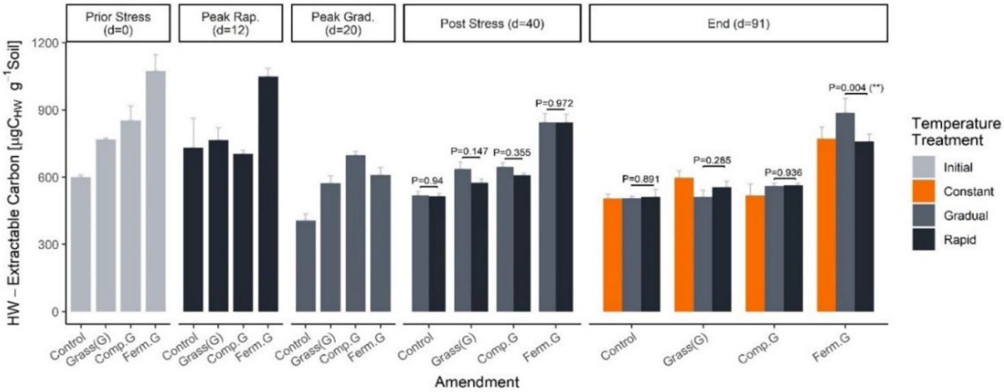

Figure J4. Hot water extractable carbon: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

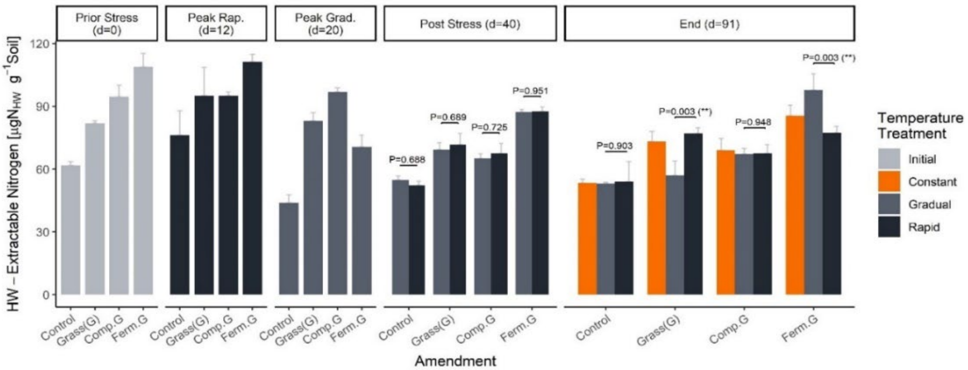

Figure J5. Hot water extractable nitrogen: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

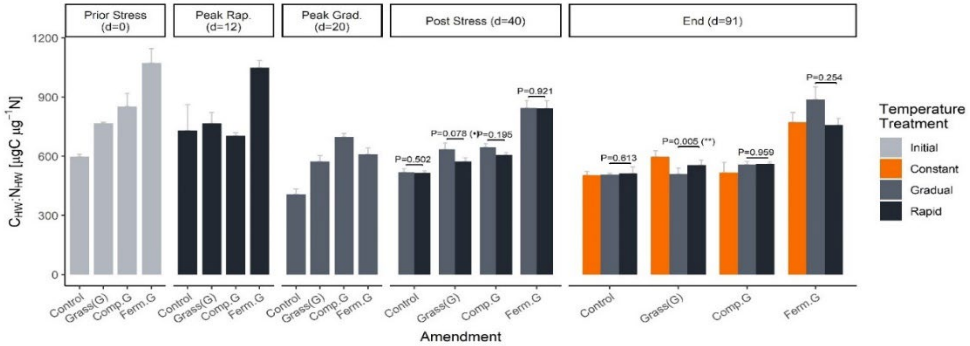

Figure J6. Hot water extractable carbon to nitrogen ratio: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

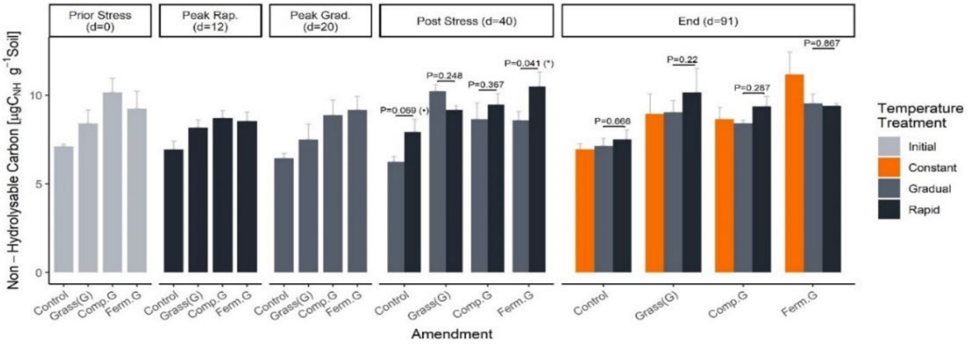

Figure J7. Acid non-hydrolysable carbon: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

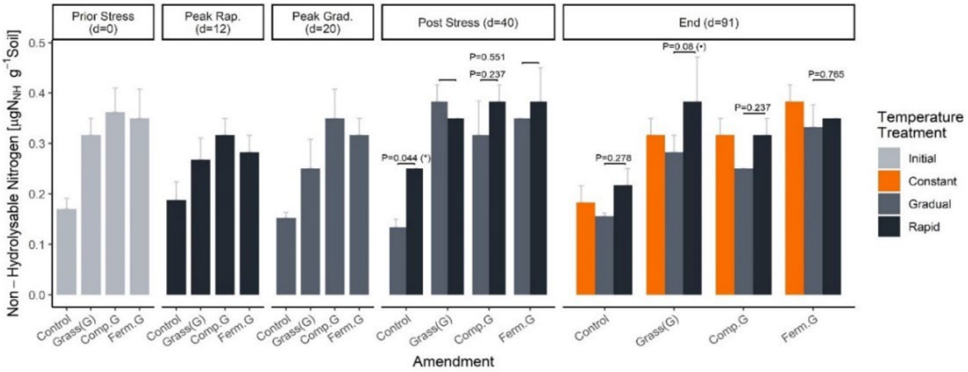

Figure J8. Acid non-hydrolysable nitrogen: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

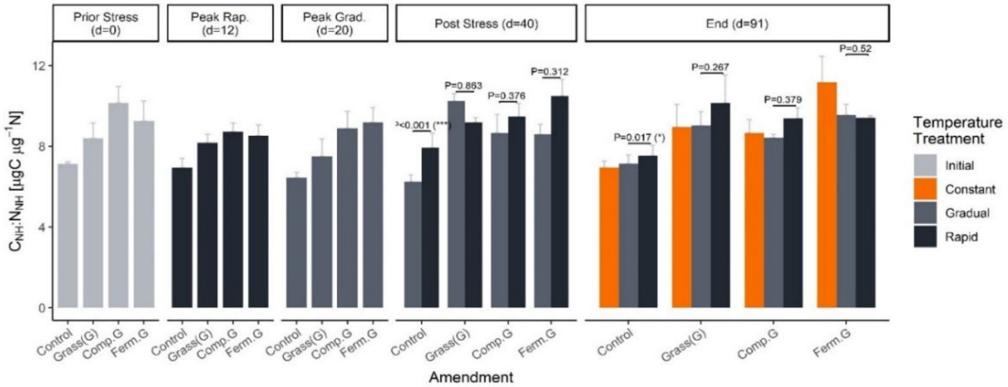

Figure J9. Acid non-hydrolysable carbon to nitrogen ratio: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

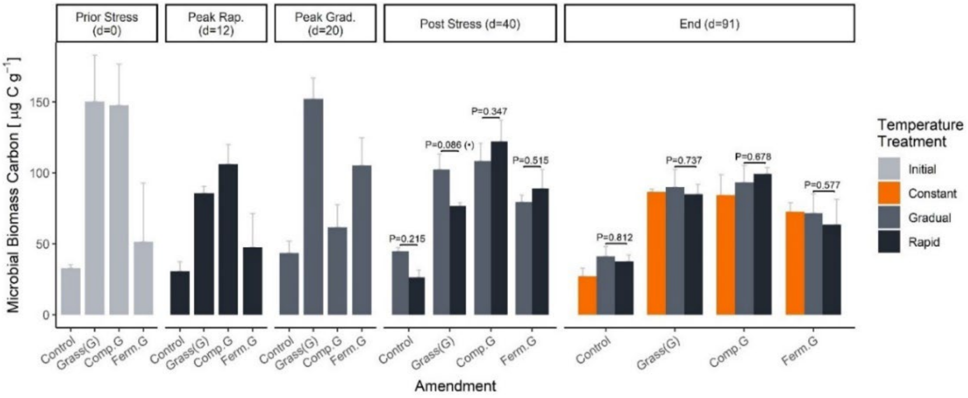

Figure J10. Microbial biomass carbon: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

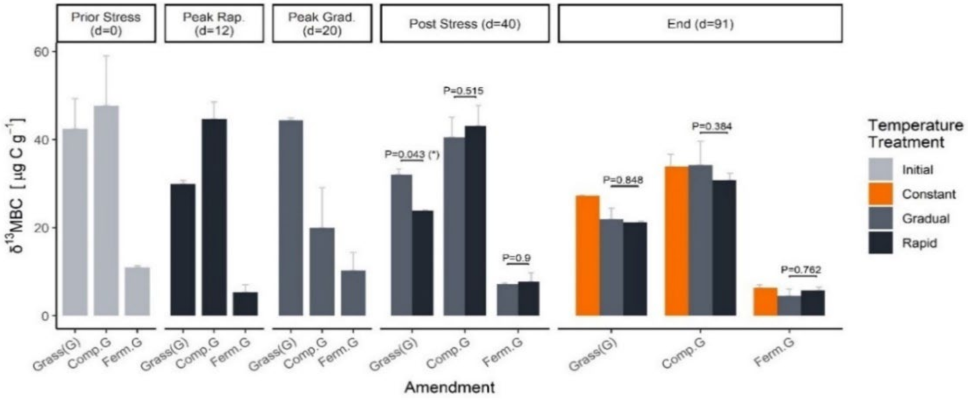

Figure J11. Amendment-derived biomass carbon: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

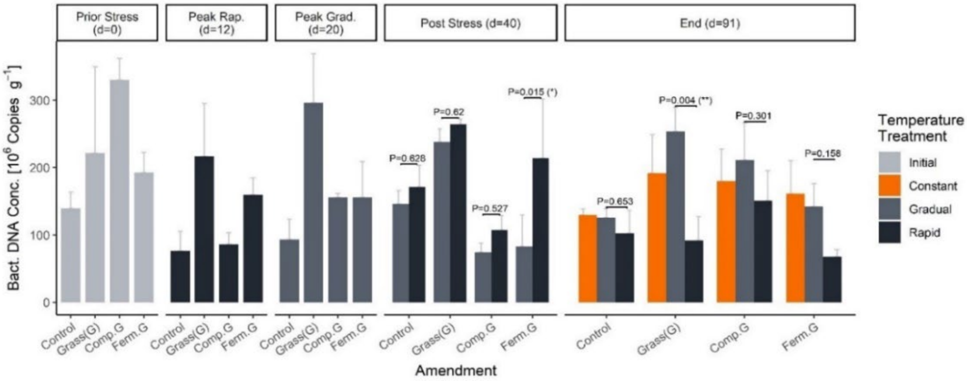

Figure J12. Bacterial DNA concentrations: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

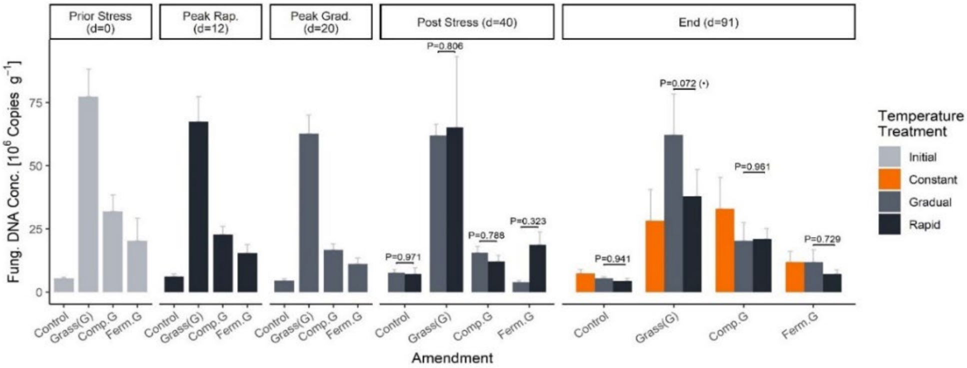

Figure J13. Fungal DNA concentrations: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

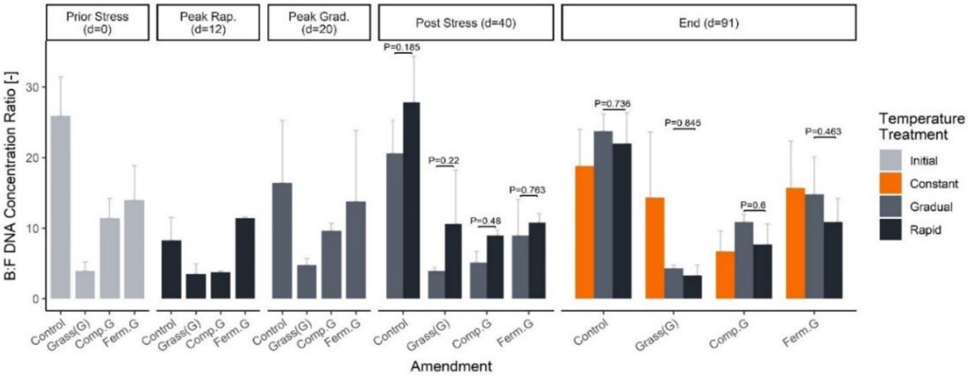

Figure J14. Fungal to bacterial DNA ratio’s: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

