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Temperature response of soil respiration largely unaltered with experimental warming

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Supporting Methods

Dataset Generation and Description

A literature search was conducted on September 22, 2014 using Web of Science, which produced five studies presenting non-aggregated instantaneous data that were extractable (Table S1). Published datasets (16-17) and unpublished values make up the majority of the data in the dataset. We obtained unpublished data by first creating a list of all known experimental warming studies globally and asking the principal investigators to supply soil respiration data with corresponding soil temperature and moisture values. Because of widely variable experimental designs across studies, we averaged all plot-scale values for each sampling event to obtain one average (\pm SD) for each treatment for each sampling event ('sampling events' typically refer to a single day of sampling, although several studies complete full suites of sampling (i.e., 'sampling events') from all plots in both morning and afternoon). Only soil respiration values with corresponding soil moisture and soil temperature values from experimental warming studies were included in our analysis. Only observations from single-factor treatments (i.e., warming) were used, excluding values that combined warming with other treatments (e.g., precipitation or nitrogen manipulation). Four studies included more than one level of warming treatment (e.g., both 1.5 and 3°C warming treatments); in these cases, data from all levels of warming were used for our temperature response function analyses. All data were reported as instantaneous change in CO₂ efflux over a fixed

31 area, with belowground (i.e., roots and rhizomes), but not aboveground vegetation, included. Thus, soil
32 respiration values presented here include both heterotrophic and autotrophic soil respiration.

33

34 Experiment locations ranged from 33.5 to 68.4 °N latitude (Fig. S5) and the duration of warming at
35 experiments ranged from <1 to 22 years (average 5.1 years) (Fig. S6). Depths of soil temperature (1-10
36 cm) and moisture measurements (5-30 cm) ranged across studies, but were always consistent between
37 warmed and control plots within a particular study. The majority of the observations were taken between
38 5 and 10 years after warming commenced (n=1534), followed by 2-5 year duration (n=1109), less than 2
39 years (n=896) and >10 years (n=278). Each site was classified into a particular biome (grassland, northern
40 shrubland (i.e., peatlands and heathlands), southern shrubland (i.e., Mediterranean or sub-tropical
41 shrublands), tundra, desert, meadow, temperate agriculture, temperate forest and boreal forest) by the
42 associated principal investigator. Tropical biomes are not represented in our analysis because no data
43 from experimental warming studies in the tropics are yet available. However, the first known tropical
44 warming experiment, Tropical Responses to Altered Climate Experiment (TRACE), is currently being set
45 up in Luquillo Experimental Forest in Puerto Rico, with heating scheduled to commence during spring
46 2016.

47

48 Seasonality was defined by principal investigators contributing data as those months that fall into the
49 following categories: growing (plants actively growing), non-growing (plants not actively growing), or
50 shoulder (takes into account months of transition and intra-annual variability) season. Data from the
51 growing season accounted for more than half of our observations (n=1840), followed by shoulder season
52 (n=1112), and non-growing season (n=865). Absolute differences in soil temperature, moisture, and
53 respiration across sites were always calculated as values from warmed plots minus values from control
54 plots for each sampling event: e.g., $\Delta T = T_w - T_c$.

55

56 *Evaluating role of Soil Moisture, Seasonality, and Warming Duration in Controlling Soil Respiration*

57 We investigated the role of soil moisture in controlling the response of soil respiration in four ways. First,
58 we evaluated the significance of soil moisture as a predictor of soil respiration by adding moisture as an
59 additional continuous variable in a multiple linear regression model (Model e in Table S3, Table S2):

60

$$61 \quad (2) \quad \ln(R) = a_0 + a_1T + a_2T^2 + a_3M$$

62

63 where R is soil respiration ($\mu\text{mol C m}^2 \text{ s}^{-1}$), T is soil temperature ($^{\circ}\text{C}$), and M is soil moisture ($\text{cm}^3 \text{ cm}^{-3}$).

64 In cases where significant differences in the response functions of warmed vs. control treatments were
65 observed (boreal and desert biomes), separate models that included moisture were run for each treatment
66 (Table S2). Because respiration rates are often not linearly related to moisture content, we also conducted
67 our analysis with an additional model (Eq. 4), which resulted in no differences in our conclusions (Table
68 S6). Next, we created partial regression plots (i.e., added-variable plots) for both temperature and
69 moisture (Fig. S7), allowing for visual inspection of the role of moisture compared to temperature in
70 controlling the respiration response. Third, we examined how moisture alters the temperature sensitivity
71 of respiration by running a separate model of respiration as a function of temperature with moisture as the
72 interaction term (Model f in Table S3). To evaluate this response visually, we then partitioned the data
73 into moisture quantiles and plotted the temperature sensitivities of respiration at these four different
74 moisture levels (Fig. S3), reporting the coefficients in Table S4. Finally, we normalized each
75 instantaneous difference in respiration between warmed and control plots (ΔR) by ΔT , and binned those
76 values by amount of moisture available in warmed plots as a fraction of control plots (Fig. 3). Moisture
77 bins containing less than 5% of total observations from each biome are not shown (not applicable in Fig.
78 3, where all bins represent at least 5% total data). This analysis allowed us to understand how differences
79 in the magnitude of respiration between treatments change with moisture availability (Fig. S3).

80

81 We evaluated the influence of warming duration and seasonality on the respiration response between
82 treatments in two ways: 1) by partitioning the observations into categories of warming duration (<2, 2-5,
83 5-10, and >10 years) and season (growing, non-growing, and shoulder) and running the multivariate
84 regression model shown in Table 1 for each category separately, and 2) by running additional multivariate
85 models (Models h and i in Table S3) that included duration or season as a fixed factor, with an interaction
86 with warming treatment.

87

88 **Supporting Results**

89 *Magnitudes of Temperature and Respiration Change with Experimental Warming*

90 Experimental warming generally stimulated soil respiration, with a larger ΔT significantly correlated to a
91 larger respiration effect size ($p < 0.01$ and $r = 0.66$; Fig. S2B, Table S1). Across all sites, experimental
92 warming increased soil temperatures by $1.91\text{ }^{\circ}\text{C}$ on average, although average soil warming by biome
93 ranged from 0°C in southern shrublands to $4.09\text{ }^{\circ}\text{C}$ in temperate forests, with relatively large inter-biome
94 differences (Table S1). On average, the magnitude of soil warming at many sites was too low (when ΔT
95 $< 1.72\text{ }^{\circ}\text{C}$) to statistically increase respiration rates (Fig. S2B). In turn, the relatively low degree of average
96 warming across many sites resulted in an insignificant grand mean effect size for soil respiration ($RR =$
97 0.05 [95% CI: -0.03 - 0.14], $n = 26$), regardless of season and warming duration, with just five sites (Site
98 IDs 2, 6, 7, 8, 27 Table S1) having a significantly positive response of respiration in the warmed plots.
99 Methodological differences in warming methods resulted in a range of ΔT , and thus, ΔR across sites. In
100 our dataset, experiments that warmed via electric cables observed the greatest average soil warming (ΔT
101 $= 3.6\text{ }^{\circ}\text{C}$, $n = 5$), compared to infrared ($\Delta T = 2.3\text{ }^{\circ}\text{C}$, $n = 11$) and passive ($\Delta T = 0.4\text{ }^{\circ}\text{C}$, $n = 11$) warming
102 methods. Electric cable was the dominant warming method in the temperate forest (4 out of 5 sites) and
103 temperate agriculture (one site) biomes and in turn, these biomes were the only ones when analyzed
104 individually to display a significant increase in respiration (ΔR) with warming using traditional meta-
105 analysis (temperate forest: $RR = 0.18$; 95% CI: 0.06 - 0.30 , temperate agriculture: $RR = 0.21$; 95% CI: 0.06 -
106 0.37).

107

108 *Standardized Mean Difference of Temperature Sensitivity*

109 Beyond investigating differences in the log-quadratic temperature response function (Eq. 1) between
110 warming treatments, we also conducted a traditional meta-analysis on site-level temperature sensitivity
111 parameters using the standardized mean difference (SMD) as our index of effect size, which normalizes
112 raw mean differences by the pooled standard deviation. Examining data from across all sites, the grand
113 mean effect size was not significantly different from zero (SMD= -0.29 [95% CI: -1.21, 0.64], n=27),
114 demonstrating further evidence for the general lack of difference in temperature sensitivities between
115 warmed and control plots with experimental warming (Fig. S8). Although the grand mean effect size was
116 not significantly different from zero, 12 sites showed significantly higher SMDs of temperature
117 sensitivity in warmed plots (Site IDs 5, 8, 9, 13, 14,16, 19, 21, 23, 26-28), while eight sites (Site ID 1, 2,
118 11, 12, 15, 20, 22, 24) demonstrated significantly lower SMD in warmed plots compared to control plots.

