

Supplementary Materials:

Table S1. Average monthly temperature and total monthly precipitation from PRISM ¹ during important winter wheat growth stages in 2016 and 2017, when the experiment was conducted, and the 30-year average from 1981-2010.

Month	2016		2017		1981-2010 Average	
	Average Temp (°C)	Total Precip (mm)	Average Temp (°C)	Total Precip (mm)	Average Temp (°C)	Total Precip (mm)
March	3.7	48	5.1	42	1.6	34
April	7.9	53	6	93	5.8	57
May	9.8	68	10.6	69	10.4	79
June	16	28	15.2	69	14.5	79
4-month	9.4	197	9.2	273	8.1	249

¹PRISM Climate Group. (2018). Oregon State University. <http://prism.oregonstate.edu>.

Table S2. Agronomic management details in cover crops and winter wheat across conventional no-till, reduced-till grazed organic, and tilled organic between 2013 to 2017 at Fort Ellis Research and Extension Center in Bozeman, MT, USA.

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Year	m	Crop	Agronomic management details
2013	Conventional no-till	Cover crop	Glyphosate (1680 g ai/ha) preemergence, Dicamba (280 g ai/ha) mixed with *Hel-Fire adjuvant (897 ml/ha). ^Seeding rate = 95 kg/ha.
		Winter wheat	2,4-D (700 g ai/ha), Dicamba (210 g ai/ha). ¥Urea (336 kg/ha). Seeding rate = 63 kg/ha.
2014		Cover crop	Glyphosate (2241 g ai/ha) 2X mixed with **MSO adjuvant (1793 ml/ha) 2X, Saflufenacil (140 g ai/ha) 2X mixed with \$AWS adjuvant (210 ml/ha) 2X
		Winter wheat	acid ester of bromoxynil + 2-ethylhexyl ester of MCPA (841 g ai/ha). Seeding rate = 61 kg/ha.
2015		Cover crop	(2241 g ai/ha) mixed with *R11 adjuvant (897 ml/ha), Saflufenacil (140 g ai/ha) mixed with AWS adjuvant (105 ml/ha)
		Winter wheat	ml/ha). Urea (390 kg/ha). Seeding rate = 79 kg/ha.
2016		Cover crop	Glyphosate (2241 g ai/ha) mixed with Hel-Fire adjuvant (448 gm/ha), 2,4-D (1680 g ai/ha) mixed with R11 adjuvant (448 ml/ha)
		Winter wheat	Glyphosate (1680 g ai/ha) preemergence mixed with Hel-Fire adjuvant (448 ml/ha), Glyphosate (2241 g ai/ha) preemergence mixed with R11 adjuvant (448 ml/ha), fluroxypyr 1-methylheptyl ester (1121 g ai/ha) mixed with AWS adjuvant (105 ml/ha). Urea (244 kg/ha). Seeding rate = 79 kg/ha.
2017		Cover crop	Glyphosate (2800 g ai/ha) mixed with Hel-Fire adjuvant (448 ml/ha), Glyphosate (2241 g ai/ha) mixed with Hel-Fire adjuvant (448 ml/ha)