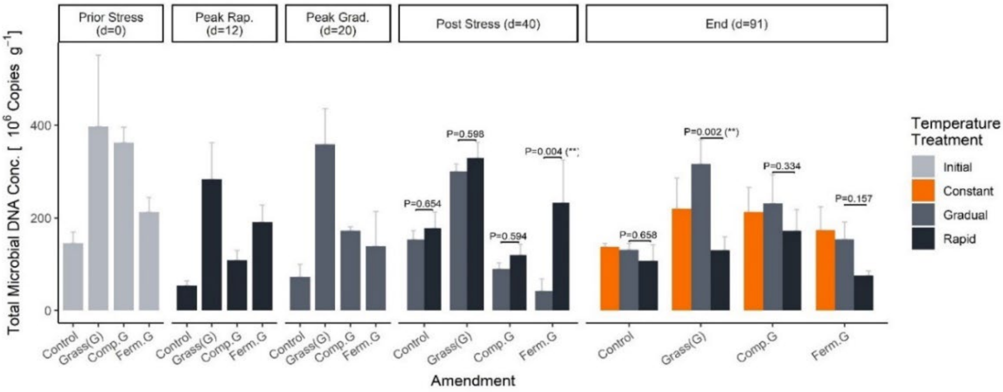

Figure J15. Total microbial DNA concentrations: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

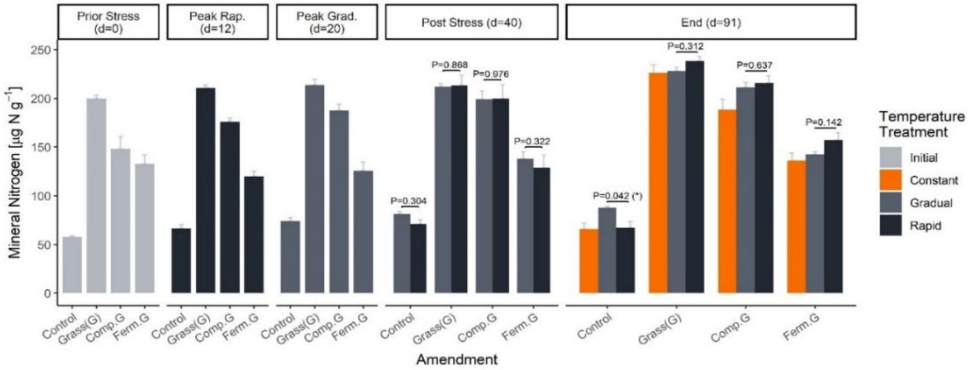

Figure J16. Mineral nitrogen: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

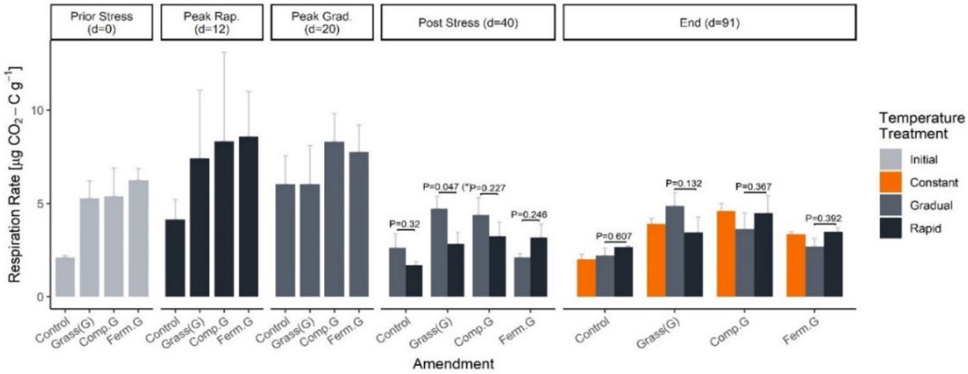

Figure J17. CO_2 respiration rates: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

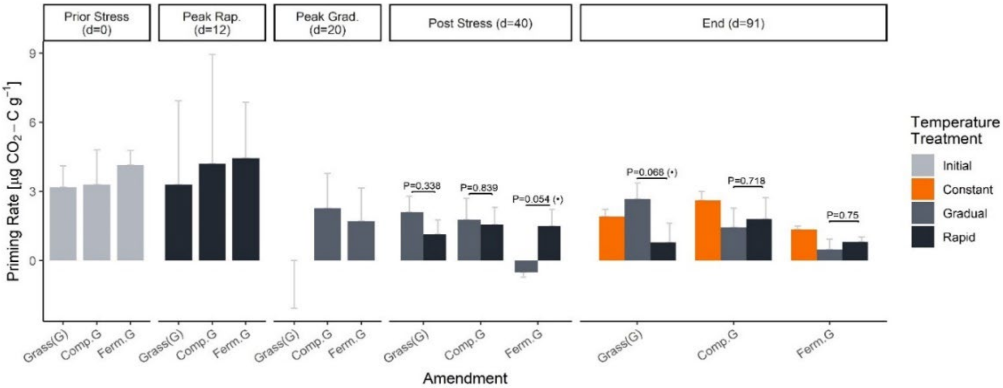

Figure J18. Priming rates: observed means, standard error and Tukey pairwise test results (for pulse temp. treatments only).

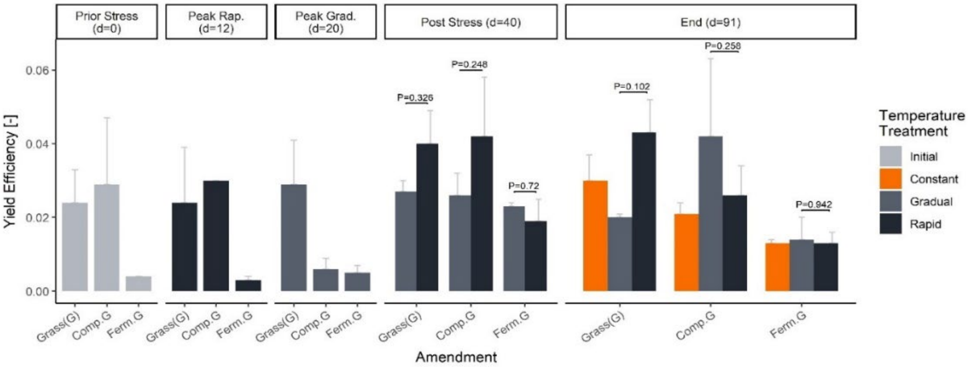

Figure J19. Yield efficiency (amendment derived biomass divided by sum of amendment derived biomass and ^{13}C-respiration rate): observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

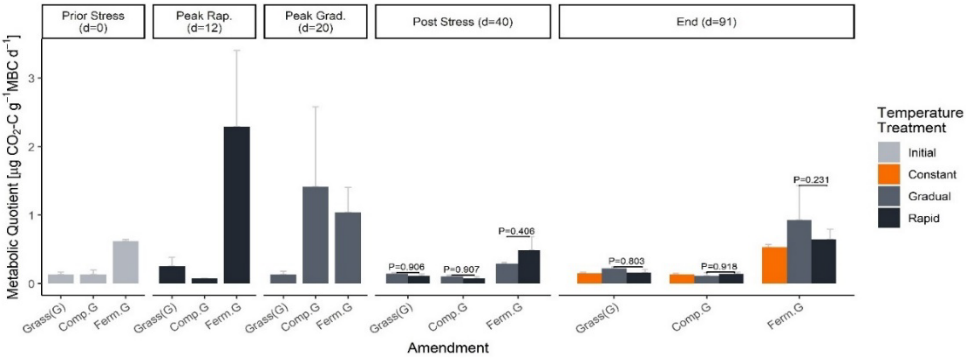

Figure J20. Metabolic quotient: observed means, standard error and Tukey pairwise test results (for pulse temperature treatments only).

K Complete ANOVA summaries per soil and microbial property.

ANOVA III	Dissolvable Organic Carbon					Dissolvable Organic Nitrogen				
	Degr Frd..	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Deg Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A)	3	7369.52	2456.51	84.72	3.92E-17	3	112798	37599	62.04	6.6E-15
Day (S)	1	307.90	307.90	10.62	0.0023	1	356.69	356.69	0.59	0.4476
Temp (T)	2	106.19	53.09	1.83	0.1737	2	803.27	401.64	0.66	0.5212
A:D	3	68.84	22.95	0.79	0.5060	3	4597.93	1532.64	2.53	0.0713
A:T	6	127.53	21.26	0.73	0.6259	6	4328.36	721.39	1.19	0.3317
D:T	1	26.52	26.52	0.91	0.3447	1	508.40	508.40	0.84	0.3654
A:D:T	3	9.56	3.19	0.11	0.9538	3	77.94	25.98	0.04	0.9880
Residuals	39	1130.77	28.99			39	23636.39	606.06		

ANOVA III	Dissolvable Organic Carbon to Nitrogen Ratio					Hot Water Extractable Carbon				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A)	3	0.6284	0.2095	23.6368	6.9E-09	3	838732	279577	93.04	4.E-18
Day (S)	1	0.0058	0.0058	0.6575	0.4224	1	28764.6	28764.6	9.57	0.0036
Temp (T)	2	0.0100	0.0050	0.5620	0.5746	2	6647.0	3323.5	1.11	0.3408
A:D	3	0.0601	0.0200	2.2624	0.0964	3	9449.8	3149.9	1.05	0.3818
A:T	6	0.0241	0.0040	0.4529	0.8385	6	24226.6	4037.8	1.34	0.2609
D:T	1	0.0348	0.0348	3.9224	0.0547	1	154.1	154.1	0.05	0.8220
A:D:T	3	0.0044	0.0015	0.1637	0.9201	3	21737.9	7246.0	2.41	0.0810
Residuals	39	0.3456	0.0089			40	120192	3004.8		

ANOVA III	Hot Water Extractable Nitrogen					Hot Water Extractable Carbon to Nitrogen Ratio				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A)	3	8562.58	2854.19	46.599	4.03E-13	3	17.149	5.716	12.306	7.E-06
Day (S)	1	0.19	0.19	0.003	0.9561	1	4.812	4.812	10.359	0.0026
Temp (T)	2	16.64	8.32	0.136	0.8734	2	2.221	1.110	2.390	0.1046
A:D	3	17.27	5.76	0.094	0.9629	3	3.739	1.246	2.683	0.0595
A:T	6	762.49	127.08	2.075	0.0779	6	7.793	1.299	2.796	0.0229
D:T	1	0.64	0.64	0.010	0.9191	1	0.110	0.110	0.236	0.6297
A:D:T	3	562.97	187.66	3.064	0.0389	3	1.325	0.442	0.951	0.4253
Residuals	40	2450.01	61.25			40	18.580	0.465		

NOVA III	Insoluble Carbon					Insoluble Nitrogen				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A	3	64.581	21.527	14.666	1.37E-06	3	0.2745	0.0915	21.1095	2.E-08
Day (S)	1	0.003	0.003	0.002	0.9657	1	0.0114	0.0114	2.6219	0.1133
Temp (T)	2	6.119	3.060	2.085	0.1377	2	0.0357	0.0179	4.1219	0.0236
A:D	3	1.575	0.525	0.358	0.7839	3	0.0058	0.0019	0.4462	0.7213
A:T	6	8.729	1.455	0.991	0.4444	6	0.0126	0.0021	0.4837	0.8165
D:T	1	0.197	0.197	0.134	0.7159	1	0.0007	0.0007	0.1650	0.6867
A:D:T	3	7.744	2.581	1.759	0.1706	3	0.0151	0.0050	1.1602	0.3369
Residuals	40	58.711	1.468			40	0.1734	0.0043		

ANOVA III	Insoluble Carbon to Nitrogen Ratio					Mineral Nitrogen				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A)	3	1606.073	535.358	23.624	5.81E-09	3	201842	67281	445.59	3.3E-30
Day (S)	1	74.838	74.838	3.302	0.0767	1	998.7	998.7	6.61	0.0140
Temp (T)	2	273.995	136.997	6.045	0.0051	2	1665.3	832.6	5.51	0.0078
A:D	3	19.469	6.490	0.286	0.8349	3	837.2	279.1	1.85	0.1544
A:T	6	344.874	57.479	2.536	0.0356	6	1173.2	195.5	1.30	0.2823
D:T	1	2.777	2.777	0.123	0.7281	1	128.1	128.1	0.85	0.3627
A:D:T	3	70.994	23.665	1.044	0.3835	3	450.5	150.2	0.99	0.4055
Residuals	40	906.460	22.661			39	5888.7	151.0		

ANOVA III	OA-Derived Biomass					Biomass Carbon				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A	2	6949.61	3474.80	172.644	7.8E-17	3	36500	12167	40.155	5.E-12
Day (S)	1	293.58	293.58	14.586	0.0007	1	1473.44	1473.44	4.863	0.0334
Temp (T)	2	50.24	25.12	1.248	0.3020	2	415.55	207.77	0.686	0.5097
A:D	2	86.71	43.36	2.154	0.1342	3	1214.03	404.68	1.336	0.2768
A:T	4	67.22	16.80	0.835	0.5142	6	1606.41	267.74	0.884	0.5160
D:T	1	1.23	1.23	0.061	0.8065	1	19.52	19.52	0.064	0.8009
A:D:T	2	67.85	33.93	1.686	0.2030	3	752.52	250.84	0.828	0.4866
Residuals	29	583.68	20.13			39	11816	303.00		