119

120 *Role of Moisture in Controlling Respiration Rates*

121 Meta-analysis of soil moisture data reveals that moisture was significantly reduced with warming (RR=-
122 0.08, [95% CI:-0.12- -0.03]), with 7 out of 27 sites having significantly less soil moisture at the warmed
123 compared to control plots. However, such decreases were only marginally significantly correlated with
124 ΔT ($r= -0.32$, $p=0.08$) (Fig. S2A). Multivariate linear regression highlights that moisture typically
125 explains a much smaller fraction (0-8%) of the total respiration response compared to temperature (34-
126 82%), except in the case of southern shrublands, where moisture is a stronger predictor of respiration than
127 soil temperature (R^2 model a or b versus Model e in Table S3, Fig. S7). We used partial regression plots
128 (Fig. S7) to help visualize the effect of adding an additional variable (i.e., soil moisture) to a multiple
129 regression model. Partial regression with temperature and moisture highlight the more important role of
130 temperature in driving the soil respiration response compared to moisture (Fig. S7). This response is
131 demonstrated by the lower slopes on the added-variable moisture plots (right hand panels). An exception
132 to this is southern shrublands, where moisture added-variable plot has a much steeper slope compared to

133 other biomes, aligning with the multivariate regression output showing moisture playing a more important
134 role in predicting respiration compared to temperature in the southern shrublands.

135

136 Ambient soil moisture is a critical factor in mitigating the respiration-temperature relationship. For
137 example, a negative $\Delta R/\Delta T$ response with soil drying is only apparent in the desert, grassland, and
138 southern shrubland biomes (Fig. S9), likely because these biomes have the lowest ambient soil moisture
139 content (Table S1) and thus, even minor desiccation with warming suppresses C fluxes. On the other
140 hand, in the forest biomes where soil drying with warming was most severe (warmed plots have on
141 average 84% and 87% of the moisture that was observed in control plots in the boreal and temperate
142 forests, respectively), fluxes were still consistently higher from warmed plots despite drying (Fig. S9),
143 due in part to relatively elevated ambient soil moisture conditions at these sites (Table S1).

144

145 Soil moisture often has a non-linear relationship with soil respiration. In order to determine if our
146 multivariate linear model (Table S2) was a factor influencing our results, we re-ran our analysis using an
147 additional function (Eq. 4, see below), which shows little difference in model fits (Table S6). Our study
148 does not take into account differences in soil type between sites, as differences in soil type between
149 warmed and control plots within a site should be minimal. In addition, soil moisture content largely
150 reflects soil type across sites, as sandier soils hold less water than more clay-type soils. We see this in our
151 data, as average soil moisture content in several biomes was negatively related to percent sand ($r=0.98$,
152 0.62 , $r=0.55$ in northern shrublands, grasslands and forests, respectively). Our analyses of soil moisture
153 are based on soil water content (SWC), otherwise known as soil moisture concentrations. However, soil
154 matric potentials are a much better indicator of water availability in soils, as this metric takes into account
155 soil texture and organic matter content, which can affect relative water availability at the site level (1, 2).
156 Because both factors undoubtedly change across sites, soil matric potentials are likely a more sensitive
157 metric to evaluate how differences in moisture availability influence soil respiration rates.

158

159 *Role of Warming Duration and Seasonality on Soil Respiration Rates*

160 Multivariate analysis of respiration that included warming duration as a predictor, with an interaction with
161 warming treatment (Model h in Table S3) revealed a significant interaction between duration and
162 warming treatment in four biomes: desert, boreal forest, temperate forest, and northern shrubland. Except
163 for northern shrublands, the other three biomes displayed significantly depressed soil respiration rates
164 with increasing warming duration. Considering that it is in these three biomes where we observed
165 moderate (temperate forest) to strong (boreal forest and desert) evidence of altered temperature response
166 functions to soil warming, it appears that duration of experimental warming is an important factor in
167 driving these results. We also evaluated how duration of warming changes the temperature response
168 function of respiration in warmed versus control treatments by re-running our analysis shown in Table 1
169 with data partitioned into the following groupings of years of warming duration (<2, 2-5, 5-10, and >10).
170 This analysis continues to support prior conclusions, with no significant differences in the temperature
171 response function in any biome regardless of warming duration, except the boreal forests and desert, and
172 moderate ($p=0.06$) differences from 2-5 years of warming duration in temperate forest.

173

174 We investigated how season influenced soil respiration rates in a similar fashion to duration. First, we
175 added season as a predictor to our multilinear regression model, with an interaction with warming
176 treatment (Model i in Table S3). Here we found a significant interaction between season and warming
177 treatment in the desert and boreal forest biomes only, indicating that in these two biomes respiration from
178 warmed and control plots responds differently to temperature depending on the time of year. Next, we re-
179 ran our analysis shown in Table 1 with data partitioned into season (non-growing, growing, shoulder) and
180 found a similar result; for all biomes except the desert and boreal forests, no differences in temperature
181 sensitivity were observed when analyzing any particular season in isolation. In the boreal forest,
182 differences in temperature sensitivity were driven by growing season data, which make up the majority of
183 the data (70%) for the boreal forest biome. On the other hand, the differences in sensitivity observed in
184 the desert biome are driven by data from the non-growing season; this was the only season, when

185 examined in isolation, where significant differences in the temperature sensitivity of respiration from
186 warmed versus control plots are observed in the desert biome.

187

188 *Model Choice*

189 We used several different multivariate models (Table S3) to answer specific questions during our
190 analysis. To address our first objective (i.e., determine whether respiration response from warmed plots
191 paralleled that from control plots), we used a temperature-treatment interaction model (Models c or d in
192 Table S3, depending on whether the 2nd-order temperature term was significant when including the
193 treatment interaction term). We also compared the fits (specifically AICs) of Models c or d with models
194 excluding warming treatment as a predictor (Models a or b) to determine if warming treatments had an
195 effect on the respiration response (Table S3). Lower AICs in Models a or b (Table S3) compared to
196 Models c or d (Table S3) provides further evidence that experimental warming does not alter the shape of
197 the curve to a large degree in those biomes. Parameter values for Models a and b (Table S3) also shown in
198 Table S5. Next, to evaluate our second objective (i.e., investigate the role of soil moisture in influencing
199 how respiration responds to temperature across treatments), we included soil moisture as a predictor, with
200 an interaction term with temperature in our multivariate models (Models e and f in Table S3). Finally, to
201 determine how warming duration and seasonality were influencing our results, we ran three additional
202 models with these terms as predictors (Model g in Table S3), with an interaction term with warming
203 treatment (Models h and i in Table S3).

204

205 We did not use the traditional exponential model (the Q_{10} model) or the Arrhenius model to fit our data as
206 these models cannot adequately reflect our findings that the temperature sensitivity decreased when
207 temperature is above $\sim 25^{\circ}\text{C}$. The inability of these models to represent varying temperature sensitivities
208 across the temperature gradient has been discussed previously (3, 4). This study focused on understanding
209 the temperature response of soil respiration with experimental warming, rather than modeling soil
210 respiration. However, we also simulated our data using the following equation (5):

211

212 (4)
$$R = e^{\alpha(T-T_o)} \left(\frac{T_m - T}{T_m - T_o} \right)^{\alpha(T_m - T_o)} \left(\frac{M}{k_m + M} \right)$$

213

214 With R = non-transformed soil respiration rate, T= soil temperature (°C), T_o = optimum soil temperature
215 (°C), T_m = maximum soil temperature (°C), M = soil moisture concentration (cm³ cm⁻³). T_o, T_m, k_m and α
216 were solved individually for each biome. Irrespective of having a similar or better overall performance
217 (R² in Table S6), we selected the log-linear or log-quadratic equations to fit our data (Table 1, Eq. 1,
218 Models c and d in Table S3) because it facilitated use of the binary categorical variable to evaluate
219 differences in temperature response functions with warming treatment.

220

221 *Cross-Biome Differences*

222 Temperature response functions of soil respiration were not equal across biomes; not only were the
223 temperature sensitivities different (γ₁ and γ₂, Table 1), but the magnitudes of respiration (γ_o, Table 1) also
224 differed, with highest fluxes from boreal forests and lowest fluxes from deserts (Fig. S4). Multivariate
225 regression output highlights these across-biome differences, as adding ‘biome’ as a predictor to the larger
226 multivariate regression of all non-desert data increased the predictive power of the model by 28% (Model
227 j in Table S3).