	Winter wheat	Glyphosate (1680 g ai/ha) preemergence, fluroxypyr 1-methylheptyl ester (946 g ai/ha) mixed with AWS adjuvant (105 ml/ha). Urea (242 kg/ha). Seeding rate = 83 kg/ha.
2013	Cover crop	In-crop grazing with 8 sheep for 32 days. Post-harvest grazing with 20 sheep for 1 day. Disked twice. Seeding rate = 191 kg/ha.
	Winter wheat	Post-harvest grazing with 12 sheep for 54 days. Chiseled once. Seeding rate = 125 kg/ha.
2014	Cover crop	Pre-plant grazing with 6 sheep for 40 days. In-crop grazing with 16 sheep for 16 days. Post-harvest grazing with 25 sheep for 7 days.
	Winter wheat	Post-harvest grazing with 12 sheep for 60 days. Chiseled once. Seeding rate = 121 kg/ha.
2015	Cover crop	Pre-plant grazing with 30 sheep for 2 days. In-crop grazing with 18 sheep for 5 days and 36 sheep for 9 days. Post-harvest grazing with 24 sheep for 1 day, 220 sheep for 3 days, and 220 sheep for 3 days
	Winter wheat	In-crop grazing with 28 sheep for 5 days. Post-harvest grazing with 12 sheep for 65 days. Harrowed once. Seeding rate = 157 kg/ha.
2016	Cover crop	In-crop grazing with 17 sheep for 8 days and 8 sheep for 4 days. Post-harvest grazing with 17 sheep for 3 days, 17 for 3 days, and 29 sheep for 3 days.
	Winter wheat	In-crop grazing with 18 sheep for 5 days and 36 sheep for 9 days. Post-harvest grazing with 24 sheep for 1 day, 220 sheep for 3 days, and 220 sheep for 3 days. Seeding rate = 157 kg/ha.
2017	Cover crop	Post-harvest grazing with 17 sheep for 1 day, and 30 sheep for 2 days.
	Winter wheat	In-crop grazing with 11 sheep for 16 days. Chiseled once. Seeding rate = 124 kg/ha.
2013	Cover crop	Disked twice. Seeding rate = 125 kg/ha.
	Winter wheat	Chiseled once. Seeding rate = 125 kg/ha.
2014	Cover crop	Disked once and chiseled once.
	Winter wheat	Chiseled once. Seeding rate = 121 kg/ha.
2015	Cover crop	Disked once, chiseled twice, and harrowed once.
	Winter wheat	Chiseled twice and harrowed once. Seeding rate = 157 kg/ha.
2016	Cover crop	Disked three times and chiseled once.
	Winter wheat	Chiseled twice. Seeding rate = 157 kg/ha.
2017	Cover crop	Disked twice.
	Winter wheat	Chiseled twice. Seeding rate = 124 kg/ha.

^βAustrian winter was planted in fall 2012 for Year 1 (2013) of the experiment because of the biennial nature of yellow sweet clover which would have required a previous year of seeding, but Year 2-5 (2014-2017) were seeded to sweet clover, as cover crops.

*Hel-Fire: mix of aminated phosphoric, carboxylic acids, sulphurated amides, spray deposition aids.

[^]Seeding rate is not available for clover cover crops.

[¥]Urea (46-0-0).

^{**}MSO: Methylated seed oil.

[§]AWS: adding ammonium sulfate (nitrogen-based fertilizers).

[‡]R11: Alkylphenol ethoxylate, butyl alcohol, and Dimethylpolysiloxane (90% by wt).



Figure S1. Photos of the study with temperature (open top chambers) and moisture manipulation (rainout shelters) structures.