Section continues…

ANOVA III	DNA-Bacterial					DNA-Fungal				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A	3	57334.3	19111.4	4.259	0.0109	3	17800.3	5933.4	22.737	1.6E-08
Day (S)	1	2626.5	2626.5	0.585	0.4489	1	187.90	187.90	0.720	0.4016
Temp (T)	2	6688.2	3344.1	0.745	0.4814	2	79.87	39.93	0.153	0.8586
A:D	3	48692.7	16230.9	3.617	0.0216	3	1889.46	629.82	2.414	0.0821
A:T	6	17898.1	2983.0	0.665	0.6783	6	1542.48	257.08	0.985	0.4493
D:T	1	53101.9	53101.9	11.834	0.0014	1	340.29	340.29	1.304	0.2608
A:D:T	3	12648.2	4216.1	0.940	0.4311	3	489.99	163.33	0.626	0.6028
Residuals	38	170508.4	4487.1			37	9655.35	260.96		

ANOVA III	DNA-Total Microbial					Bacterial : Fungal DNA Ratio				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A	3	139162	46387.6	8.96	0.0001	3	2235.92	745.31	12.759	7.E-06
Day (S)	1	3500.5	3500.5	0.68	0.4162	1	4.629	4.629	0.079	0.7799
Temp (T)	2	6390.5	3195.3	0.62	0.5449	2	59.310	29.655	0.508	0.6060
A:D	3	67616.1	22539	4.35	0.0101	3	61.867	20.622	0.353	0.7872
A:T	6	25299.1	4216.5	0.81	0.5656	6	266.433	44.406	0.760	0.6057
D:T	1	67378	67377.6	13.02	0.0009	1	156.214	156.214	2.674	0.1105
A:D:T	3	22812	7604.0	1.47	0.2388	3	3.952	1.317	0.023	0.9953
Residuals	37	191540	5176.8			37	2161.372	58.415		

ANOVA III	CO_2 Respiration Rates					Priming Rate				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A)	3	34.002	11.334	10.859	2.37E-05	2	11.188	5.594	4.602	0.0181
Day (S)	1	1.714	1.714	1.642	0.2074	1	0.841	0.841	0.692	0.4121
Temp (T)	2	0.875	0.437	0.419	0.6605	2	2.344	1.172	0.964	0.3928
A:D	3	0.297	0.099	0.095	0.9624	2	0.088	0.044	0.036	0.9647
A:T	6	11.292	1.882	1.803	0.1231	4	10.706	2.676	2.202	0.0927
D:T	1	2.335	2.335	2.238	0.1425	1	1.031	1.031	0.848	0.3644
A:D:T	3	2.201	0.734	0.703	0.5558	2	1.944	0.972	0.799	0.4589
Residuals	40	41.749	1.044			30	36.469	1.216		

ANOVA III	OA Yield Efficiency					Metabolic Quotient				
	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)	Degr. Frd.	Sum Sq.	Mean Sq.	F-value	Pr(>F)
Amend.(A)	2	0.207	0.104	9.507	0.0007	2	1.914	0.957	14.242	4.91E-05
Day (S)	1	0.033	0.033	3.038	0.0919	1	0.197	0.197	2.934	0.0974
Temp (T)	2	0.007	0.003	0.300	0.7432	2	0.062	0.031	0.460	0.6361
A:D	2	0.018	0.009	0.835	0.4442	2	0.180	0.090	1.337	0.2783
A:T	4	0.030	0.007	0.677	0.6136	4	0.080	0.020	0.297	0.8772
D:T	1	0.002	0.002	0.162	0.6907	1	0.053	0.053	0.789	0.3816
A:D:T	2	0.022	0.011	1.000	0.3802	2	0.123	0.062	0.919	0.4104
Residuals	29	0.316	0.011			29	1.949	0.067		

L Means and standard error for soil properties per treatment

Table L1. Means and standard errors for soil properties

Day	Amend.	Temp.	N_{min} [µg mg^{-1}]	C_{do} [µg mg^{-1}]	N_{do} [µg mg^{-1}]	C_{do}:N_{do} [-]	C_{hw} [µg mg^{-1}]
0	Control	Constant	57.8±1	44.1±2	52.6±7.6	0.86±0.08	598.6±10.6
0	Grass(G)	Constant	199.68±3.32	73.6±3.5	186.2±6.3	0.4±0.01	767.4±6.8
0	Comp.G	Constant	148.39±12.46	85.4±2	214.1±6.7	0.4±0.01	851.8±66.8
0	Ferm.G	Constant	132.74±9.42	113.1±2.5	162.7±35.7	0.75±0.13	1072.1±73.3
12	Control	Rapid	66.71±3.84	50.6±3.2	69.5±8.5	0.74±0.05	731.4±131.3
12	Grass(G)	Rapid	210.78±2.86	86.6±6	196±4.8	0.44±0.04	766.2±54.7
12	Comp.G	Rapid	176.19±3.79	97.8±1.7	188±11.6	0.52±0.04	702.5±17
12	Ferm.G	Rapid	120.24±4.94	108.9±9.4	117.3±10.3	0.93±0.01	1049.7±34.8
20	Control	Gradual	73.94±3.72	44.3±2.7	69±4.1	0.64±0.01	406.3±29.5
20	Grass(G)	Gradual	213.7±5.82	76.8±9	196.9±1.5	0.39±0.04	572.6±32.1
20	Comp.G	Gradual	187.68±6.61	104.2±1.1	191.7±18	0.55±0.05	696.4±18.4
20	Ferm.G	Gradual	125.54±9.43	91.2±2.9	104.8±3.1	0.87±0.05	609.7±33.8
40	Control	Gradual	81.23±2.73	39.4±1.1	77.7±2.2	0.51±0.01	518.7±18.6
40	Control	Rapid	71.2±4.17	41.2±1.9	73±8.0	0.57±0.04	515.6±11.2
40	Grass(G)	Gradual	212.02±3.21	65.5±4	195.5±12.9	0.34±0.02	635.2±33.2
40	Grass(G)	Rapid	213.63±9.91	65.2±2.7	209.3±13.7	0.31±0.02	574.3±16.8
40	Comp.G	Gradual	199.27±8.45	69.9±2.5	157.8±26.9	0.47±0.09	646.7±16.1
40	Comp.G	Rapid	199.59±14.64	66.2±2.9	143.1±20.6	0.49±0.1	608.2±10.9
40	Ferm.G	Gradual	138.34±6.69	72±2.8	120±3.3	0.6±0.03	844.8±38.4
40	Ferm.G	Rapid	128.7±13.24	68.1±1.2	107.5±17.1	0.67±0.11	843.3±38.5
91	Control	Constant	66.03±5.87	40.2±1.3	66.6±3.6	0.61±0.05	504.3±19.1
91	Control	Gradual	87.67±1.6	40.1±2.1	66±5.2	0.62±0.06	506.6±7.7
91	Control	Rapid	67.3±6.5	36±1.3	66.7±1.9	0.54±0.02	512.3±32.5
91	Grass(G)	Constant	226.35±7.96	62±1.7	205±5.2	0.3±0.01	597±31.5
91	Grass(G)	Gradual	228.4±3.73	57.5±2.5	143.4±32.6	0.45±0.11	511.1±29.5
91	Grass(G)	Rapid	238.25±4.53	54.7±1.8	173.2±9.7	0.32±0.02	555.7±25.4
91	Comp.G	Constant	188.55±10.74	61.1±1.9	167.4±2.6	0.36±0.01	517.9±51.2
91	Comp.G	Gradual	211.45±4.78	66.9±1.6	170.9±12.4	0.39±0.02	559.2±14
91	Comp.G	Rapid	216.03±7.28	61.7±5.5	168.1±17.3	0.37±0.02	562.5±9.8
91	Ferm.G	Constant	136.28±7.41	63.7±3.7	115.7±2.3	0.55±0.03	771.8±51
91	Ferm.G	Gradual	142.82±2.37	69.1±6.7	111.9±10.2	0.62±0.02	887±65.2
91	Ferm.G	Rapid	157.26±7.51	63.4±4.8	118.4±17	0.55±0.06	758.1±33.1

Table L1 (*continued).* Means and standard errors for soil properties

Day	**Amend.**	**Temp.**	**N_{hw}** [µg mg^{-1}]	**C_{hw}:N_{hw}** [-]	**C_i** [µg mg^{-1}]	**N_i** [µg mg^{-1}]	**C_i:N_i** [-]
0	Control	Constant	61.9±1.6	9.68±0.09	7.12±0.12	0.17±0.02	43.02±4.87
0	Grass(G)	Constant	81.9±1.2	9.38±0.21	8.4±0.76	0.32±0.03	26.63±0.59
0	Comp.G	Constant	94.6±5.4	9±0.35	10.15±0.81	0.36±0.05	28.6±2.47
0	Ferm.G	Constant	108.9±6.3	9.83±0.22	9.25±0.98	0.35±0.06	27.06±2.17
12	Control	Rapid	76.3±11.7	9.52±0.23	6.95±0.46	0.19±0.04	39±5.86
12	Grass(G)	Rapid	95±13.7	8.24±0.6	8.17±0.43	0.27±0.04	31.51±3.42
12	Comp.G	Rapid	95.1±1.8	7.38±0.04	8.72±0.42	0.32±0.03	28.05±2.67
12	Ferm.G	Rapid	111.2±3.7	9.44±0.07	8.53±0.51	0.28±0.03	30.5±1.63
20	Control	Gradual	43.9±3.8	9.27±0.13	6.45±0.26	0.15±0.01	42.67±1.39
20	Grass(G)	Gradual	83±4.0	6.9±0.07	7.5±0.87	0.25±0.06	32.02±4.71
20	Comp.G	Gradual	96.9±2	7.19±0.18	8.88±0.84	0.35±0.06	26.05±2.12
20	Ferm.G	Gradual	70.6±5.5	8.66±0.2	9.18±0.74	0.32±0.03	29.38±2.45
40	Control	Gradual	54.8±2.1	9.47±0.02	6.24±0.32	0.13±0.02	47.94±6.3
40	Control	Rapid	52.2±2.0	9.89±0.22	7.92±0.73	0.25±0.01	31.67±2.92
40	Grass(G)	Gradual	69.2±3.4	9.18±0.24	10.23±0.37	0.38±0.03	26.92±1.32
40	Grass(G)	Rapid	71.8±5.2	8.05±0.39	9.18±0.23	0.35±0.01	26.24±0.67
40	Comp.G	Gradual	65.2±2.2	9.93±0.09	8.65±0.92	0.32±0.07	28.41±2.68
40	Comp.G	Rapid	67.4±4.9	9.11±0.65	9.47±0.63	0.38±0.03	24.9±1.92
40	Ferm.G	Gradual	87.2±1.2	9.69±0.46	8.58±0.49	0.35±0.01	24.52±1.40
40	Ferm.G	Rapid	87.6±2.1	9.63±0.4	10.48±0.82	0.38±0.07	28.54±3.44
91	Control	Constant	53.3±2.0	9.46±0.1	6.95±0.32	0.18±0.03	39.71±5.14
91	Control	Gradual	53.2±0.6	9.53±0.06	7.13±0.44	0.16±0.01	45.73±1.21
91	Control	Rapid	54±9.5	9.84±1.0	7.52±0.52	0.22±0.03	35.89±3.97
91	Grass(G)	Constant	73.1±5	8.18±0.13	8.95±1.12	0.32±0.03	28.14±0.87
91	Grass(G)	Gradual	57±6.8	9.09±0.53	9.03±0.67	0.28±0.03	32.19±1.41
91	Grass(G)	Rapid	77±2.8	7.21±0.07	10.15±1.36	0.38±0.09	27.77±3.12
91	Comp.G	Constant	68.9±5.8	7.5±0.12	8.65±0.67	0.32±0.03	27.51±1.03
91	Comp.G	Gradual	67.1±2.7	8.38±0.54	8.42±0.18	0.25±0.01	33.67±0.71
91	Comp.G	Rapid	67.5±4.1	8.41±0.62	9.38±0.53	0.32±0.03	30.18±2.92
91	Ferm.G	Constant	85.5±5.0	9.02±0.09	11.17±1.27	0.38±0.03	29±0.76
91	Ferm.G	Gradual	97.8±7.8	9.08±0.06	9.55±0.51	0.33±0.04	29.4±3.00
91	Ferm.G	Rapid	77.4±3.1	9.8±0.10	9.4±0.13	0.35±0.01	26.86±0.36

Table L2. Means and standard errors for microbial properties

Day	Amend.	Temp.	DNA-total.	DNA-Fung.	DNA-Bact.	DNA B:F
				[10^6 copies g^{-1}]		[-]
0	Control	Constant	145.2±23.5	5.49±0.37	139.69±23.58	25.9±5.53
0	Grass(G)	Constant	397±154.4	77.4±10.8	221.1±128.76	3.95±1.3
0	Comp.G	Constant	362.2±33.9	31.95±6.41	330.22±31.9	11.39±2.85
0	Ferm.G	Constant	212.6±31.6	20.25±9.06	192.32±30.34	13.93±4.96
12	Control	Rapid	53.7±10.7	6.15±1	76.15±29.39	8.26±3.25
12	Grass(G)	Rapid	283.7±78.4	67.39±10.04	216.3±78.99	3.47±1.43
12	Comp.G	Rapid	108.7±20.7	22.76±3.31	85.94±17.37	3.72±0.2
12	Ferm.G	Rapid	190.9±36.6	15.48±3.27	159.48±24.98	11.38±0.24
20	Control	Gradual	72.3±27	4.53±0.75	93.15±30.07	16.4±8.84
20	Grass(G)	Gradual	359±76.6	62.76±7.29	296.21±72.97	4.74±0.95
20	Comp.G	Gradual	172.7±7.3	16.7±2.35	155.97±5.51	9.62±1.03
20	Ferm.G	Gradual	138.6±74.9	11.05±2.44	155.8±52.84	13.77±10.05
40	Control	Gradual	153.6±19.2	7.6±1.25	145.97±19.89	20.57±4.65
40	Control	Rapid	178.2±34.5	7.13±2.5	171.04±32.14	27.78±6.53
40	Grass(G)	Gradual	300.3±15.7	62.05±4.36	238.26±19.04	3.91±0.52
40	Grass(G)	Rapid	329.3±33.9	65.29±27.86	263.98±8.02	10.57±7.68
40	Comp.G	Gradual	90±12.6	15.66±2.49	74.34±13.26	5.11±1.54
40	Comp.G	Rapid	119.3±23.4	12.11±2.36	107.17±21.31	8.92±0.79
40	Ferm.G	Gradual	42.4±26	3.98±0.56	82.62±46.61	8.93±5.14
40	Ferm.G	Rapid	233±92.3	18.66±5.15	214.32±87.17	10.74±1.34
91	Control	Constant	137.2±7.2	7.35±1.57	129.8±8.79	18.78±5.21
91	Control	Gradual	131±13.8	5.35±0.65	125.66±13.39	23.75±2.41
91	Control	Rapid	106.7±35.5	4.38±1.06	102.36±34.46	21.95±4.37
91	Grass(G)	Constant	219.6±66.5	28.16±12.43	191.4±57.78	14.32±9.26
91	Grass(G)	Gradual	316±51.8	62.18±16.21	253.78±35.58	4.32±0.46
91	Grass(G)	Rapid	129.8±28.7	37.84±10.73	91.92±35.18	3.27±1.5
91	Comp.G	Constant	212.9±52.6	32.96±12.45	179.91±47.33	6.7±2.88
91	Comp.G	Gradual	231.6±62.4	20.27±7.21	211.29±55.15	10.83±1.13
91	Comp.G	Rapid	171.9±45.7	21±4.15	150.95±44.6	7.68±2.89
91	Ferm.G	Constant	172.9±50.7	11.88±4.16	161.01±49.29	15.67±6.68
91	Ferm.G	Gradual	154.1±36.1	11.8±4.87	142.29±33.78	14.8±5.28
91	Ferm.G	Rapid	75.2±9.6	7.22±1.55	68±10.59	10.84±3.35