228

229 **Supporting References**

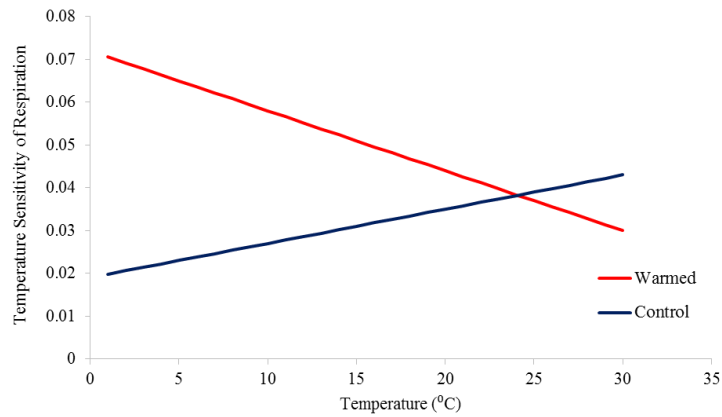
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287 **Fig. S1.**

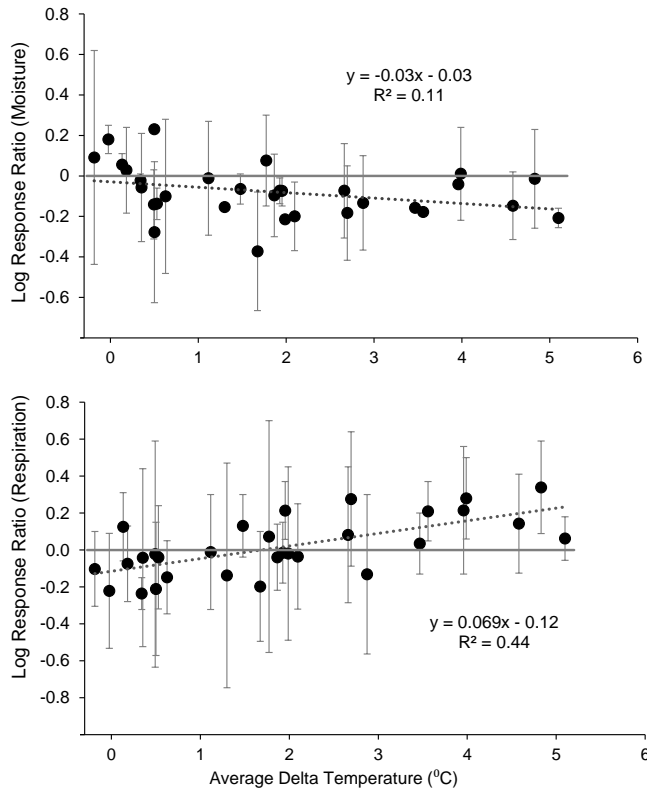


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289
290

291 Temperature sensitivities for desert calculated as the linear functions describing the derivative of the log-
292 quadratic fit of ln respiration as a function of soil temperatures: $\frac{\partial y}{\partial t} = -0.0014 T + 0.072$ (warmed) and $\frac{\partial y}{\partial t}$
293 $= 0.0008 T + 0.019$ (control), where y refers to ln of respiration ($\mu\text{mol C m}^{-2} \text{s}^{-1}$) and T refers to
294 temperature ($^{\circ}\text{C}$).

295

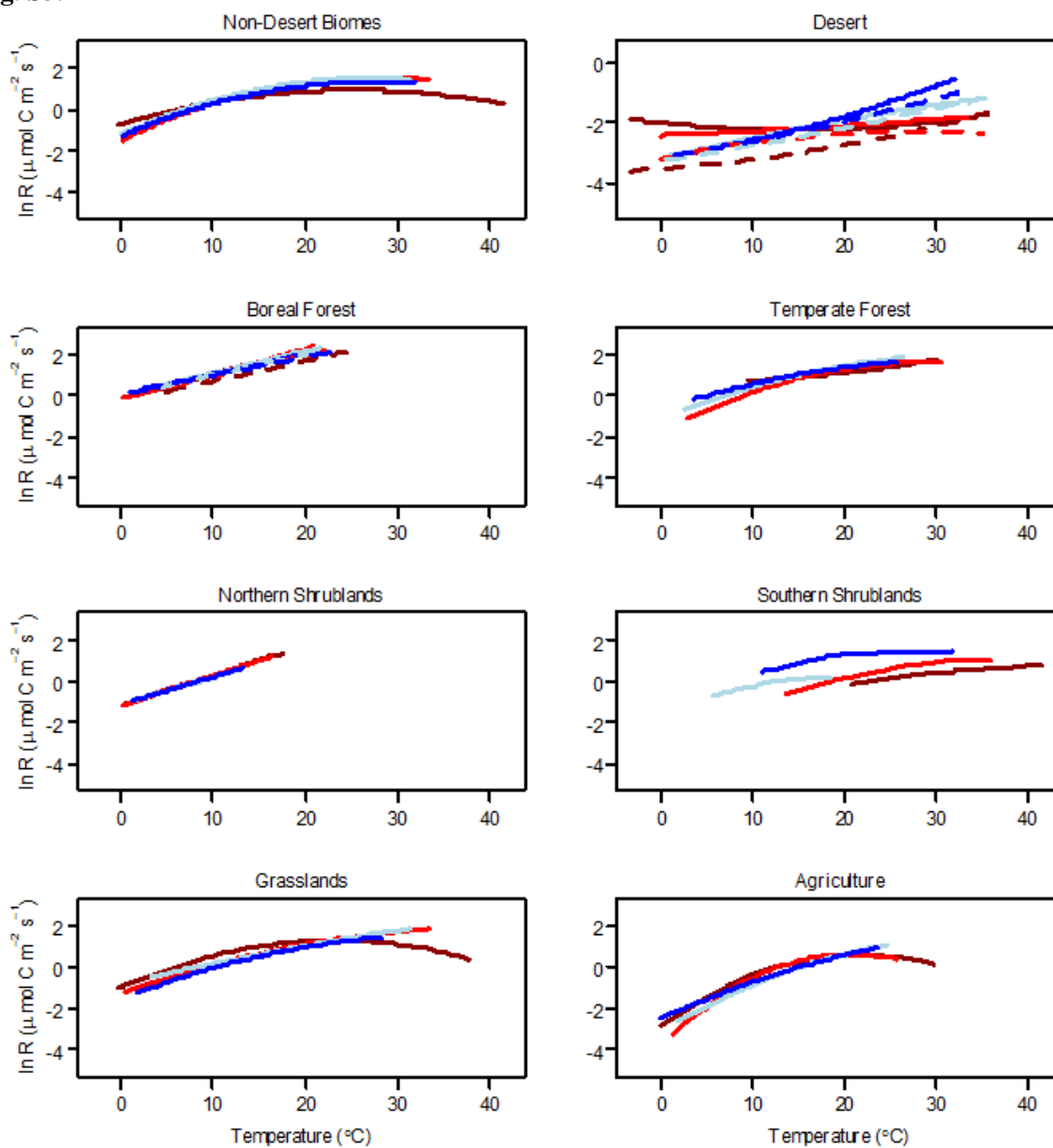
296 **Fig. S2.**



297
298 Effect size (log response ratio) as a function of degree of experimental warming (ΔT (°C)) for moisture
299 (A) and respiration (B). Data from all biomes plotted here.

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301

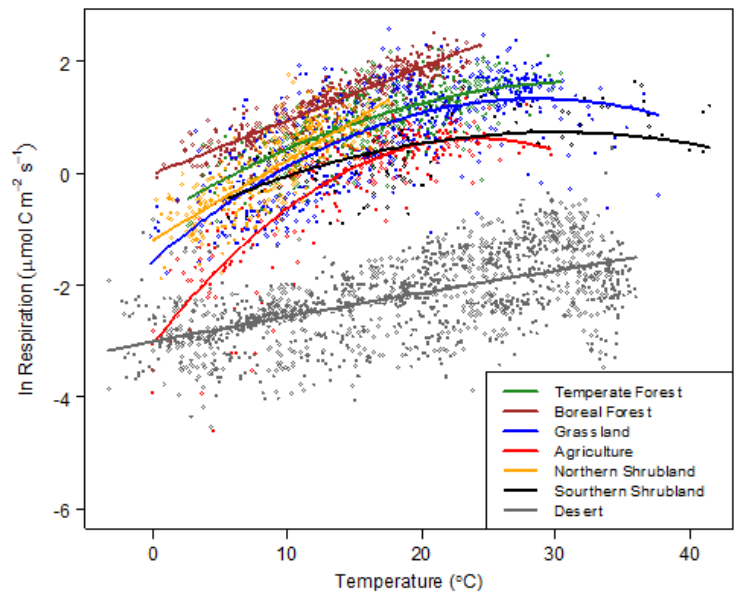
302 **Fig. S3.**



303
304
305 Best fit regression lines of natural log (ln) of respiration ($\mu\text{mol C m}^{-2} \text{s}^{-1}$) as a function of soil temperature
306 ($^{\circ}\text{C}$) across biome types, with data partitioned into moisture quantiles: dark red (1st (lowest) quartile), red
307 (2nd quartile), light blue (3rd quartile), dark blue (4th (highest) quartile). For model parameters, see Table
308 S3. Separate fits were calculated for control and warmed treatments where statistically different
309 temperature sensitivities were observed (boreal forest and desert), with dashed lines for warmed data and
310 solid lines for control data. Solid lines on all other plots represent both warmed and control data, as their

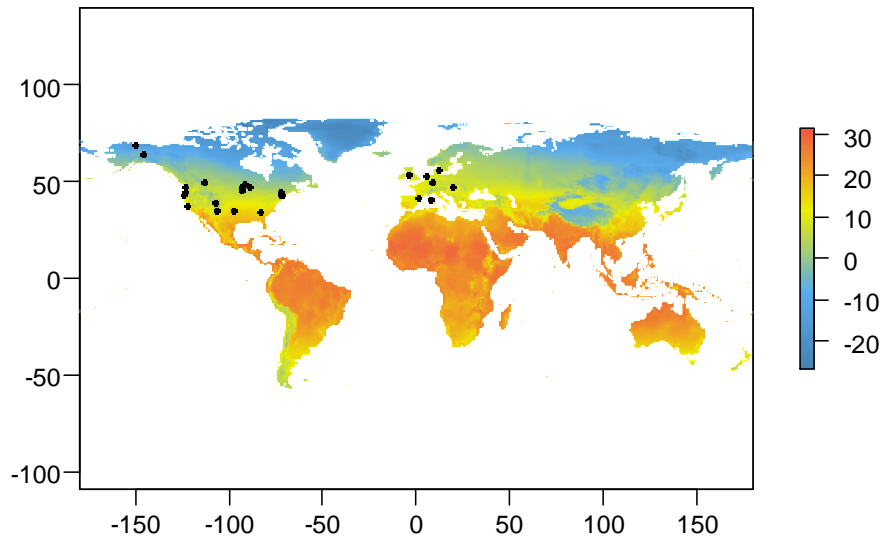
311 fits were not statistically different from one another. Note the scale of Y-axis are all equal, except for
312 desert, which had lower respiration rates compared to all other biomes.

