Supplemental Materials for *Drier soils delay plant phenology across temperate forest and grassland systems*

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Supplemental Methods

Equation for phenology models: Response variable (y) is day of year of the phenological event (budburst, leafout, or flowering). Predictors are measured air temperature (T) and soil moisture(SM). Random effects are species (sp, random slopes and intercepts), and site and year nested within site (random intercepts).

$$y_i = \alpha_{sp[i],site[year[i]]} + \beta_{temp_{sp[i]}} + \beta_{mois_{sp[i]}} + \beta_{temp:mois_{sp[i]}} + \epsilon_i \tag{1}$$

$$\alpha_{sp} \sim N(\mu_{sp}, \sigma_{sp}) \tag{2}$$

$$\mu_{site[year]} \sim N(\mu_{siteyr}, \sigma_{siteyr}) \tag{3}$$

$$\mu_{site} \sim N(\mu_{site}, \sigma_{site}) \tag{4}$$

$$\beta_{temp_{sp}} \sim N(\mu_{\beta_{temp}}, \sigma_{\beta_{temp}}) \tag{5}$$

$$\beta_{mois_{sp}} \sim N(\mu_{\beta_{mois}}, \sigma_{\beta_{mois}}) \tag{6}$$

$$\beta_{temp:mois_{sp}} \sim N(\mu_{\beta_{temp:mois}}, \sigma_{\beta_{temp:mois}}) \tag{7}$$

References to include

- Later flowering is associated with low precipitation, at least in part (Crimmins et al 2010)
- Ganjurjav et al 2020
- Cabon 2020

Supplemental Tables

Table 1: **Experimental sites and phenophases included in the ExPhen database**. Experimental sites correspond to the map (Figure S1). We give the study ID, location, source, years of data included, ecosystem, number of species, and phenophases included: budburst (bb), leafout (lo), flowering (fl), fruiting (fr), or senesence (sen) day of year. Note that some sites may have multiple sources; however, we list only one here. * denotes phenophases not included in this paper, because they were measured in fewer than three experiments.

study	location	source	data years	ecosystem	species	phenophases
exp01	Waltham, MA, USA	Hoeppner and Dukes 2012	2009-2011	grassland	44	bb,lo,fl
exp02	Montpelier, France	Morin et al. 2010	2004	temperate deciduous forest	5	fl,fr*
exp03	Duke Forest, NC, USA	Clark et al. 2014	2009-2014	temperate deciduous forest	37	bb,lo
exp04	Harvard Forest, MA, USA	Clark et al. 2014	2009-2012	temperate deciduous forest	29	bb,lo
exp07	Harvard Forest, MA, USA	Pelini et al. 2011	2010-2015	temperate deciduous forest	8	bb,lo,sen*
exp09	Stone Valley Forest, PA, USA	Rollinson and Kaye 2012	2009-2010	temperate deciduous forest	120	lo,fl,fr*,sen*
exp10	Duke Forest, NC, USA	Marchin et al. 2015	2010-2013	temperate deciduous forest	11	bb,fl
exp12	Kessler Farm Field Laboratory, OK, USA	Sherry et al. 2007	2003	grassland	12	fl,fr*

Table 2: **Summaries of budburst, leafout, and flowering models** with centered predictors.

	Average Effects						Species Effects			Site Effects			Site-Year Effects		
	mean	error	25%	75%	5%	95%	mean	error	Ngrp	mean	error	Ngrp	mean	error	Ngrp
BBμ_{α}	97.20	5.10	94.10	100.40	89.00	105.20	16.10	2.50	41	7.4	4.9	5	9.3	2.5	13
BBμ_{temp}	-7.80	2.10	-9.20	-6.40	-11.30	-4.20	11.40	1.70							
BBμ_{mois}	-1.70	0.60	-2.10	-1.30	-2.80	-0.70	2.70	0.60							
BB$\mu_{temp:mois}$	0.50	0.50	0.20	0.80	-0.40	1.30	1.70	0.70							
LOμ_{α}	131.40	11.60	124.60	138.40	112.80	149.70	12.10	2.20	147	24.7	10.5	5	12.3	3.9	13
LOμ_{temp}	-9.70	1.50	-10.80	-8.70	-12.20	-7.20	10.70	1.40							
LOμ_{mois}	-0.90	1.00	-1.60	-0.20	-2.70	0.70	4.50	1.30							
LO$\mu_{temp:mois}$	0.00	0.70	-0.50	0.50	-1.20	1.20	5.10	0.70							
FLμ_{α}	165.80	9.10	160.60	171.10	151.40	179.60	48.40	3.40	127	11.8	10.1	5	8.1	4.6	8
FLμ_{temp}	-7.90	1.30	-8.80	-7.00	-10.10	-5.70	5.90	1.20							
FLμ_{mois}	-1.20	0.90	-1.80	-0.60	-2.70	0.40	4.30	1.10							
FL$\mu_{temp:mois}$	-1.20	0.70	-1.70	-0.70	-2.30	0.00	2.40	1.00							

Supplemental Figures

Questions for co-authors:

1. Life forms vs ecosystems figures: Life forms plots histograms of speceis-level effects whereas ecosystems plots all posteriores (i.e. across 8000 samples)- what's your preference?