Table L2 (*continued)*. Means and standard errors for microbial properties

Day	**Amend.**	**Temp.**	**Biomass-C** **[μg mg^{-1}]**	**CO_2-Rate** **[μg g^{-1} d^{-1}]**	**δ^{13}MBC** **[μg mg^{-1}]**	**Priming-R** **[μg g^{-1} d^{-1}]**	**Quotient** **[μg g^{-1}MBC d^{-1}]**
0	Control	Constant	32.7±2.46	2.09±0.12	-	-	-
0	Grass(G)	Constant	150.14±32.55	5.28±0.93	42.42±6.85	3.18±0.93	0.13±0.03
0	Comp.G	Constant	147.54±29.08	5.38±1.53	47.66±11.36	3.28±1.53	0.13±0.06
0	Ferm.G	Constant	51.52±41.43	6.24±0.64	10.95±0.42	4.14±0.64	0.62±0.03
12	Control	Rapid	30.65±6.64	4.13±1.1	-	-	-
12	Grass(G)	Rapid	85.7±4.62	7.41±3.65	29.98±0.73	3.29±3.65	0.25±0.13
12	Comp.G	Rapid	106.24±13.52	8.33±4.75	44.63±3.88	4.2±4.75	0.07±0
12	Ferm.G	Rapid	47.44±24.02	8.57±2.41	5.31±1.77	4.45±2.41	2.29±1.11
20	Control	Gradual	43.53±8.35	6.04±1.52	-	-	-
20	Grass(G)	Gradual	152.15±14.65	6.03±2.08	44.37±0.58	-0.01±2.08	0.14±0.05
20	Comp.G	Gradual	61.54±15.99	8.3±1.50	19.95±9.16	2.26±1.5	1.42±1.17
20	Ferm.G	Gradual	105.25±19.37	7.76±1.43	10.32±4.06	1.72±1.43	1.04±0.36
40	Control	Gradual	44.7±2.54	2.61±0.78	-	-	-
40	Control	Rapid	26.33±5.15	1.69±0.17	-	-	-
40	Grass(G)	Gradual	102.25±11.16	4.71±0.68	32.08±1.19	2.1±0.68	0.15±0.02
40	Grass(G)	Rapid	76.53±2.46	2.83±0.61	23.85±0.16	1.14±0.61	0.12±0.03
40	Comp.G	Gradual	108.28±12.57	4.37±0.94	40.52±4.57	1.76±0.94	0.11±0.02
40	Comp.G	Rapid	122.12±14.91	3.25±0.74	43.06±4.64	1.56±0.74	0.08±0.02
40	Ferm.G	Gradual	79.33±4.88	2.1±0.21	7.25±0.28	-0.5±0.21	0.29±0.02
40	Ferm.G	Rapid	88.89±13.6	3.18±0.72	7.74±2.02	1.49±0.72	0.49±0.2
91	Control	Constant	26.98±5.73	1.99±0.28	-	-	-
91	Control	Gradual	41.06±7.06	2.2±0.40	-	-	-
91	Control	Rapid	37.58±4.45	2.67±0.07	-	-	-
91	Grass(G)	Constant	86.53±1.95	3.89±0.31	27.24±0.2	1.9±0.31	0.15±0.02
91	Grass(G)	Gradual	89.9±12.52	4.86±0.71	21.95±2.45	2.66±0.71	0.22±0.02
91	Grass(G)	Rapid	84.99±6.97	3.46±0.82	21.2±0.26	0.79±0.82	0.16±0.04
91	Comp.G	Constant	84.36±14.43	4.6±0.39	33.86±2.82	2.61±0.39	0.14±0.01
91	Comp.G	Gradual	93.14±12.01	3.64±0.84	34.2±5.39	1.44±0.84	0.12±0.04
91	Comp.G	Rapid	99.23±4.45	4.47±0.93	30.78±1.6	1.8±0.93	0.14±0.03
91	Ferm.G	Constant	72.59±6.39	3.33±0.16	6.37±0.69	1.34±0.16	0.53±0.04
91	Ferm.G	Gradual	71.63±13.4	2.68±0.44	4.56±1.57	0.48±0.44	0.93±0.5
91	Ferm.G	Rapid	63.45±17.75	3.47±0.22	5.74±0.82	0.8±0.22	0.65±0.15

M MiPrime Parameter trace and histograms

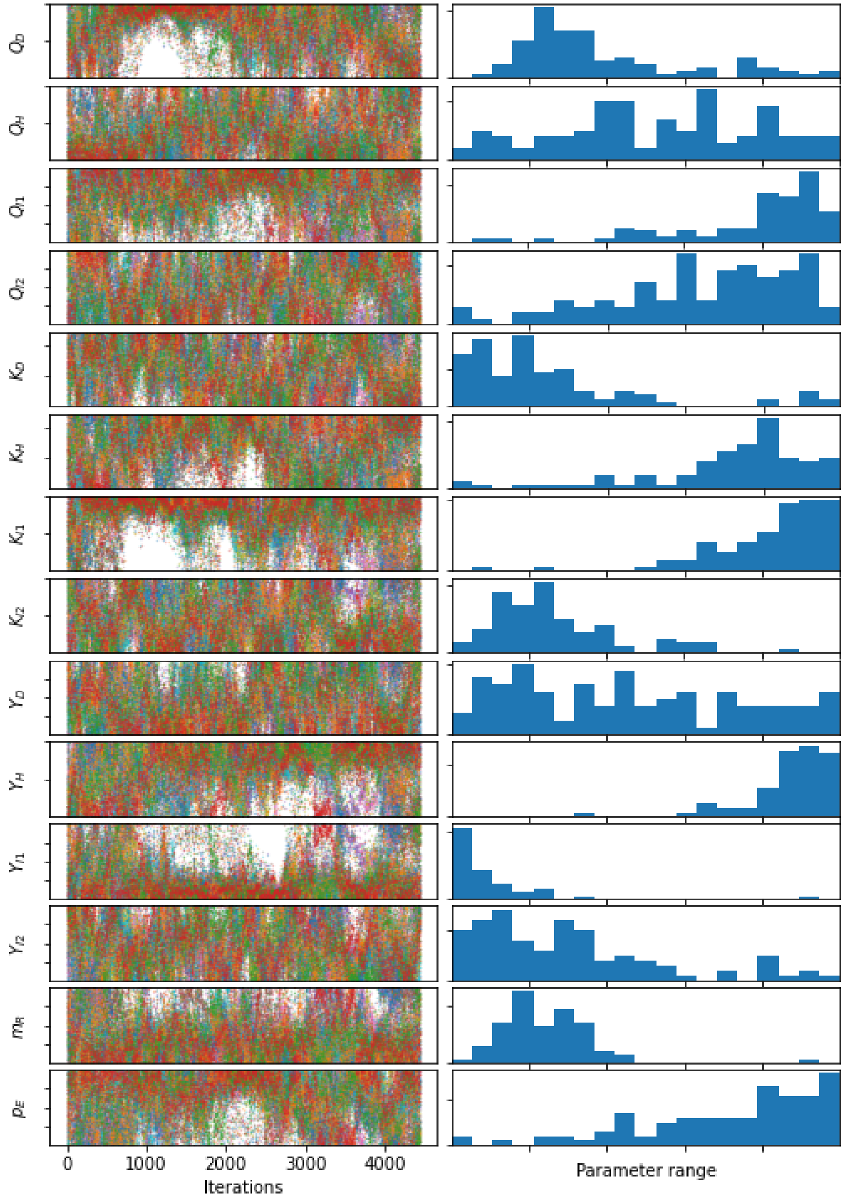

Figure M1. Parameter trace of all samples and histogram of parameter values with the top 10% highest likelihood of the last 1000 samples post-convergence. Figure continues below.

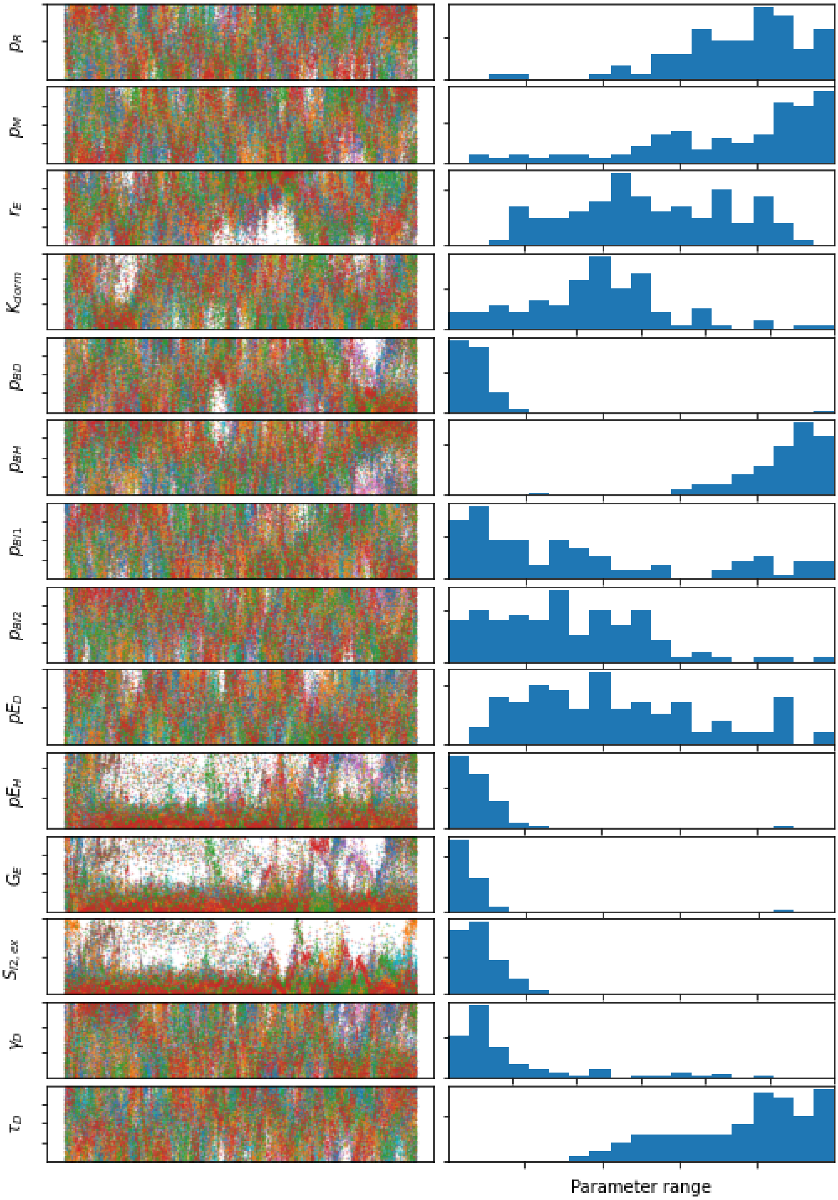

Figure M1 (continued). Parameter trace of all samples and histogram of parameter values with the top 10% highest likelihood of the last 1000 samples post-convergence.

N Observed and predicted concentrations in from EN and EX pools.