313 **Fig. S4.**
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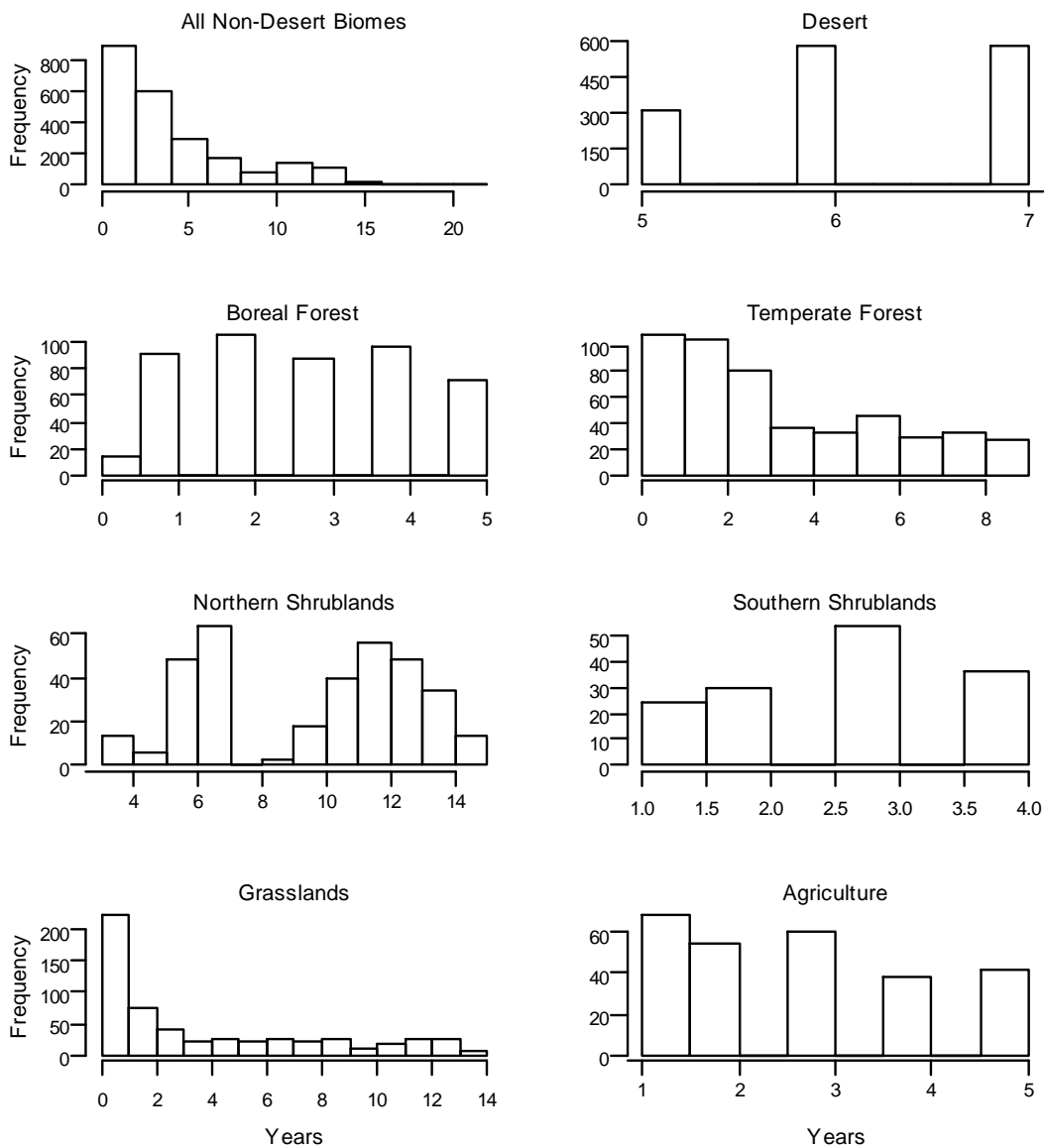
315
316
317 Ln respiration ($\mu\text{mol C m}^{-2} \text{s}^{-1}$) as a function of soil temperature ($^{\circ}\text{C}$) for all data included in our study.
318 Each dot represents an individual data point, including data from both control and warmed treatments
319 ($n=3817$). Lines are best-fit regression lines using the log-quadratic temperature response functions for all
320 biomes, except the boreal forest and northern shrublands, where log-linear functions were used (for
321 coefficients, see Table S5).
322

323 **Fig. S5.**



324
325 Map of study sites. Color refers to mean annual temperature (°C). Map created using 'maps', 'mapdata',
326 and 'raster' packages in R.