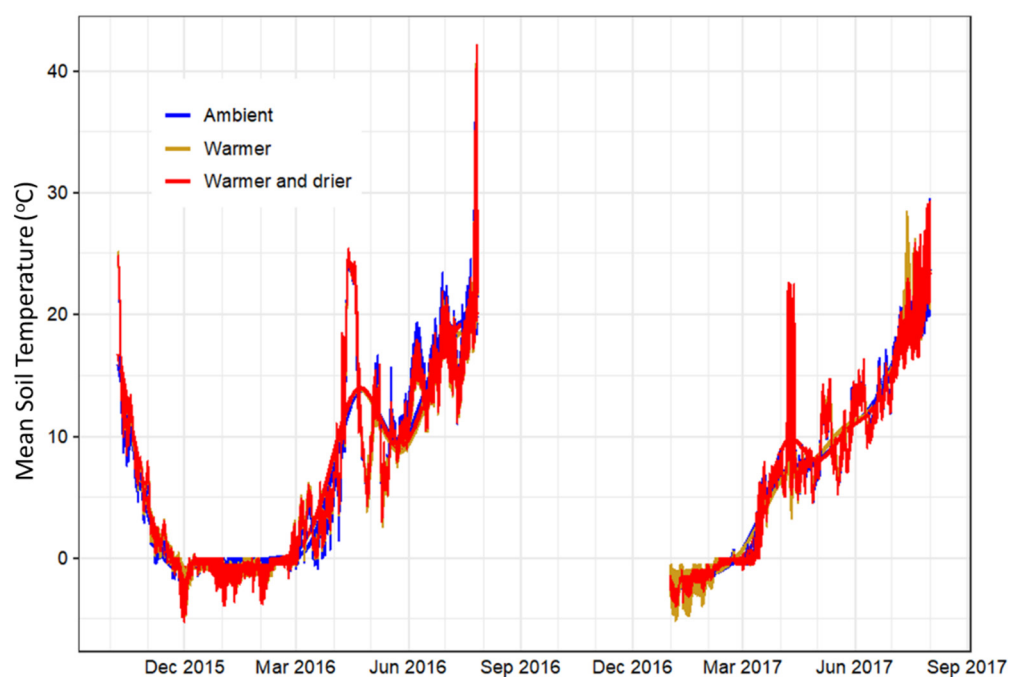


Figure S2. Daily soil temperature 5 cm below the surface in winter wheat fields with ambient conditions and climate manipulations that made the soil temperature warmer using open-top chambers, and warmer and drier using open-top chambers and rainout shelters that block 50% of the area above the plots.

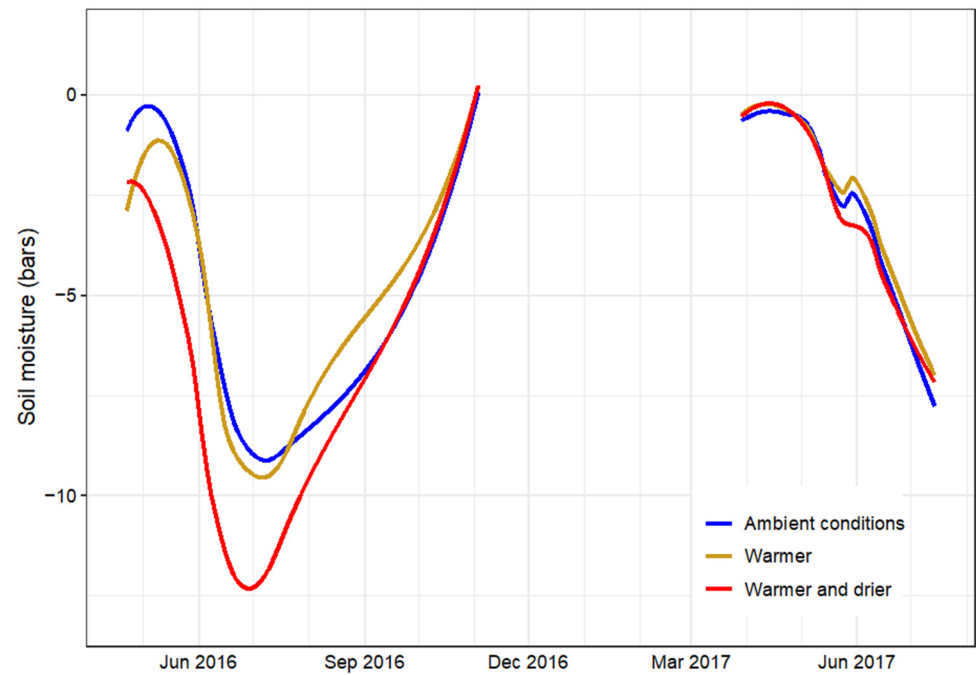


Figure S3. Seasonal variation in soil moisture 5 cm below the surface in winter wheat fields with ambient conditions and climate manipulations that made the soil temperature warmer using open-top chambers, and warmer and drier using open-top chambers and rainout shelters that block 50% of the area above the plots.