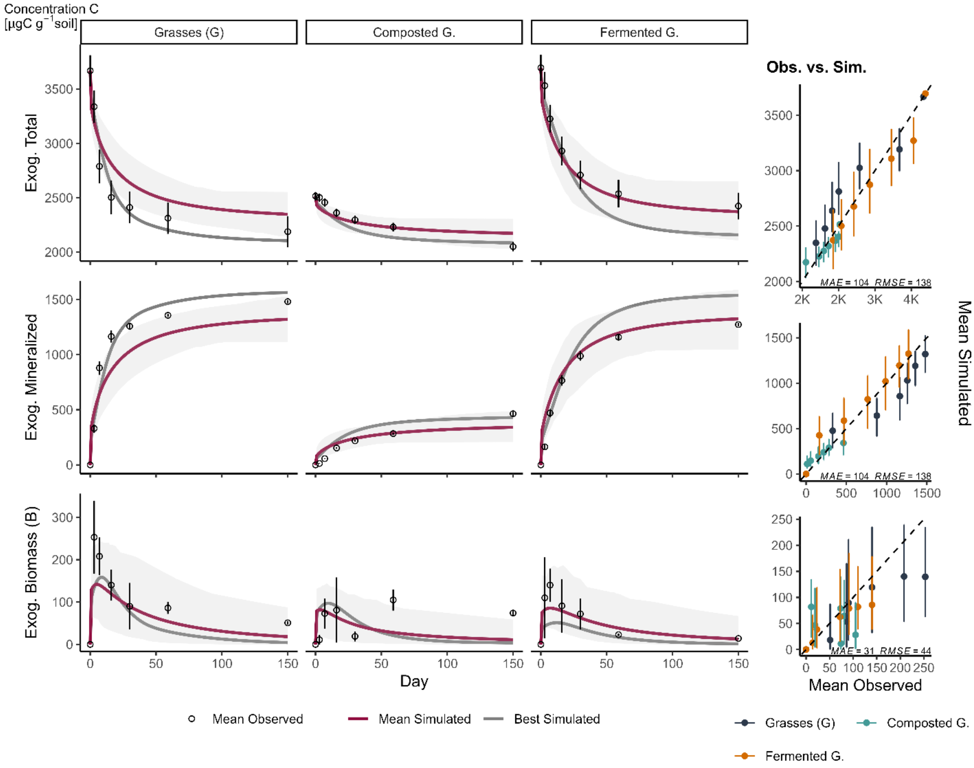

Figure N1. Model simulation and observed data for total, mineralized, microbial biomass and primed exogenous carbon concentrations after amending a podzol with grasses, composted grasses, fermented grasses and no organic amendment (control). The shaded area denotes the 5% and 95%quantiles. The dashed line in observed vs. simulated plots is the line of perfect fit (1:1 match of observed to simulated data)

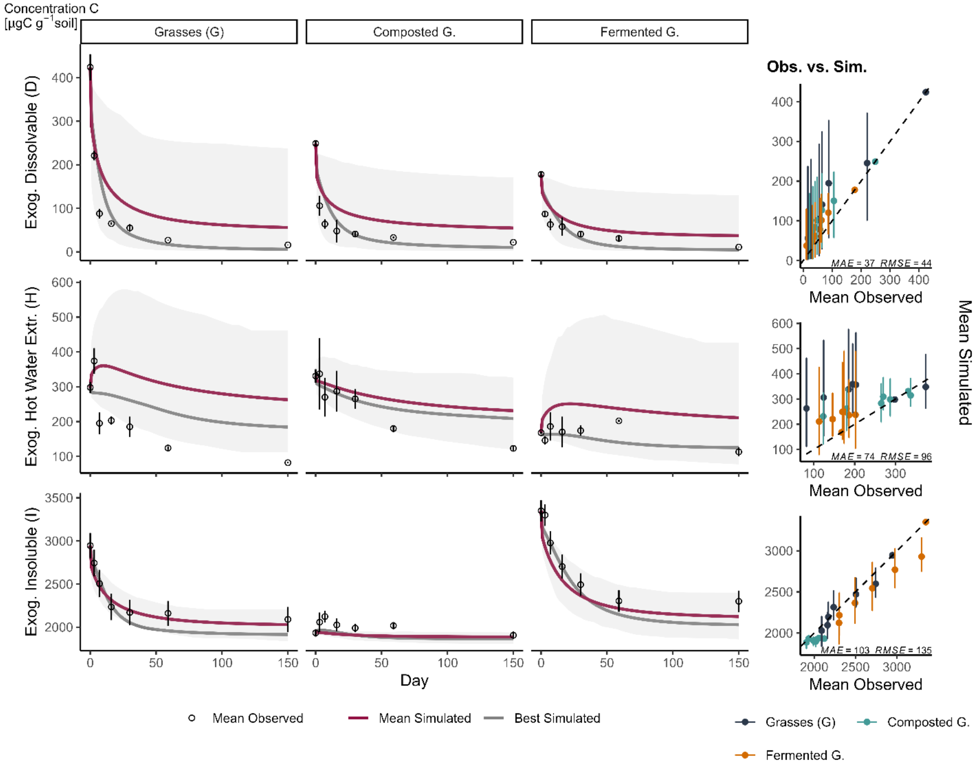

Figure N2. Model simulation and observed data for Dissolvable (D), hot water extractable (H) and Insoluble (I) exogenous carbon concentrations after amending a podzol with grasses, composted grasses, fermented grasses and no organic amendment (control). The shaded area denotes the 5% and 95% quantiles. The dashed line in observed vs. mean simulated plots is the line of perfect fit (1:1 match of observed to simulated data).

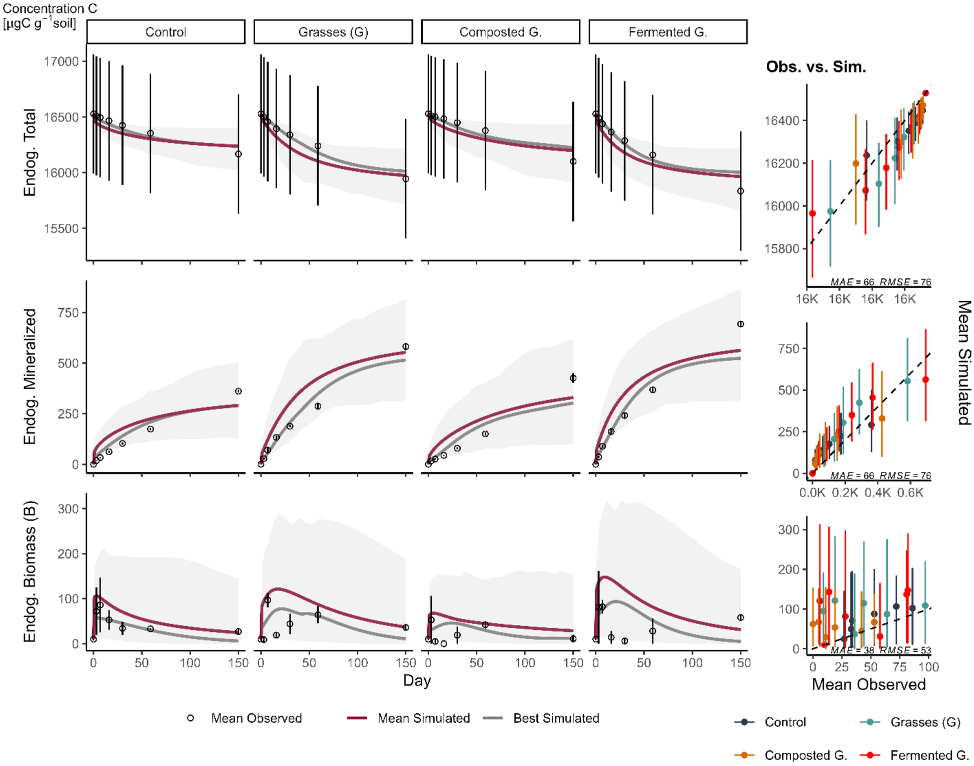

Figure N3. Model simulation and observed data for total, mineralized, microbial biomass and primed endogenous carbon concentrations after amending a podzol with grasses, composted grasses, fermented grasses and no organic amendment (control). The shaded area denotes the 5% and 95% quantiles. The dashed line in observed vs. simulated plots is the line of perfect fit (1:1 match of observed to simulated data).

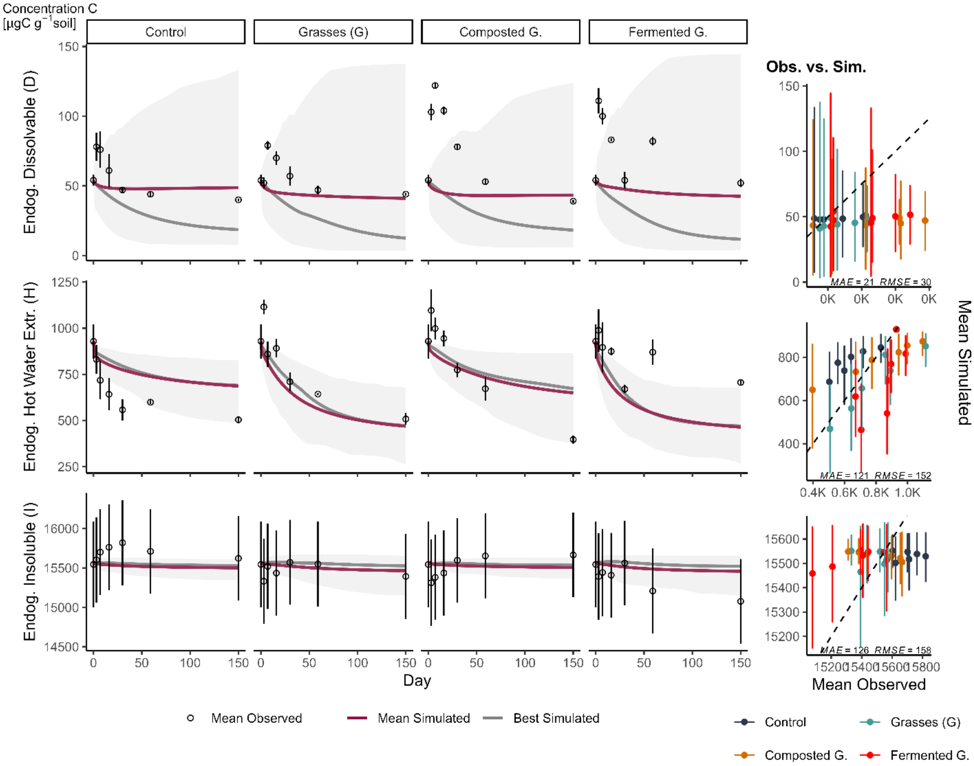

Figure N4. Model simulation and observed data for Dissolvable (D), hot water extractable (H) and Insoluble (I) endogenous carbon concentrations after amending a podzol with grasses, composted grasses, fermented grasses and no organic amendment (control). The shaded area denotes the 5% and 95% quantiles. The dashed line in observed vs. mean simulated plots is the line of perfect fit (1:1 match of observed to simulated data).

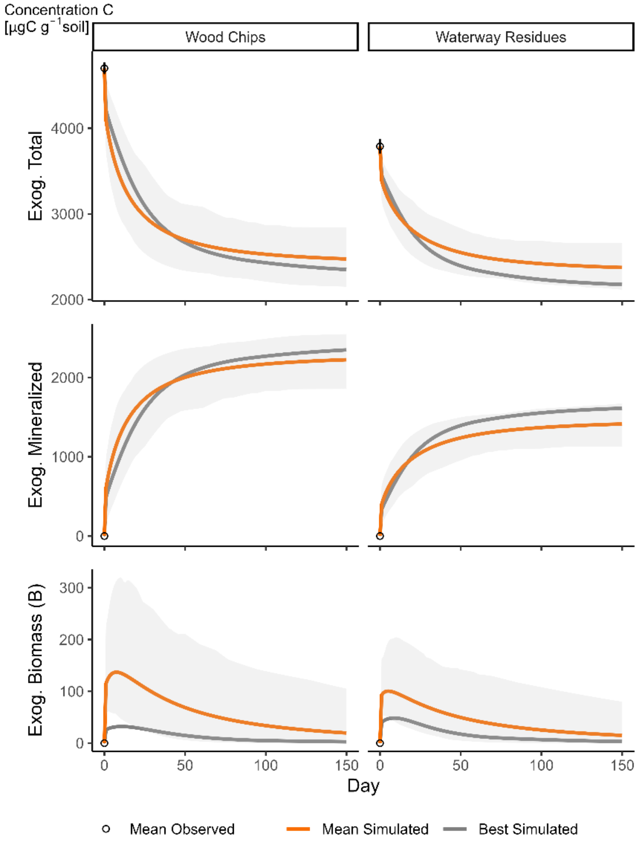

Figure N5. Model predictions of total, mineralized, microbial biomass and primed exogenous carbon concentrations after amending a podzol with wood chips and waterway residues. The shaded area denotes the 5% and 95% quantiles.

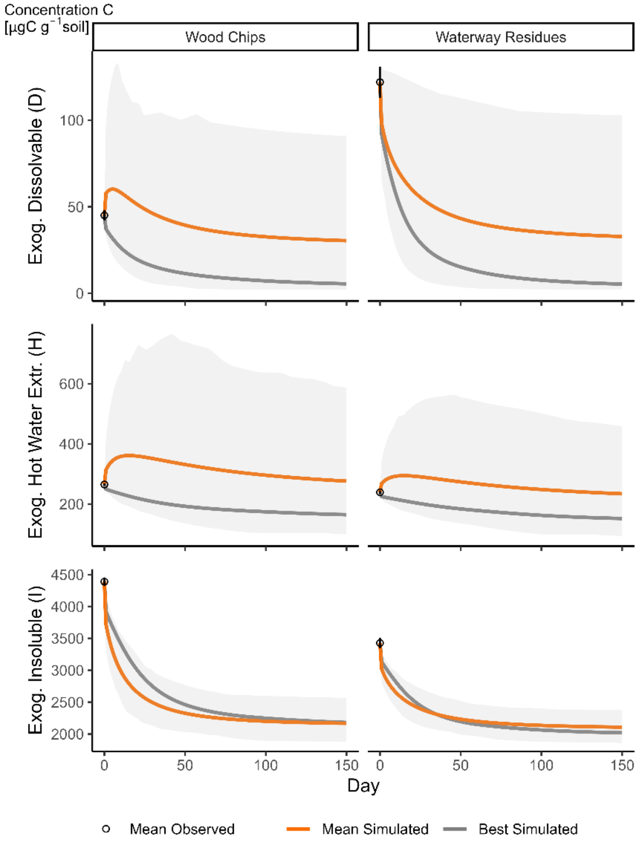

Figure N6. Model predictions of Dissolvable (D), Hot water extractable (H) and Insoluble (I) exogenous carbon concentrations after amending a podzol with wood chips and waterway residues. The shaded area denotes the 5% and 95% quantiles.