327 **Fig S6.**

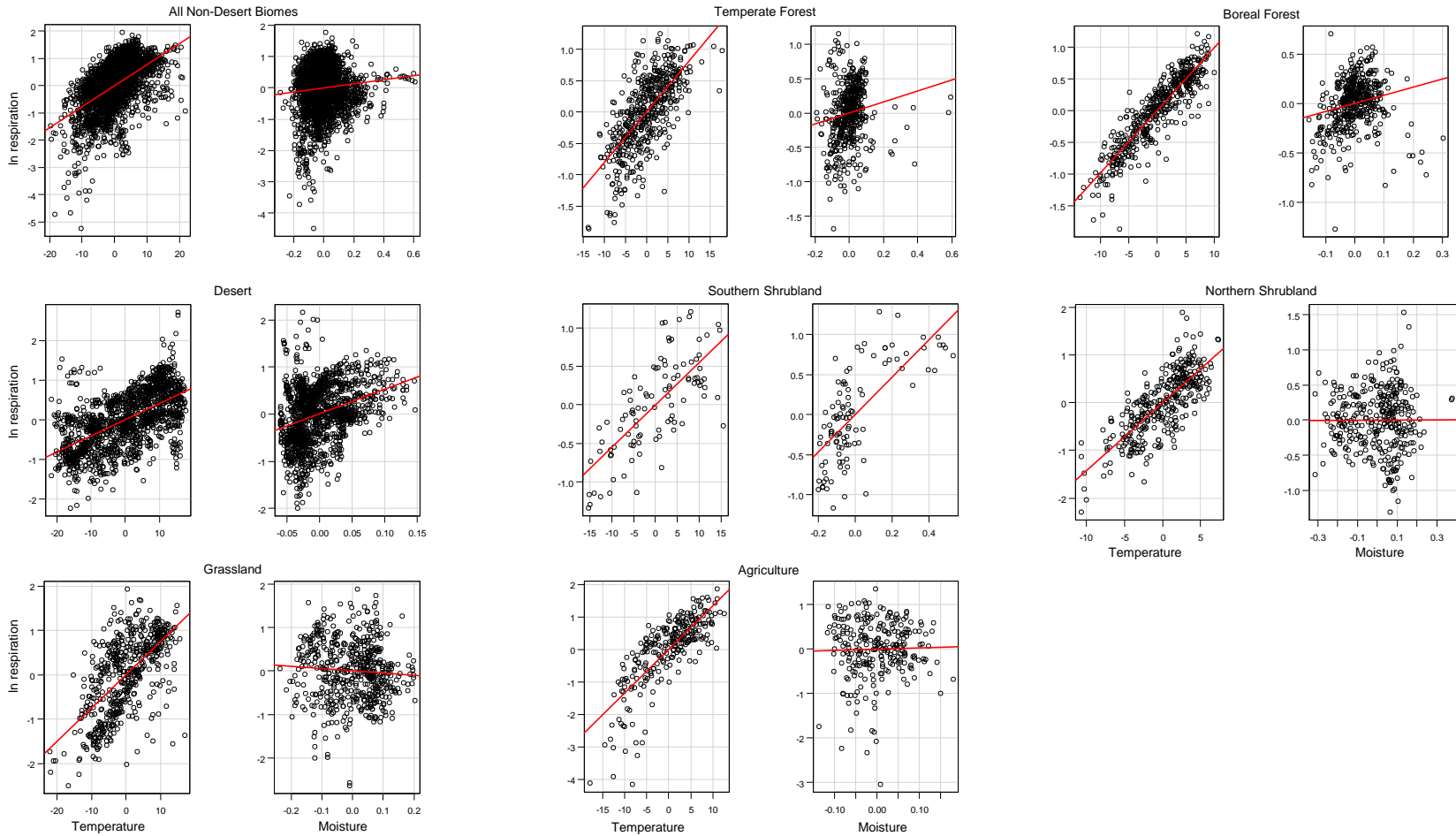


328

329 Histogram of duration of warming within each biome.

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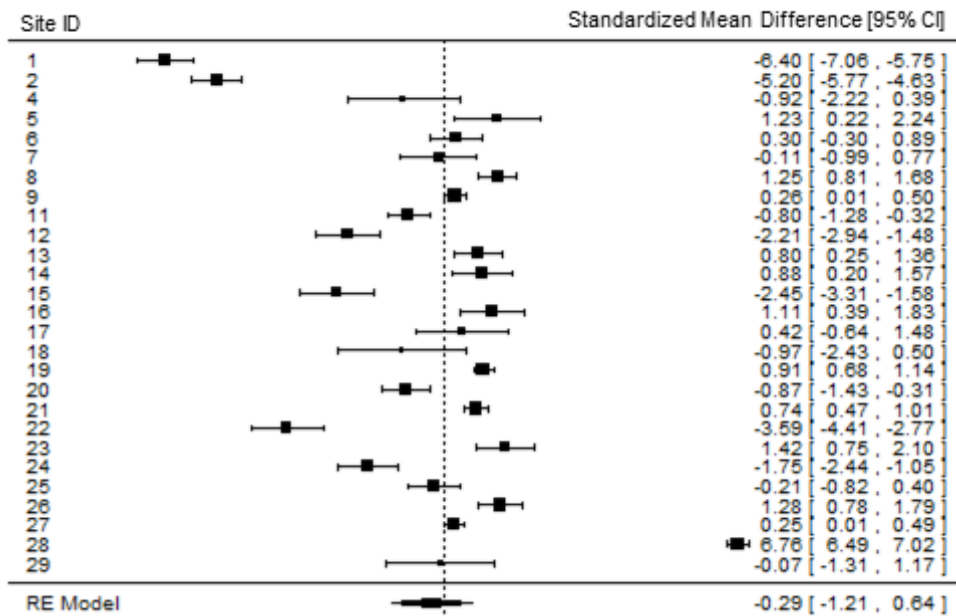
Fig. S7.



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Partial regression plots of soil respiration as a function of temperature and moisture across all biomes. Plots created using the 'car' package and AvPlots function in R.

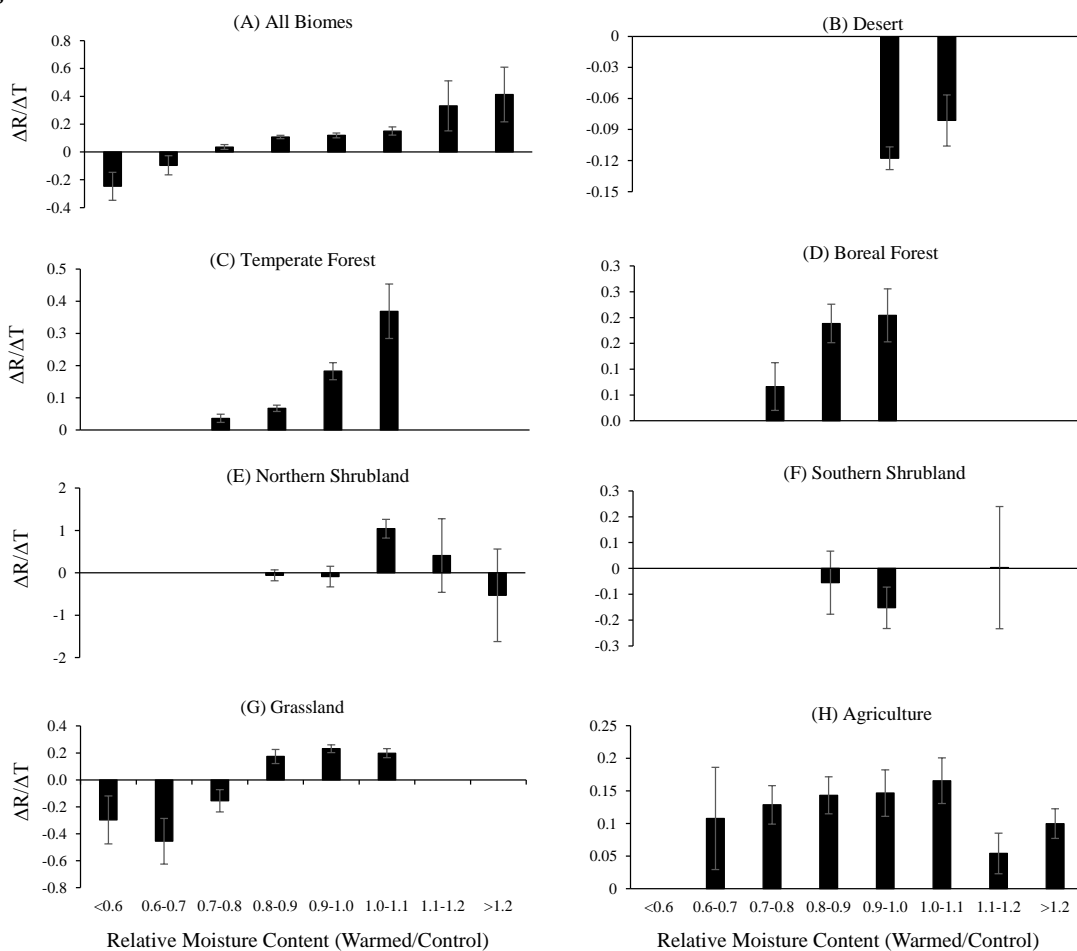
336 **Fig. S8**



337
 338 Forest plot of first-order temperature sensitivities (γ_1 in Eq. 1) at each site. Size of filled squares indicates
 339 number of observations. Error bars represent 95% confidence intervals. Error bars that do not cross zero
 340 line indicate significant differences in temperature sensitivity between warmed and control plots. Values
 341 on right of zero line indicate higher sensitivity in warmed plots, while values on left of zero line indicate
 342 lower sensitivity of warmed plots.

343
 344

345 **Fig. S9.**



346
 347
 348 Difference in respiration ($\mu\text{mol C m}^{-2} \text{s}^{-1}$) between warmed and control plots (ΔR) normalized by degree
 349 of warming (ΔT °C), binned by amount of soil desiccation with warming (soil moisture content in
 350 warmed plots divided by soil moisture content in control plots) for each individual biome. X axis values
 351 <1 indicate warmed plots have less moisture available than control plots. Y axis values <0 indicate that
 352 respiration rates were lower from warmed plots, despite warmer soil temperatures. Respiration data not
 353 log transformed. Note the scales of the Y-axes are different. For number of observations by biome see
 354 Table S3.