2. Should I make plots of the distribution of soil moisture and temperature by site?

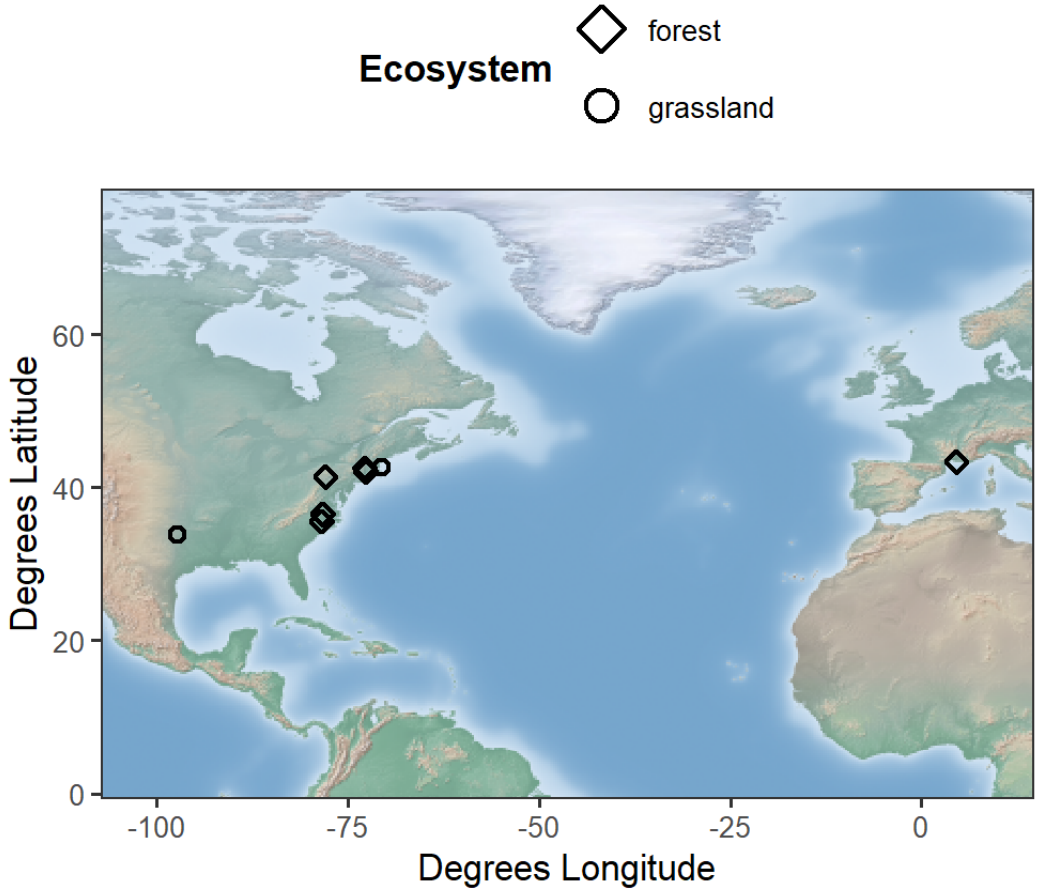

Figure 1: **Map of locations of experiments** included in this meta-analysis .Add phenophases to this, perhaps, by filling shapes with colors associated with phenophase