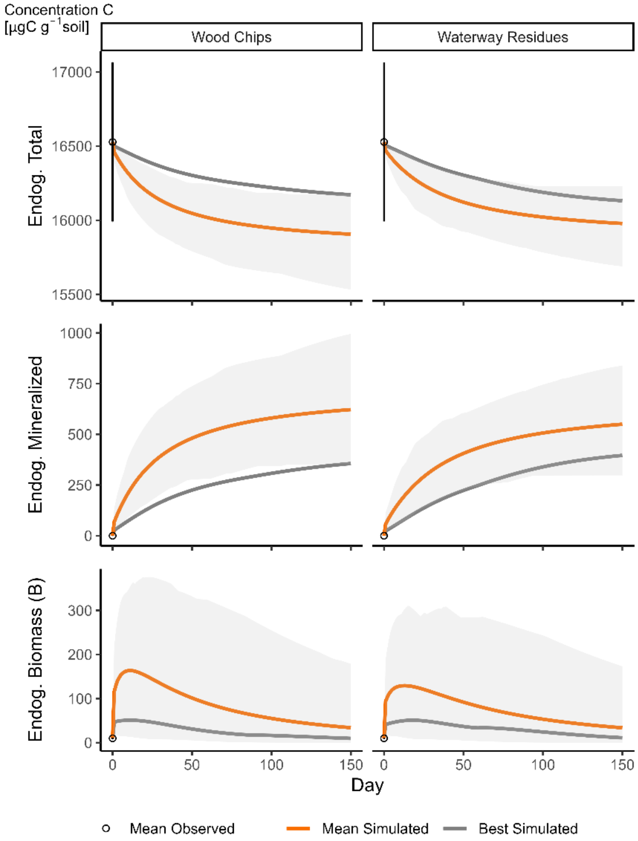

Figure N7. Model prediction of total, mineralized, microbial biomass and primed endogenous carbon concentrations after amending a podzol with wood chips and waterway residues. The shaded area denotes the 5% and 95% quantiles.

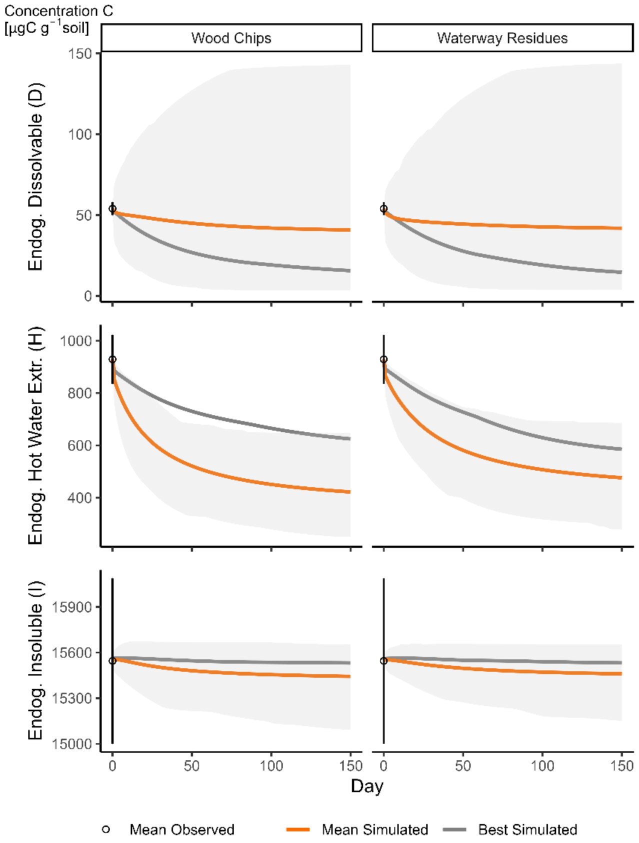

Figure N8. Model prediction of data for dissolvable (d), hot water extractable (h) and insoluble (i) endogenous carbon fractions after amending a podzol with wood chips and waterway residues. The shaded area denotes the 5% and 95% quantiles.

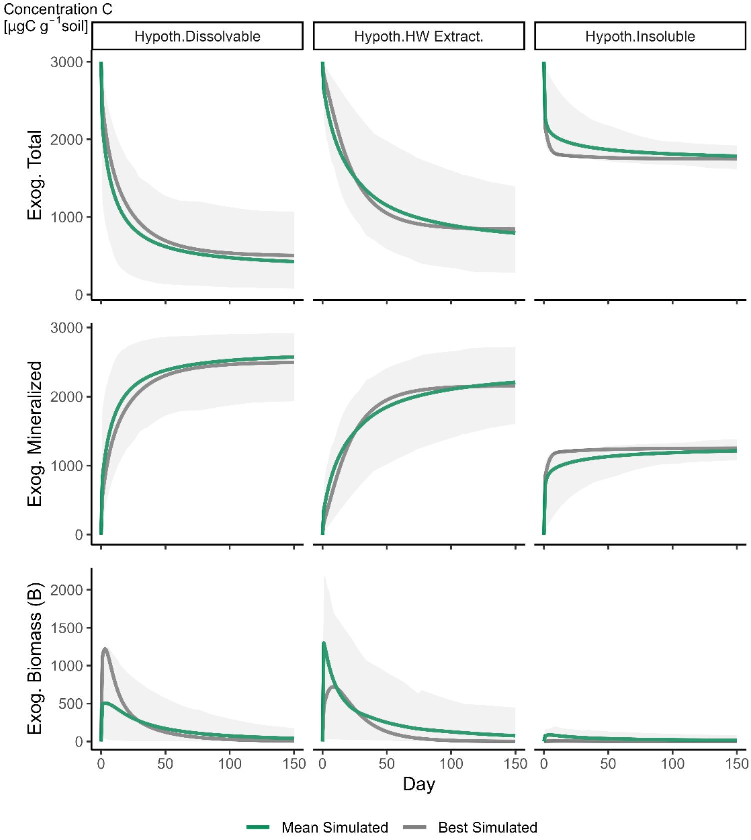

Figure N9. Model predictions of total, mineralized, microbial biomass and primed exogenous carbon concentrations after the hypothetical application of pure Dex, Hex and Iex substances. The shaded area denotes the 5% and 95% quantiles.

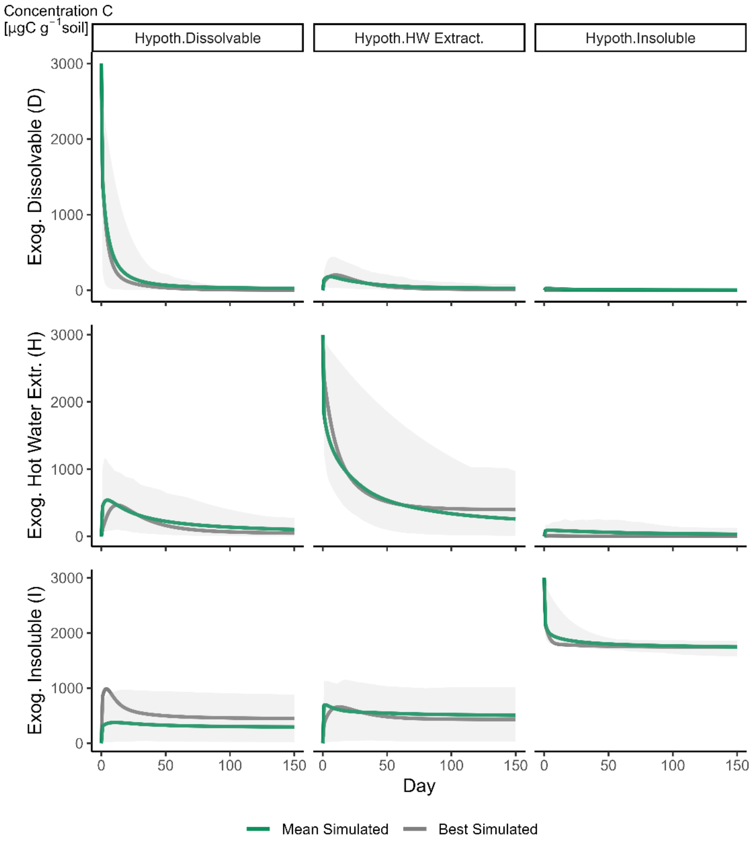

Figure N10. Model predictions of Dissolvable (D), Hot water extractable (H) and Insoluble (I) exogenous carbon concentrations after the hypothetical application of pure Dex, Hex and Iex substances. The shaded area denotes the 5% and 95% quantiles.

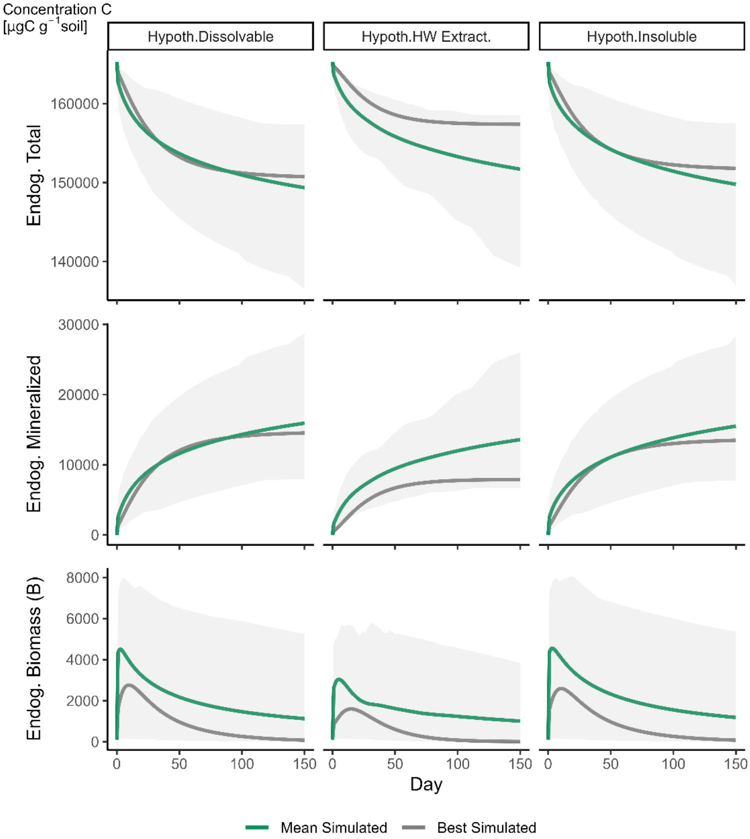

Figure N11. Model prediction of total, mineralized, microbial biomass and primed endogenous carbon concentrations after the hypothetical application of pure Dex, Hex and Iex substances. The shaded area denotes the 5% and 95% quantiles.

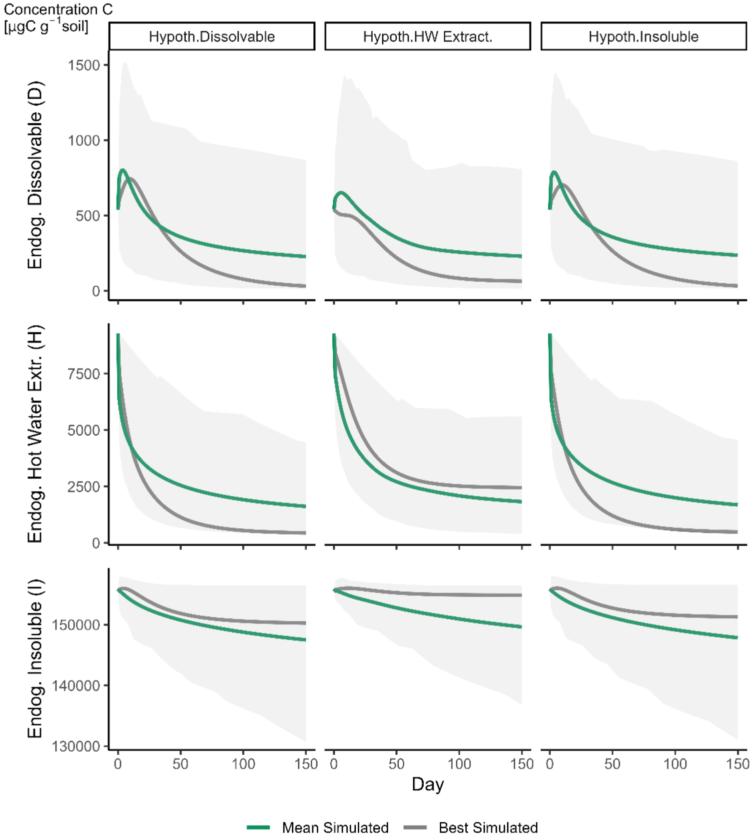

Figure N12. Model prediction of data for Dissolvable (D), Hot water extractable (H) and Insoluble (I) endogenous carbon fractions after the hypothetical application of pure Dex, Hex and Iex substances. The shaded area denotes the 5% and 95% quantiles.

O Soil Properties

Table O1. Soil properties at Heelsum and Harreveld, sampled at 0-30 cm depth.

Property		**Anthrosol**	**Podzol**
Location		Heelsum	Harreveld
Sampling date baseline prop.	[dd-mm-yy]	12-03-2018	13-03-2018
Sand (>50µm)	[%]	74 (coarse)	72 (fine)
Silt (2-50µm)	[%]	20	19
Clay (<2µm)	[%]	2	3
C/N-Ratio	[-]	15	16
Organic Matter	[%]	3.7	6.2
pH	[-]	5.4	5.6
CEC	[meq]	56	105
N – *Total*	[kg N/Ha]	5860	8440
P - *Total*	[kg P/Ha]	1610	1245
K - *Total*	[kg K/Ha]	360	420
S – *Total*	[kg S/Ha]	1125	1500
Ca – *Total*	[kg Ca/Ha]	3540	6525
N – *Plant available*	[kg N/Ha]	80	105
P – *Plant available*	[kg P/Ha]	11	1.1
K – *Plant available*	[kg K/Ha]	215	135
Mg – *Plant available*	[kg Mg/Ha]	255	635

P Field Management

Table P1. Dates of interventions at the Heelsum site.