355 **Supplementary Tables**

356

357 **Table S1.**

| Site ID | Name | Ecosystem Type | Warming Method | n | Average Delta Temperature (°C) | Control | | Warmed Treatment (multiple levels) | | Average Ambient Moisture (cm ³ cm ⁻³) | Average Delta Moisture (cm ³ cm ⁻³) | MAP (mm) | MAT (°C) | Elevation (m) | Duration Range** | %Sand | %Silt | %Clay |
|---------|-----------------|-----------------------|----------------|-----|--------------------------------|---|------|---|------|--|--|----------|----------|---------------|------------------|-------|-------|-------|
| | | | | | | Average Respiration (μmol m ⁻² s ⁻¹) | SE | Average Respiration (μmol m ⁻² s ⁻¹) | SE | | | | | | | | | |
| 1 | B4W_CFC | Boreal Forest | Infrared | 75 | 1.87 | 4.38 | 0.29 | 4.21 | 0.25 | 0.213 | 0.020 | 752 | 4.23 | 413 | 5 | 60.9 | 30.5 | 8.6 |
| 1 | B4W_CFC | Boreal Forest | Infrared | 75 | 3.47 | | | 4.53 | 0.24 | | -0.031 | | | | | | | |
| 2 | B4W_HWRC | Boreal Forest | Infrared | 71 | 1.93 | 4.08 | 0.26 | 4.02 | 0.22 | 0.278 | 0.020 | 665 | 3.57 | 383 | 5 | 62.3 | 23.5 | 14.2 |
| 2 | B4W_HWRC | Boreal Forest | Infrared | 71 | 3.56 | | | 5.03 | 0.25 | | -0.045 | | | | | | | |
| 4 | Tower_Burn | Boreal Forest | Passive | 5 | 0.49 | 1.68 | 0.40 | 1.65 | 0.34 | 0.475 | 0.062 | 303 | -2 | 457 | 2 | 31.6 | 56.8 | 11.8 |
| 5 | Tower_Control | Boreal Forest | Passive | 9 | 0.50 | 2.40 | 0.19 | 1.94 | 0.33 | 0.202 | 0.049 | 303 | -2 | 499 | 2 | 34.1 | 53.5 | 12.4 |
| 6 | Ford^ | Temperate Forest | Infrared | 22 | 4.58 | 2.89 | 0.28 | 3.33 | 0.31 | 0.240 | 0.033 | 879 | 4.9 | 402 | 5 | 62.1 | 29.0 | 9.0 |
| 7 | HBEF | Temperate Forest | Electric Cable | 10 | 4.83 | 5.18 | 0.52 | 7.28 | 0.61 | 0.144 | 0.002 | 1400 | 5.2 | 252 | 1 | 60.0 | 30.0 | 10.0 |
| 8 | HF_Frey | Temperate Forest | Electric Cable | 48 | 3.99 | 1.91 | 0.16 | 2.53 | 0.19 | 0.243 | -0.003 | 1100 | 7 | 1026.5 | 8 | 62.0 | 22.0 | 15.0 |
| 9 | HF_Melillo | Temperate Forest | Electric Cable | 130 | 5.10 | 3.03 | 0.14 | 3.22 | 0.13 | 0.276 | 0.052 | 1080 | 7 | 1026.5 | 9 | 62.0 | 22.0 | 15.0 |
| 11 | Whitehall | Temperate Forest | Electric Cable | 29 | 2.10 | 3.10 | 0.34 | 3.00 | 0.29 | 0.171 | 0.031 | 99 | 17.6 | 207 | 4 | 63.9 | 18.0 | 18.1 |
| 11 | Whitehall | Temperate Forest | Electric Cable | 19 | 3.96 | | | 4.24 | 0.50 | | -0.007 | | | | | | | |
| 12 | BACE^ | Temperate Grassland | Infrared | 14 | 0.35 | 3.22 | 0.59 | 3.09 | 0.51 | 0.225 | 0.013 | 1194 | 9.5 | 17 | 2 | 45.0 | 46.0 | 9.0 |
| 12 | BACE^ | Temperate Grassland | Infrared | 14 | 1.99 | | | 3.16 | 0.49 | | -0.044 | | | | | | | |
| 12 | BACE^ | Temperate Grassland | Infrared | 14 | 2.93 | | | 3.26 | 0.45 | | -0.070 | | | | | | | |
| 13 | BioCON | Temperate Grassland | Infrared | 27 | 1.67 | 5.30 | 0.59 | 4.35 | 0.46 | 0.079 | 0.025 | 660 | 6.7 | 282 | 2 | 94.4 | 0.0 | 2.5 |
| 14 | COR | Temperate Grassland | Infrared | 18 | 2.66 | 2.75 | 0.38 | 2.99 | 0.37 | 0.257 | 0.018 | 1134 | 11.4 | 164 | 2 | 36.5 | 49.0 | 14.5 |
| 15 | SOR | Temperate Grassland | Infrared | 18 | 2.88 | 2.92 | 0.47 | 2.56 | 0.38 | 0.234 | 0.029 | 1434 | 12.3 | 395 | 2 | 31.5 | 37.5 | 31.0 |
| 16 | WA | Temperate Grassland | Infrared | 17 | 2.70 | 2.18 | 0.29 | 2.87 | 0.37 | 0.162 | 0.027 | 1196 | 10.5 | 134 | 2 | 75.0 | 21.5 | 3.5 |
| 17 | FluxnetCanada * | Temperate Grassland | Passive | 7 | 0.50 | 3.27 | 0.70 | 8.44 | 0.98 | 0.220 | -0.057 | 386 | 5.4 | 960 | 1 | 28.8 | 40.0 | 31.2 |
| 18 | JasperRidge | Temperate Grassland | Infrared | 4 | 1.77 | 4.87 | 1.53 | 5.23 | 0.35 | 0.076 | -0.006 | 531 | 15.3 | 120 | 1 | 37.0 | 48.0 | 15.0 |
| 19 | Kessler | Temperate Grassland | Infrared | 164 | 1.48 | 2.20 | 0.13 | 2.51 | 0.15 | 0.255 | 0.016 | 914 | 16.3 | 335 | 13 | 36.0 | 55.0 | 10.0 |
| 20 | MountainMeadow^ | Meadow | Infrared | 27 | 1.12 | 2.49 | 0.29 | 2.46 | 0.27 | 0.109 | 0.001 | 750 | | 2920 | 20 | na | na | na |
| 21 | Clocaenog | Northern Shrubland | Passive | 114 | 0.13 | 1.23 | 0.09 | 1.40 | 0.09 | 0.421 | -0.024 | 1289 | 8.2 | 490 | 13 | 40.2 | 50.0 | 9.8 |
| 22 | Garraf | Southern Shrubland | Passive | 30 | 0.18 | 1.11 | 0.09 | 1.03 | 0.07 | 0.185 | -0.005 | 570 | 15.6 | 215 | 2 | 42.9 | 38.7 | 18.4 |
| 23 | Hungary* | Southern Shrubland | Passive | 21 | 0.63 | 0.42 | 0.03 | 0.37 | 0.03 | 0.051 | 0.005 | 505 | 10.4 | | 3 | | | |
| 24 | Oldbroek | Northern Shrubland | Passive | 22 | -0.02 | 1.39 | 0.16 | 1.11 | 0.12 | 0.215 | -0.043 | 1072 | 10.1 | 25 | 3 | 93.5 | 6.0 | 0.5 |
| 25 | PCCC^ | Southern Shrubland | Passive | 21 | -0.18 | 3.08 | 0.22 | 2.78 | 0.20 | 0.328 | -0.031 | 640 | 16.8 | 40 | 3 | 75.6 | 11.2 | 13.4 |
| 26 | Brandbjerg | Northern Shrubland | Passive | 36 | 0.53 | 1.73 | 0.17 | 1.66 | 0.17 | 0.178 | 0.023 | 757 | 8.7 | 9 | 2 | 91.0 | 7.0 | 2.0 |
| 27 | HoCC | Temperate Agriculture | Electric Cable | 131 | 1.95 | 1.07 | 0.06 | 1.32 | 0.07 | 0.210 | 0.015 | 679 | 8.7 | 395 | 5 | 9.0 | 69.0 | 22.0 |
| 28 | Sevilleta | Desert | Passive | 737 | 0.34 | 0.16 | 0.00 | 0.13 | 0.00 | 0.112 | 0.003 | 250 | 13.2 | 1525 | 3 | 68.0 | 22.0 | 10.0 |
| 29 | Toolik | Wet Sedge Tundra | Passive | 5 | 1.30 | 0.76 | 0.20 | 0.66 | 0.11 | 0.700 | 0.100 | 331 | -8.5 | 717 | 1 | na | na | na |

*data from published literature only

^ data from both published and unpublished data

**Years of observations since warming started

358

359 Characteristics of each site included in study, including both published and unpublished sources (6–17).

360

361 **Table S2**

| Parameters for models: $\ln(R) \sim \alpha_0 + \alpha_1 T + \alpha_2 T^2 + \alpha_3 M$ | | | | | | |
|--|--|--|--|--|----------|----------------------|
| Model | $\alpha_0 \pm \text{SE}$ | $\alpha_1 \pm \text{SE}$ | $\alpha_2 \pm \text{SE}$ | $\alpha_3 \pm \text{SE}$ | n | R² |
| <i>All Biomes Except Desert</i> | -1.547 ± 0.078 | 0.210 ± 0.008 | -0.004 ± 0.0022 | 0.692 ± 0.142 | 2343 | 0.39 |
| <i>Desert</i> | | | | | | |
| Control Treatment | -2.875 ± 0.069 | 0.009 ± 0.007 | 0.001 ± 0.0002 | 3.320 ± 0.474 | 737 | 0.38 |
| Warming Treatment | -4.065 ± 0.078 | 0.005 ± 0.008 | <0.0001 ± 0.0002 | 7.228 ± 0.549 | 737 | 0.53 |
| <i>Boreal Forest</i> | | | | | | |
| Control Treatment | 0.020 ± 0.085 | 0.108 ± 0.003 | na | -0.286 ± 0.256 | 160 | 0.88 |
| Warming Treatment | -0.368 ± 0.074 | 0.098 ± 0.003 | na | 1.301 ± 0.231 | 306 | 0.82 |
| <i>Temperate Forest</i> | -1.082 ± 0.157 | 0.152 ± 0.017 | -0.002 ± 0.0005 | 0.817 ± 0.234 | 497 | 0.52 |
| <i>Northern Shrubland</i> | -1.180 ± 0.106 | 0.142 ± 0.006 | na | 0.020 ± 0.187 | 344 | 0.63 |
| <i>Southern Shrubland</i> | -1.825 ± 0.244 | 0.109 ± 0.022 | -0.001 ± 0.0005 | 2.236 ± 0.234 | 102 | 0.6 |
| <i>Grassland</i> | -1.338 ± 0.145 | 0.201 ± 0.015 | -0.004 ± 0.0004 | -0.708 ± 0.299 | 566 | 0.52 |
| <i>Temperate Agriculture</i> | -3.076 ± 0.206 | 0.304 ± 0.022 | -0.006 ± 0.0078 | 0.202 ± 0.597 | 262 | 0.72 |

362

363

364 Parameters for multivariate regression model of soil respiration (natural log, in $\mu\text{mol C m}^{-2} \text{s}^{-1}$) (R) as a365 function of soil temperature ($^{\circ}\text{C}$) (T) and soil moisture ($\text{cm}^3 \text{cm}^{-3}$) (M). In biomes with significantly

366 different temperature sensitivities between warming and control treatments (boreal and desert biomes),

367 control and warmed data were run in model separately. n= number of observations, R² = coefficient of368 determination. Parameter units: $\alpha_0 = \ln \mu\text{mol C m}^{-2} \text{s}^{-1}$; $\alpha_1 = ^{\circ}\text{C}^{-1}$; $\alpha_2 = ^{\circ}\text{C}^{-2}$, $\alpha_3 = \text{cm}^{-3} \text{cm}^3$.