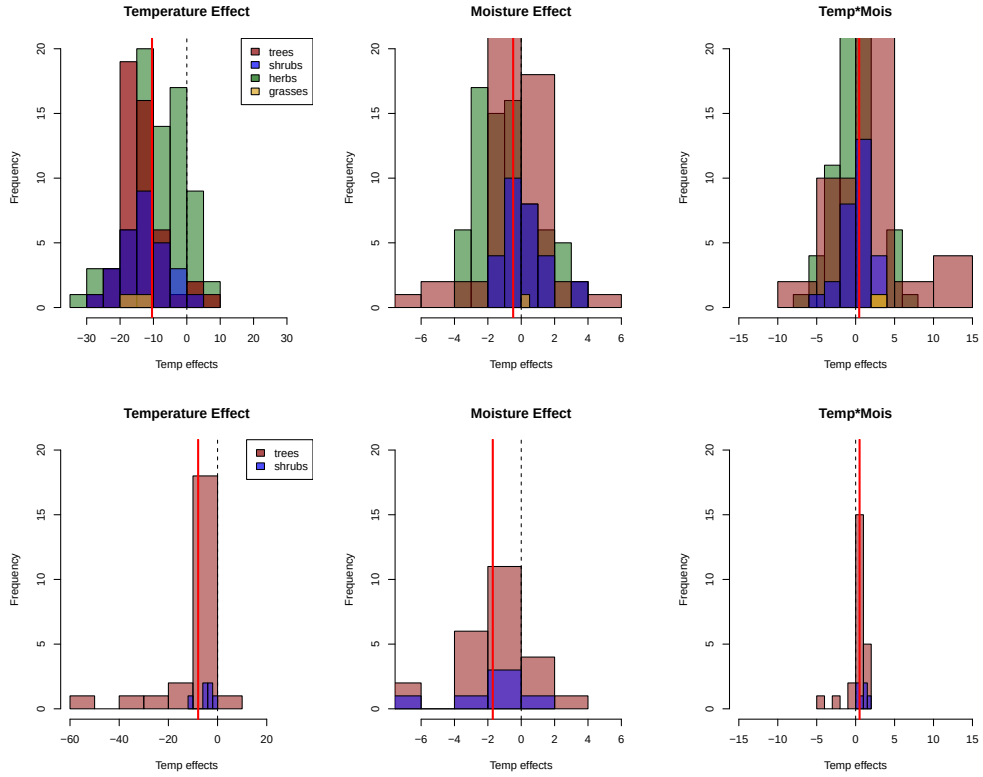

Figure 2: **Effects of temperature, soil moisture, and their interaction do not differ strongly across life forms** for leafout (top) and budburst (bottom) models. Histograms show species-level estimated effects for temeprature, soil, and their interactions across four life forms (trees, shrubs, forms, and grasses).

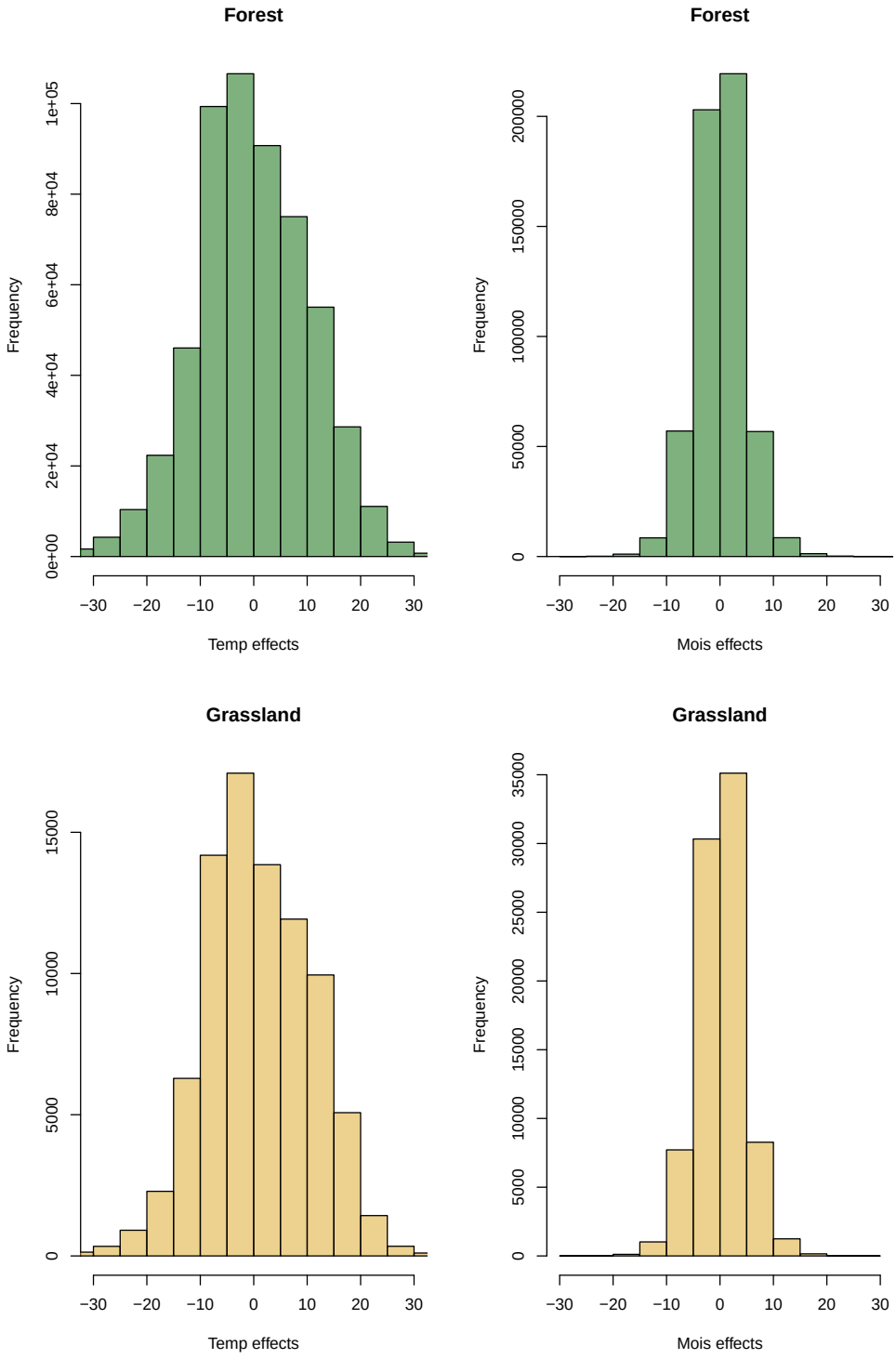

Figure 3: **Effects of temperature and soil moisture do not differ strongly across ecosystems (forest vs grassland) for leafout (top) and budburst (bottom) models.**.