Anthrosol/Heelsum	**2018**	**2019**	**2020**
Tilled	20-Feb	Feb	Feb
Organic amendment application	23-Mar	19-Mar	16-Mar
Integration of amendments into soil	4-Apr	20-Mar	17-Mar
Sowing Maize	6-Apr	8-Apr	9-Apr
Mineral fertilizer application	9-Apr	4-Apr	24-Apr
Summer sampling	n/a	27-Jun	29-Jun
Harvest Maize	1-Aug	Aug	17-Aug
Autumn sampling	n/a	28-Nov	23-Nov
Tillage and sowing catch-crop	17-Aug	Aug	Aug

.**Table P2.** Dates of interventions at the Harreveld site

Podzol/Harreveld	**2018**	**2019**	**2020**
Tillage catch-crop removal	27-Mar	7-Mar	Mar
Tilled	Apr	17-Apr	23.Apr
Organic amendment application	10-Apr	5-Apr	25-Mar
Sowing Maize	27-Apr	24-Apr	24-Apr
Mineral fertilizer application	Apr	18-Apr	29-Apr
Summer sampling	n/a	21-Jun	23-Jun
Harvest Maize	1-Sep	28-Sep	23-Sep
Autumn sampling	n/a	22-Nov	20-Nov

Q Amendment application rates

Table Q1. Application rates per treatment block for the Anthrosol soil at the Heelsum site.

Anthrosol/ Heelsum	**Treatm.**	**Fresh matter** [ton Ha^{-1}]	**Dry matter** [ton Ha^{-1}]	**Organic matter** [ton Ha^{-1}]	**Total Nitrogen** [kg Ha^{-1}]	**P_2O_5** [kg Ha^{-1}]	**K_2O** [kg Ha^{-1}]	**N Supp.** [ton Ha^{-1}]	**P_2O_5 Supp.** [kg Ha^{-1}]	**K_2O Supp.** [kg Ha^{-1}]
2018	Control	0	0	0	0	0	0	140	50	200
	Compost	21.3	13.2	3.7	136	96	158	126	0	42
	Manure	34	2.8	2.1	124	45	184	65	5	16
	Grasses	26.3	16.8	14.3	373	123	208	0	0	0
	G&M	60.3	19.6	16.4	497	168	392	0	0	0
2019	Control	0	0	0	0	0	0	106	65	200
	Compost	22.7	13.6	3.5	138	118	157	92	0	43
	Manure	30	2.4	2	128	42	141	47	23	59
	Grasses	18.8	7	3.9	99	43	119	56	22	152
	G&M	48.8	9.4	5.9	227	85	260	0	0	0
2020	Control	0	0	0	0	0	0	120	50	200
	Compost	21.8	11.7	3.6	146	80	118	99	0	82
	Manure	27.5	2.4	2	114	40	113	67	10	87
	Grasses	13.5	10	8.1	151	37	117	35	13	83
	G&M	41	12.4	10.1	265	77	230	0	0	0

Table Q2. Application rates per treatment block for the Podzol soil at the Harreveld site. Treatment abbreviations: ‘WWR’ is waterway residues, ‘B’ is bokashi, and ‘M’ is manure.

Podzol/ Harre-veld	**Treatm.**	**Fresh matter**	**Dry matter**	**Organic matter**	**Total Nitrogen**	**P_2O_5**	**K_2O**	**N Supp.**	**P_2O_5 Supp.**	**K_2O Supp.**
		[ton Ha^{-1}]	[ton Ha^{-1}]	[ton Ha^{-1}]	[kg Ha^{-1}]	[kg Ha^{-1}]	[kg Ha^{-1}]	[ton Ha^{-1}]	[kg Ha^{-1}]	[kg Ha^{-1}]
2018	Control	0	0	0	0	0	0	140	50	200
	Compost	18.3	10.9	3.1	113	100	152	127	0	41
	Manure	34	3.5	2.8	63	50	214	46	0	0
	WWR	26.7	14.5	7.3	276	50	45	0	0	148
	WWR&M	60.7	18	10.1	339	100	259	0	0	0
2019	Control	0	0	0	0	0	0	95	65	200
	Compost	21.7	12.7	3.4	134	111	178	80	0	22
	Manure	30	2.9	2.3	90	45	195	36	20	5
	WWR	15.1	3.9	2.2	44	41	136	52	24	64
	WWR&M	45.1	6.8	4.5	134	86	331	0	0	0
2020	Control	0	0	0	0	0	0	128	50	200
	Compost	24.2	17.5	3.1	130	68	92	111	0	108
	Manure	30	2.5	1.9	81	41	189	73	20	11
	Bokashi	18.8	10.6	2.8	51	41	62	91	9	138
	B&M	48.8	13.1	4.7	132	82	251	0	0	0

R Amendment composition

Table R1. Characteristics of amendments applied to the Anthrosol soil at the Heelsum site.

Anthrosol Heelsum	**Amend.**	**Dry matter** [kg ton^{-1}]	**Organic matter** [kg ton^{-1}]	**N-*Total*** [kg ton^{-1}]	**N-*Min*** [kg ton^{-1}]	**P_2O_5** [kg ton^{-1}]	**K_2O** [kg ton^{-1}]	**C-*Tot*** [kg ton^{-1}]	**C/N** [-]
2018	Compost	618	174	6.4		4.5	7.4	87	13.6
	Manure	83	62	3.7	1.5	1.3	5.4	52.2	14.1
	Grasses	638	542	14.2		4.7	7.9	271.2	19.1
2019	Compost	599	155	6		5.2	6.9	76.8	12.8
	Manure	80	66	4.25	2	1.4	4.7	60.8	14.3
	Grasses	370	208	5.3	0.1	2.3	6.3	107.1	20.2
2020	Compost	537	166	6.7		3.7	5.4	83.1	12.4
	Manure	88	72	4.15	1.9	1.5	4.1	65.1	15.7
	Grasses	743	600	11.1		2.7	8.7	298.6	26.9

Table R2. Characteristics of amendments applied to the Podzol soil at the Harreveld site. Amendment abbreviations: ‘WWR’ is waterway residues.

Podzol/ Harreveld	**Amend.**	**Dry matter** [kg ton^{-1}]	**Organic matter** [kg ton^{-1}]	**N-*Total*** [kg ton^{-1}]	**N-*Min*** [kg ton^{-1}]	**P_2O_5** [kg ton^{-1}]	**K_2O** [kg ton^{-1}]	**C-*Total*** [kg ton^{-1}]	**C/N** [-]
2018	Compost	596	172	6.9	0.8	5.5	8.3	86.25	12.5
	Manure	102	82	4.6	2.1	1.5	6.3	75.44	16.4
	WWR	544	272	11.2	0.3	1.9	1.7	135.52	12.1
2019	Compost	587	158	6.9		5.1	8.2	79.35	11.5
	Manure	96	75	4.95	2.2	1.5	6.5	66.33	13.4
	WWR	258	147	6.5		2.3	4.6	130.65	~20.1
2020	Compost	724	130	5.9		2.8	3.8	64.9	11
	Manure	84	64	4.53	2.3	1.4	6.3	65.685	14.5
	Bokashi	564	149	4.5		2.2	3.3	74.25	16.5

S Contrast analysis amendment improvements

Table S1. Contrast analysis for bulk density at the Anthrosol site where EMM is the model estimated marginal mean of absolute values, and G&M is an abbreviation for the grasses&manure combination.

OA Contrast with Control	Season and Season Contrast	EMM	Std. Error	Z-ratio	p-value	Change rel. to control
		[g cm^{-3}]	[g cm^{-3}]	[-]	[-]	[%]
Control	Summer	1.30	0.03	-	-	-
	Winter	1.27	0.03	-	-	-
	Wint. - Sum.	-0.03	0.06	-	-	-
Grasses - Control	Summer	-0.08	0.05	-1.77	3.8E-02	-6.15
	Winter	-0.04	0.03	-1.36	8.8E-02	-3.15
	Wint. - Sum.	0.04	0.06	0.77	4.4E-01	3
G&M - Control	Summer	-0.07	0.05	-1.57	5.8E-02	-5.38
	Winter	-0.04	0.03	-1.39	8.2E-02	-3.15
	Wint. - Sum.	0.03	0.06	0.59	5.5E-01	2.23
Compost - Control	Summer	-0.10	0.04	-2.76	2.9E-03	-7.69
	Winter	-0.02	0.03	-0.67	2.5E-01	-1.57
	Wint. - Sum.	0.08	0.05	1.72	8.6E-02	6.12
Manure - Control	Summer	-0.04	0.04	-1.14	1.3E-01	-3.08
	Winter	-0.08	0.03	-2.80	2.6E-03	-6.3
	Wint. - Sum.	-0.04	0.05	-0.76	4.5E-01	-3.22

Table S2. Contrast analysis for infiltration capacity at the Anthrosol site where EMM is the model estimated marginal mean of absolute values, and G&M is an abbreviation for the grasses&manure combination.

OA Contrast with Control	Season and Season Contrast	EMM	Std. Error	Z-ratio	p-value	Change rel. to control
		[mm min^{-1}]		[-]	[-]	[%]
Control	Summer	6.66	0.76	-	-	-
	Winter	7.22	0.88	-	-	-
	Wint. - Sum.	0.57	1.64	-	-	-
Grasses - Control	Summer	4.49	1.70	2.65	4.1E-03	67.42
	Winter	-0.11	1.11	-0.10	5.4E-01	-1.52
	Wint. - Sum.	-4.60	2.02	-2.28	2.3E-02	-68.94
G&M - Control	Summer	7.20	1.86	3.87	5.3E-05	108.11
	Winter	0.86	1.18	0.73	2.3E-01	11.91
	Wint. - Sum.	-6.34	2.20	-2.88	4.0E-03	-96.2
Compost - Control	Summer	-0.92	1.09	-0.84	8.0E-01	-13.81
	Winter	-0.30	1.15	-0.27	6.0E-01	-4.16
	Wint. - Sum.	0.61	1.59	0.38	7.0E-01	9.65
Manure - Control	Summer	2.30	1.43	1.61	5.4E-02	34.53
	Winter	-0.79	1.04	-0.75	7.7E-01	-10.94
	Wint. - Sum.	-3.09	1.76	-1.76	7.9E-02	-45.47

Table S3. Contrast analysis for aggregate stability at the Anthrosol site where EMM is the model estimated marginal mean of absolute values, and G&M is an abbreviation for the grasses&manure combination treatment.

OA Contrast with Control	Season and Season Contrast	EMM [mm]	Std. Error [mm]	Z-ratio [-]	p-value [-]	Change rel. to control [%]
Control	Summer	1.34	0.11	-	-	-
	Winter	1.25	0.14	-	-	-
	Wint. - Sum.	-0.09	0.25	-	-	-
Grasses - Control	Summer	0.40	0.15	2.67	3.8E-03	29.85
	Winter	0.45	0.13	3.34	4.2E-04	36
	Wint. - Sum.	0.05	0.20	0.24	8.1E-01	6.15
G&M - Control	Summer	0.62	0.15	4.13	1.8E-05	46.27
	Winter	0.75	0.15	5.03	2.5E-07	60
	Wint. - Sum.	0.13	0.21	0.62	5.4E-01	13.73
Compost - Control	Summer	0.11	0.13	0.84	2.0E-01	8.21
	Winter	0.45	0.14	3.36	3.9E-04	36
	Wint. - Sum.	0.34	0.19	1.81	7.0E-02	27.79
Manure - Control	Summer	0.28	0.13	2.07	1.9E-02	20.9
	Winter	0.62	0.14	4.35	6.9E-06	49.6
	Wint. - Sum.	0.35	0.20	1.77	7.7E-02	28.7

Table S4. Contrast analysis for water retention at the Anthrosol site where EMM is the model estimated marginal mean of relative change in PAW (volumetric) when compared to the control, and G&M is an abbreviation for the grasses&manure combination treatment. An EMM of 0 would indicate no change relative to the control, whereas positive and negative values indicate mean percentual increases and decreases relative to the control.

OA Contrast with Control	Season and Season Contrast	EMM [%]	Std. Error [%]	Z-ratio [-]	p-value [-]
$\frac{\text{Grasses} - \text{Control}}{\text{Control}}$	Summer	47.39	22.67	2.09	1.4E-01
	Winter	57.48	23.24	2.47	1.1E-01
	Winter - Summer	10.09	8.87	1.14	3.4E-01
$\frac{\text{G\&M} - \text{Control}}{\text{Control}}$	Summer	19.06	21.96	0.87	2.8E-01
	Winter	44.69	23.24	1.92	1.4E-01
	Winter - Summer	25.63	10.49	2.44	8.5E-02
$\frac{\text{Compost} - \text{Control}}{\text{Control}}$	Summer	9.85	5.12	1.92	7.5E-02
	Winter	-19.57	7.24	-2.70	9.6E-01
	Winter - Summer	-29.41	8.87	-3.32	4.4E-02
$\frac{\text{Manure} - \text{Control}}{\text{Control}}$	Summer	-5.05	5.12	-0.99	8.0E-01
	Winter	-28.26	7.24	-3.90	9.9E-01
	Winter - Summer	-23.21	8.87	-2.62	7.8E-02

Table S5. Contrast analysis for bulk density at the Podzol site. Abbreviations: EMM is the model estimated marginal mean, WWR is waterway residues, WWR&M is waterway residues & manure combination treatment, and B&M is Bokashi & manure combination.