369

370 **Table S3.**

| Model ID | Model Terms | Significant Interaction? | df | R ² | Δ AICc |
|--|--|--------------------------|------|----------------|--------|
| <i>All Biomes Except Desert (n=2343)</i> | | | | | |
| a | R~T | NA | 2341 | 0.30 | 1745 |
| b | R~T + T ² | NA | 2340 | 0.39 | 1436 |
| c | R~T*W | No | 2339 | 0.30 | 1744 |
| d | R~T*W + T ² *W | No | 2327 | 0.39 | 1437 |
| e | R~T + T ² + Moisture | NA | 2339 | 0.39 | 1415 |
| f | R~T*Moisture + T ² *Moisture | No | 2337 | 0.41 | 1359 |
| g | R~T + T ² + Moisture + Duration | NA | 2338 | 0.40 | 1393 |
| h | R~T + T ² + Duration*W | No | 2337 | 0.39 | 1429 |
| i | R~T + T ² + Season*W | No | 2335 | 0.44 | 1222 |
| j | R~T*Biome + T ² *Biome + Moisture | Yes | 2321 | 0.67 | 0 |
| <i>Desert (n=1474)</i> | | | | | |
| a | R~T | NA | 1472 | 0.34 | 318 |
| b | R~T + T ² | NA | 1471 | 0.34 | 320 |
| c | R~T*W | Yes | 1470 | 0.41 | 153 |
| d | R~T*W + T ² *W | Yes | 1468 | 0.42 | 144 |
| e | R~T + T ² + Moisture | NA | 1470 | 0.42 | 140 |
| f | R~T*Moisture + T ² *Moisture | Yes | 1468 | 0.47 | 0 |
| g | R~T + T ² + Moisture + Duration | NA | 1469 | 0.42 | 139 |
| h | R~T + T ² + Duration*W | Yes | 1468 | 0.42 | 143 |
| i | R~T + T ² + Season*W | Yes | 1466 | 0.44 | 76 |
| <i>Boreal Forest (n=466)</i> | | | | | |
| a | R~T | NA | 464 | 0.82 | 52 |
| b | R~T + T ² | NA | 463 | 0.82 | 43 |
| c | R~T*W | Yes | 463 | 0.84 | 2 |
| d | R~T*W + T ² *W | No | 460 | 0.84 | 0 |
| e | R~T + Moisture | NA | 463 | 0.82 | 34 |
| f | R~T*Moisture | Yes | 462 | 0.83 | 21 |
| g | R~T + Moisture + Duration | NA | 462 | 0.83 | 29 |
| h | R~T + Duration*W | Yes | 461 | 0.83 | 8 |
| i | R~T + T ² + Season*W | Yes | 459 | 0.83 | 12 |
| <i>Temperate Forest (n=497)</i> | | | | | |
| a | R~T | NA | 495 | 0.49 | 92 |
| b | R~T + T ² | NA | 494 | 0.51 | 77 |
| c | R~T*W | No | 493 | 0.52 | 62 |
| d | R~T*W + T ² *W | No | 491 | 0.54 | 46 |
| e | R~T + T ² + Moisture | NA | 493 | 0.52 | 67 |
| f | R~T*Moisture + T ² *Moisture | No | 491 | 0.52 | 69 |
| g | R~T + T ² + Moisture + Duration | NA | 492 | 0.52 | 69 |
| h | R~T + T ² + Duration*W | Yes | 491 | 0.54 | 45 |
| i | R~T + T ² + Season*W | No | 489 | 0.58 | 0 |
| <i>Northern Shrubland (n=344)</i> | | | | | |
| a | R~T | NA | 342 | 0.63 | 60 |
| b | R~T + T ² | NA | 341 | 0.63 | 62 |
| c | R~T*W | No | 340 | 0.63 | 64 |
| d | R~T*W + T ² *W | No | 338 | 0.63 | 65 |
| e | R~T + Moisture | NA | 341 | 0.63 | 62 |
| f | R~T*Moisture | No | 340 | 0.63 | 63 |
| g | R~T + Moisture + Duration | NA | 340 | 0.69 | 0 |
| h | R~T + Duration*W | Yes | 339 | 0.69 | 7 |
| i | R~T + Season*W | No | 337 | 0.63 | 66 |

371

372

373 **Table S3 Continued.**

| Model ID | Model Terms | Significant Interaction? | df | R ² | ΔAICc |
|--|--|--------------------------|-----|----------------|-------|
| <i>Southern Shrubland - no Hungary (n=102)</i> | | | | | |
| a | R~T | NA | 100 | 0.15 | 92 |
| b | R~T + T ² | NA | 99 | 0.23 | 85 |
| c | R~T*W | No | 98 | 0.16 | 96 |
| d | R~T*W + T ² *W | No | 96 | 0.25 | 88 |
| e | R~T + T ² + Moisture | NA | 98 | 0.60 | 19 |
| f | R~T*Moisture + T ² *Moisture | No | 96 | 0.60 | 23 |
| g | R~T + T ² + Moisture + Duration | NA | 97 | 0.68 | 0 |
| h | R~T + T ² + Duration*W | No | 96 | 0.47 | 46 |
| i | R~T + T ² + Season*W | No | 94 | 0.18 | 93 |
| <i>Southern Shrubland - with Hungary (n=144)</i> | | | | | |
| a | R~T | NA | 142 | 0.06 | 124 |
| b | R~T + T ² | NA | 141 | 0.09 | 120 |
| c | R~T*W | No | 140 | 0.06 | 127 |
| d | R~T*W + T ² *W | No | 138 | 0.11 | 123 |
| e | R~T + T ² + Moisture | NA | 140 | 0.6 | 4 |
| f | R~T*Moisture + T ² *Moisture | No | 128 | 0.62 | 0 |
| g | R~T + T ² + Moisture + Duration | NA | 139 | 0.62 | 1 |
| <i>Grassland (n=566)</i> | | | | | |
| a | R~T | NA | 564 | 0.45 | 151 |
| b | R~T + T ² | NA | 563 | 0.52 | 82 |
| c | R~T*W | No | 562 | 0.45 | 154 |
| d | R~T*W + T ² *W | No | 560 | 0.51 | 87 |
| e | R~T + T ² + Moisture | NA | 562 | 0.52 | 78 |
| f | R~T*Moisture + T ² *Moisture | Yes | 560 | 0.54 | 51 |
| g | R~T + T ² + Moisture + Duration | NA | 561 | 0.56 | 24 |
| h | R~T + T ² + Duration*W | No | 560 | 0.56 | 24 |
| i | R~T + T ² + Season*W | No | 558 | 0.58 | 0 |
| <i>Temperate Agriculture (n=262)</i> | | | | | |
| a | R~T | NA | 260 | 0.66 | 73 |
| b | R~T + T ² | NA | 259 | 0.72 | 17 |
| c | R~T*W | No | 258 | 0.66 | 75 |
| d | R~T*W + T ² *W | No | 256 | 0.73 | 22 |
| e | R~T + T ² + Moisture | NA | 258 | 0.72 | 19 |
| f | R~T*Moisture + T ² *Moisture | Yes | 256 | 0.74 | 9 |
| g | R~T + T ² + Moisture + Duration | NA | 257 | 0.73 | 16 |
| h | R~T + T ² + Duration*W | No | 256 | 0.73 | 18 |
| i | R~T + T ² + Season*W | No | 254 | 0.74 | 0 |

374
375 Summary of various models and their fits of soil respiration as a function of multiple variables. R = soil
376 respiration (natural log, in $\mu\text{mol C m}^{-2} \text{ s}^{-1}$), T = soil temperature ($^{\circ}\text{C}$), M= soil moisture content ($\text{cm}^3 \text{ cm}^{-3}$),
377 ³), W = treatment (control or warmed), df=degrees of freedom, R²= coefficient of determination, ΔAICc =
378 delta Akaike information criterion, with zero as best and all other model values presented relative to zero.
379 Bold indicates significant predictor of respiration. Asterisk indicates interaction term in model.

380 **Table S4.**

| Parameters for models: $\text{LnR} \sim \alpha_0 + \alpha_1 T + \alpha_2 T^2$ | | | | | |
|---|------------|------------|------------|-----|-------|
| Moisture Quartile ($\text{cm}^3 \text{cm}^{-3}$) | α_0 | α_1 | α_2 | n | R^2 |
| <i>Non-desert biomes</i> | | | | | |
| First quartile (<0.163) | -0.897 | 0.147 | -0.0029 | 585 | 0.13 |
| Second quartile (0.163-0.228) | -1.410 | 0.211 | -0.0038 | 580 | 0.49 |
| Third quartile (0.228-0.29) | -1.224 | 0.201 | -0.0036 | 559 | 0.42 |
| Fourth quartile (>0.29) | -1.276 | 0.188 | -0.0033 | 605 | 0.46 |
| <i>Desert - Control</i> | | | | | |
| First quartile (<0.082) | -2.010 | -0.032 | 0.0011 | 184 | 0.01 |
| Second quartile (0.082-0.102) | -2.418 | 0.016 | 0.0002 | 185 | 0.23 |
| Third quartile (0.102-0.139) | -3.200 | 0.074 | -0.0005 | 183 | 0.59 |
| Fourth quartile (>0.139) | -3.170 | 0.046 | 0.0012 | 185 | 0.88 |
| <i>Desert - Warmed</i> | | | | | |
| First quartile (<0.082) | -3.544 | 0.023 | 0.0008 | 184 | 0.60 |
| Second quartile (0.082-0.102) | -3.220 | 0.066 | -0.0012 | 183 | 0.17 |
| Third quartile (0.102-0.14) | -3.300 | 0.051 | 0.0002 | 184 | 0.46 |
| Fourth quartile (>0.14) | -3.155 | 0.049 | 0.0054 | 186 | 0.76 |
| <i>Boreal Forest - Control</i> | | | | | |
| First quartile (<0.21) | -0.147 | 0.110 | na | 40 | 0.90 |
| Second quartile (0.21-0.245) | -0.150 | 0.120 | na | 40 | 0.94 |
| Third quartile (0.245-0.284) | -0.014 | 0.108 | na | 40 | 0.94 |
| Fourth quartile (>0.284) | 0.026 | 0.100 | na | 40 | 0.72 |
| <i>Boreal Forest - Warmed</i> | | | | | |
| First quartile (<0.186) | -0.308 | 0.099 | na | 77 | 0.85 |
| Second quartile (0.186-0.226) | -0.069 | 0.100 | na | 77 | 0.82 |
| Third quartile (0.226-0.263) | -0.067 | 0.103 | na | 76 | 0.90 |
| Fourth quartile (>0.263) | 0.106 | 0.087 | na | 76 | 0.75 |
| <i>Temperate Forest</i> | | | | | |
| First quartile (<0.176) | 0.530 | 0.002 | 0.0013 | 124 | 0.20 |
| Second quartile (0.176-0.233) | -1.800 | 0.232 | -0.0040 | 128 | 0.68 |
| Third quartile (0.223-0.279) | -1.126 | 0.176 | -0.0024 | 120 | 0.64 |
| Fourth quartile (>0.279) | -0.672 | 0.140 | -0.0019 | 125 | 0.54 |
| <i>Northern Shrubland</i> | | | | | |
| First quartile (<0.2157) | -1.183 | 0.145 | na | 86 | 0.83 |
| Second quartile (0.2157-0.389) | -1.167 | 0.144 | na | 86 | 0.57 |
| Third quartile (0.389-0.458) | -1.106 | 0.128 | na | 86 | 0.37 |
| Fourth quartile (>0.458) | -1.115 | 0.132 | na | 86 | 0.45 |
| <i>Southern Shrubland</i> | | | | | |
| First quartile (<0.1128) | -1.990 | 0.114 | -0.0012 | 26 | 0.31 |
| Second quartile (0.1128-0.199) | -3.200 | 0.230 | -0.0031 | 25 | 0.54 |
| Third quartile (0.199-0.2898) | -1.505 | 0.167 | -0.0040 | 25 | 0.37 |
| Fourth quartile (>0.2898) | -1.560 | 0.228 | -0.0042 | 26 | 0.55 |
| <i>Grassland</i> | | | | | |
| First quartile (<0.141) | -0.990 | 0.195 | -0.0040 | 141 | 0.29 |
| Second quartile (0.141-0.23) | -1.240 | 0.156 | -0.0020 | 142 | 0.68 |
| Third quartile (0.23-0.29) | -0.827 | 0.104 | 0.0006 | 142 | 0.47 |
| Fourth quartile (>0.291) | -1.570 | 0.175 | -0.0020 | 141 | 0.52 |
| <i>Temperate Agriculture</i> | | | | | |
| First quartile (<0.151) | -2.816 | 0.310 | -0.0070 | 65 | 0.74 |
| Second quartile (0.151-0.198) | -3.810 | 0.431 | -0.0100 | 66 | 0.78 |
| Third quartile (0.198-0.25) | -3.126 | 0.264 | -0.0039 | 65 | 0.62 |
| Fourth quartile (>0.25) | -2.530 | 0.207 | -0.0026 | 66 | 0.76 |

381
382 Parameters for models of natural log (ln) respiration ($\mu\text{mol C m}^{-2} \text{s}^{-1}$) as a function of soil temperature

383 ($^{\circ}\text{C}$) by moisture quartile for each biome. Data also shown in Fig. S3.

384 **Table S5**

| Model | $\gamma_0 \pm \text{SE}$ | $\gamma_1 \pm \text{SE}$ | $\gamma_2 \pm \text{SE}$ | n | R ² |
|--|--------------------------|--------------------------|--------------------------|------|----------------|
| <i>All Biomes Except Desert</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -0.445 ± 0.038 | 0.072 ± 0.002 | na | 2343 | 0.30 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -1.302 ± 0.059 | 0.204 ± 0.008 | -0.0041 ± 0.0002 | 2343 | 0.39 |
| <i>Desert</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -2.970 ± 0.032 | 0.042 ± 0.002 | na | 1474 | 0.34 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -2.993 ± 0.047 | 0.046 ± 0.006 | -0.0001 ± 0.0002 | 1474 | 0.34 |
| <i>Boreal Forest</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | 0.003 ± 0.031 | 0.095 ± 0.002 | na | 466 | 0.82 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -0.170 ± 0.060 | 0.127 ± 0.010 | -0.0012 ± 0.0004 | 466 | 0.82 |
| <i>Temperate Forest</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -0.288 ± 0.061 | 0.076 ± 0.004 | na | 497 | 0.49 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -0.803 ± 0.136 | 0.146 ± 0.017 | -0.0022 ± 0.0005 | 497 | 0.51 |
| <i>Northern Shrubland</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -1.171 ± 0.057 | 0.142 ± 0.006 | na | 344 | 0.63 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -1.176 ± 0.100 | 0.143 ± 0.024 | -0.0001 ± 0.0013 | 344 | 0.63 |
| <i>Southern Shrubland</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -0.132 ± 0.145 | 0.026 ± 0.006 | na | 102 | 0.15 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -1.020 ± 0.317 | 0.118 ± 0.030 | -0.0020 ± 0.0006 | 102 | 0.23 |
| <i>Grassland</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -0.654 ± 0.070 | 0.077 ± 0.004 | na | 566 | 0.45 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -1.531 ± 0.120 | 0.202 ± 0.015 | -0.0035 ± 0.0004 | 566 | 0.51 |
| <i>Temperate Agriculture</i> | | | | | |
| $\ln(R) \sim \gamma_0 + \gamma_1 T$ | -2.166 ± 0.097 | 0.134 ± 0.006 | na | 262 | 0.66 |
| $\ln(R) \sim \gamma_0 + \gamma_1 T + \gamma_2 T^2$ | -3.025 ± 0.138 | 0.304 ± 0.022 | -0.0063 ± 0.0008 | 262 | 0.72 |

385
386 Parameters for multivariate regression model of soil respiration (natural log, in $\mu\text{mol C m}^{-2} \text{s}^{-1}$) (R) as a
387 function of soil temperature ($^{\circ}\text{C}$) (T), including data from both control and warmed treatments (Models a
388 and b in Table S3). Parameters shown for both the log-linear and log-quadratic temperature response
389 functions. n = sample size, R^2 = correlation coefficient. Parameter units: $\gamma_0 = \ln \mu\text{mol C m}^{-2} \text{s}^{-1}$; $\gamma_1 = ^{\circ}\text{C}^{-1}$, γ_2
390 = $^{\circ}\text{C}^{-2}$. All models significant ($p < 0.001$). For comparison of model fits, see Table S3. For model
391 parameters of control versus warmed plots, see Table 1.

392

393 **Table S6.**
394

| Comparison of Model Fits (R²) | | |
|---|--------------|--------------|
| Biome Type | Eq. 2 | Eq. 4 |
| All non-desert | 0.39 | 0.33 |
| Desert | 0.42 | 0.40 |
| Boreal Forest | 0.82 | 0.80 |
| Temperate Forest | 0.51 | 0.44 |
| Northern Shrubland | 0.63 | 0.53 |
| Southern Shrubland (no Hungary) | 0.60 | 0.13 |
| Southern Shrubland (includes Hungary) | 0.60 | 0.03 |
| Grassland | 0.52 | 0.39 |
| Agriculture | 0.72 | 0.63 |

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Comparison of model fits (Eq. 2, Eq. 4) evaluating role of soil moisture in driving soil respiration.