OA Contrast with Control	Season and Season Contrast	EMM	Std. Error	Z-ratio	p-value	Ch. rel. to contr.
		[g cm^{-3}]		[-]	[-]	[%]
Control	Summer	1.22	0.03	-	-	-
	Winter	1.15	0.02	-	-	-
	Winter - Summer	-0.07	0.05	-	-	-
Compost - Control	Summer	-0.12	0.04	-2.85	2.2E-03	-9.84
	Winter	0.01	0.03	0.21	5.8E-01	0.87
	Winter - Summer	0.13	0.05	2.35	1.9E-02	10.71
Manure - Control	Summer	-0.03	0.05	-0.72	2.4E-01	-2.46
	Winter	0.07	0.04	1.92	9.7E-01	6.09
	Winter - Summer	0.10	0.06	1.71	8.8E-02	8.55
Bokashi - Control	Summer	-0.10	0.05	-2.06	2.0E-02	-8.2
	Winter	-0.04	0.03	-1.21	1.1E-01	-3.48
	Winter - Summer	0.06	0.06	0.98	3.3E-01	4.72
B&M - Control	Summer	-0.04	0.05	-0.80	2.1E-01	-3.28
	Winter	-0.02	0.03	-0.51	3.0E-01	-1.74
	Winter - Summer	0.02	0.06	0.36	7.2E-01	1.54

Table S6. Contrast analysis for infiltration capacity at the Podzol site. Abbreviations: EMM is the model estimated marginal mean, WWR is waterway residues, WWR&M is waterway residues & manure combination treatment, and B&M is Bokashi & manure combination.

OA Contrast with Control	Season and Season Contrast	EMM	Std. Error	Z-ratio	p-value	Ch. rel. to contr.
		[mm min^{-1}]		[-]	[-]	[%]
Control	Summer	5.55	0.85	-	-	-
	Winter	2.65	0.38	-	-	-
	Winter - Summer	-2.9	1.23	-	-	-
Compost - Control	Summer	-0.07	1.16	-0.06	5.2E-01	-1.26
	Winter	1.07	0.83	1.29	9.9E-02	40.38
	Winter - Summer	1.14	1.46	0.78	4.4E-01	41.64
Manure - Control	Summer	0.59	1.39	0.43	3.3E-01	10.63
	Winter	0.77	0.76	1.01	1.6E-01	29.06
	Winter - Summer	0.17	1.63	0.11	9.2E-01	18.43
WWR - Control	Summer	5.52	2.43	2.27	1.2E-02	99.46
	Winter	0.70	1.03	0.68	2.5E-01	26.42
	Winter - Summer	-4.82	2.62	-1.84	6.6E-02	-73.04
WWR&M - Control	Summer	2.99	1.89	1.58	5.7E-02	53.87
	Winter	2.67	1.37	1.94	2.6E-02	100.75
	Winter - Summer	-0.33	2.32	-0.14	8.9E-01	46.88
Bokashi - Control	Summer	-1.22	1.39	-0.88	8.1E-01	-21.98
	Winter	-0.91	0.69	-1.33	9.1E-01	-34.34
	Winter - Summer	0.30	1.49	0.20	8.4E-01	-12.36
B&M - Control	Summer	-1.13	1.40	-0.81	7.9E-01	-20.36
	Winter	1.01	1.05	0.96	1.7E-01	38.11
	Winter - Summer	2.14	1.70	1.26	2.1E-01	58.47

Table S7. Contrast analysis for aggregate stability at the Podzol site. Abbreviations: EMM is the model estimated marginal mean, WWR is waterway residues, WWR&M is waterway residues & manure combination treatment, and B&M is Bokashi & manure combination treatment.

OA Contrast with Control	Season and Season Contrast	EMM	Std. Error	Z-ratio	p-value	Ch. rel. to contr.
		[mm]	[mm]	[-]	[-]	[%]
Control	Summer	1.86	0.16	-	-	-
	Winter	1.80	0.14	-	-	-
	Winter - Summer	-0.06	0.30	-	-	-
Compost - Control	Summer	0.02	0.21	0.08	4.7E-01	1.08
	Winter	0.46	0.20	2.33	9.9E-03	25.56
	Winter - Summer	0.44	0.29	1.54	1.2E-01	24.48
Manure - Control	Summer	0.32	0.20	1.57	5.8E-02	17.2
	Winter	0.28	0.20	1.41	8.0E-02	15.56
	Winter - Summer	-0.04	0.28	-0.14	8.9E-01	-1.64
WWR - Control	Summer	-0.08	0.22	-0.38	6.5E-01	-4.3
	Winter	0.31	0.25	1.26	1.0E-01	17.22
	Winter - Summer	0.39	0.32	1.24	2.2E-01	21.52
WWR&M - Control	Summer	-0.07	0.22	-0.34	6.3E-01	-3.76
	Winter	0.22	0.24	0.92	1.8E-01	12.22
	Winter - Summer	0.29	0.31	0.94	3.5E-01	15.98
Bokashi - Control	Summer	-0.48	0.23	-2.13	9.8E-01	-25.81
	Winter	0.73	0.28	2.57	5.1E-03	40.56
	Winter - Summer	1.21	0.34	3.55	3.8E-04	66.37
B&M - Control	Summer	0.16	0.30	0.52	3.0E-01	8.6
	Winter	0.50	0.27	1.88	3.0E-02	27.78
	Winter - Summer	0.34	0.38	0.89	3.7E-01	19.18

Table S8. Contrast analysis for water retention at the Podzol site.An EMM of 0 would indicate no change relative to the control, whereas positive and negative values indicate mean percentual increases and decreases relative to the control.

OA Contrast with Control	Season and Season Contrast	EMM	Std. Error	Z-ratio	p-value
		[%]	[%]	[-]	[-]
$\frac{\text{Compost} - \text{Control}}{\text{Control}}$	Summer	-9.0	8.3	-1.1	8.0E-01
	Winter	11.1	11.8	0.9	2.2E-01
	Winter - Summer	20.2	14.4	1.4	3.0E-01
$\frac{\text{Manure} - \text{Control}}{\text{Control}}$	Summer	-0.3	8.3	0.0	5.1E-01
	Winter	17.8	11.8	1.5	1.4E-01
	Winter - Summer	18.1	14.4	1.3	3.4E-01
$\frac{\text{WWR} - \text{Control}}{\text{Control}}$	Summer	10.0	13.6	0.7	2.5E-01
	Winter	*n.d*	*n.d*	*n.d*	*n.d*
	Winter - Summer	*n.d*	*n.d*	*n.d*	*n.d*
$\frac{\text{WWR\&M} - \text{Control}}{\text{Control}}$	Summer	31.1	13.6	2.3	4.4E-02
	Winter	*n.d*	*n.d*	*n.d*	*n.d*
	Winter - Summer	*n.d*	*n.d*	*n.d*	*n.d*
$\frac{\text{Bokashi} - \text{Control}}{\text{Control}}$	Summer	10.5	13.6	0.8	2.4E-01
	Winter	50.0	13.1	3.8	1.5E-02
	Winter - Summer	39.5	17.1	2.3	1.4E-01
$\frac{\text{B\&M} - \text{Control}}{\text{Control}}$	Summer	33.5	13.6	2.5	3.6E-02
	Winter	77.8	13.1	5.9	4.6E-03
	Winter - Summer	44.3	17.1	2.6	1.2E-01

T Largest and smallest changes relative to the control for organic amendment treatments per site and per season

Table T1. Maximum (greatest positive), minimum (lowest negative), largest (greatest absolute) and least (smallest absolute) percent change in soil properties relative to the unamended control for all OA treatments per sampling site and season. Calculated from data presented in Appendix S.

			Maximum change	Minimum change	Largest change (absolute)	Least change (minimum)	Difference max-min change	Difference largest-least change
			[%]	[%]	[%]	[%]	[%]	[%]
Bulk density	**Anthrosol**	**Summer**	-3.1	-7.7	7.7	3.1	4.6	4.6
		Winter	-1.6	-6.3	6.3	1.6	4.7	4.7
	Podzol	**Summer**	-2.5	-9.8	9.8	2.5	7.4	7.4
		Winter	6.1	-3.5	6.1	0.9	9.6	5.2
	Both sites	**Summer**	-2.5	-9.8	9.8	2.5	7.4	7.4
		Winter	6.1	-6.3	6.3	0.9	12.4	5.4
		Both seasons	6.1	-9.8	9.8	0.9	15.9	9.0
Infiltration Capacity	**Anthrosol**	**Summer**	108.1	-13.8	108.1	13.8	121.9	94.3
		Winter	11.9	-10.9	11.9	1.5	22.9	10.4
	Podzol	**Summer**	99.5	-22.0	99.5	1.3	121.4	98.2
		Winter	100.8	-34.3	100.8	26.4	135.1	74.3
	Both sites	**Summer**	108.1	-22.0	108.1	1.3	130.1	106.9
		Winter	100.8	-34.3	100.8	1.5	135.1	99.2
		Both seasons	108.1	-34.3	108.1	1.3	142.5	106.9

Table T1 (*Continued*). Maximum (greatest positive), minimum (lowest negative), largest (greatest absolute) and least (smallest absolute) percent change in soil properties relative to the unamended control for all OA treatments per sampling site and season. Calculated from data presented in Appendix S.

			Maximum change	Minimum change	Largest change (absolute)	Least change (minimum)	Difference max-min change	Difference largest-least change
			[%]	[%]	[%]	[%]	[%]	[%]
Aggregate Stability	**Anthrosol**	**Summer**	46.3	8.2	46.3	8.2	38.1	38.1
		Winter	60.0	36.0	60.0	36.0	24.0	24.0
	Podzol	**Summer**	17.2	-25.8	25.8	1.1	43.0	24.7
		Winter	40.6	12.2	40.6	12.2	28.3	28.3
	Both sites	**Summer**	46.3	-25.8	46.3	1.1	72.1	45.2
		Winter	60.0	12.2	60.0	12.2	47.8	47.8
		Both seasons	60.0	-25.8	60.0	1.1	85.8	58.9
Water Retention	**Anthrosol**	**Summer**	47.4	-5.1	47.4	5.1	52.4	42.3
		Winter	57.5	-28.3	57.5	19.6	85.7	37.9
	Podzol	**Summer**	33.5	-9.0	33.5	0.3	42.5	33.2
		Winter	77.8	11.1	77.8	11.1	66.7	66.7
	Both sites	**Summer**	47.4	-9.0	47.4	0.3	56.4	47.1
		Winter	77.8	-28.3	77.8	11.1	106.1	66.7
		Both seasons	77.8	-28.3	77.8	0.3	106.1	77.5

U Comparison of compost and manure results with other studies

Compost generally produced temporally favorable impacts by i) reducing in bulk density during the growing season, potentially facilitating oxygen diffusion and root penetration and ii) increasing in aggregate stability by winter, potentially benefitting nutrient retention outside the growing season and inhibiting nutrient leaching, and iii) for the podzol site, increasing infiltration capacity by winter, potentially facilitating the discharge of intensified winter precipitation (Table 7). Comparing compost impacts is difficult as more than 600 studies on its role in agriculture have been published over the past 11 years alone (Rivier et al. 2022:20). Studies on its impacts have reported decreases in bulk density of 4% for sandy soils after 30 days (Rivier et al. 2022:20), 11.2% within several months (Mylavarapu and Zinati 2009), up to 20% after 12 years (Celik et al. 2010), general variations between 0.7% and 23% (Martínez-Blanco et al. 2013), which all coincide well with our observations of decreases of 1.6%-7.7% and 0.87%-9.8% for anthrosol and podzol sites respectively. In a review of 80 studies on aggregate stability, Abiven et al. (2009) show the that compost applications typically improve soil aggregate stability in the range of 0-30%. Assuming wide variation in sampling moment for these 80 studies, these findings align with current results showing a 1-36% variation in the effect of compost on aggregate stability. Studies report positive impacts of compost on infiltration capacity of c.a. 24-50% (Logsdon, Sauer, and Shipitalo 2017), as well as 18% decreases (Demir and Doğan Demir 2019) and increases as high as 700% (Gonzalez and Cooperband 2002), of which the lower ranges coincide with our observations of -13% (decrease, not tested for significance) to 40% increases. Infiltration capacity measurements are often difficult to compare as they are sensitive to many factors, including the many different methods employed for its determination (Deb and Shukla 2012).

Manure only produced temporally beneficial effects on aggregate stability at the anthrosol site and on bulk density and aggregate stability at the podzol site. Comparatively, the grass & manure combination treatment, which was only applied at the anthrosol soil, seems a more promising alternative to applying manure alone as it produced temporally favorable effects for more soil properties, namely aggregate stability, bulk density, and water retention (though the large improvements in water retention, of up to 45% increased PAW, were not statistically significant). The application of manure is a traditional soil improvement strategy that dates back to 6000 B.C. (Bogaard et al. 2013) and its effects are therefore historically extensively studied and reported (Rayne and Aula 2020). As an indication of several observed trends, dairy manure has shown to decrease bulk density by

2.1% when combined with artificial fertilizers (Haque et al. 2019), 2.7% to 9.5% (Rasoulzadeh, Yaghoubi, and others 2010), 4%, 8%, and 9% with increasing application rates (Ahmad et al. 2016), extending to 13.1% (Meng et al. 2019), and even 14% after 12 years (Celik et al. 2010). Our observations are on the somewhat lower end of these ranges, namely at 3.1% to 6.3% and 2.5% to -6.1% (increase) for the anthrosol and podzol sites respectively. Aggregate stability changes are reported from no significant effects (Karami et al. 2012), 43.1% and 51.1% (Rasoulzadeh et al. 2010), 75% (Celik et al. 2010), to variations of -20% to 40% depending on the method (Annabi et al. 2011). These findings roughly agree with this study's observed ranges of 21% to 50% and 17% to 15% for anthrosol and podzol sites, respectively. Changes in hydraulic conductivity for manure are observed to vary significantly with observations ranging around 62.2%, 35.5% (Khan et al., 2010), 160% to 174% (Rasoulzadeh et al. 2010), -4.6% to 35.4% (Aday, Hameed, and Al-faris 2019), -35% (Demir and Doğan Demir 2019), 115%, 167%, and 234% for increasing application rates (Fares et al. 2008). Our observations range from -11% to 35% and 11% to 29% for anthrosol and podzol sites, respectively, and are therefore at a somewhat lower end of changes reported in other studies.