

Supplemental tables and figures

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This document includes all the supplemental tables and figures that accompany “Precipitation moderates associations between native shrubs and invasive buffelgrass (*Pennisetum ciliare*) growth in the Sonoran Desert while local topography has less influence” by Ossanna et al. (2026).

Tables

Table S1. Actual values averaged by year

Actual values of variables measured, averaged across all plots for each year (to contextualize year-to-year change values used in analyses). Precipitation measured in mm, buffelgrass density measured in individuals per m², and cover measured in percent.

Year	Precipitation	Buffelgrass				Native vegetation	
		Total culms	Repro culms	Density	Cover	Shrub cover	Herb cover
2020	222	24 ± 19	12 ± 13	3.8 ± 1.5	39 ± 19	18 ± 12	5.9 ± 10.5
2021	362	38 ± 33	14 ± 16	8 ± 7.6	40 ± 21	13 ± 8	9.9 ± 8.7
2022	264	53 ± 40	26 ± 25	6.8 ± 4.1	35 ± 17	12 ± 10	5.1 ± 6.4
2023	250	129 ± 80	53 ± 35	3 ± 1.5	39 ± 13	22 ± 13	2.6 ± 2.7

Table S2. Total culms model

Model coefficients of the buffelgrass culm count model (response variable: year-to-year change in total number of culms). Marginal R² = 0.0.119; conditional R² = 0.410.

Coefficient	Estimate	Std. Error	df	t value	Pr(> t)
Intercept	12.6627	10.4781	3.9758	1.208	0.2938
Previous year precipitation	-3.2292	1.5376	1207.7732	-2.100	0.0359*
Aspect, N	7.8120	7.8661	20.2496	0.993	0.3324
Aspect, S	0.1528	5.6111	19.8523	0.027	0.9786
Aspect, SW	18.3063	7.7117	19.9935	2.374	0.0277*
Aspect, W	4.3308	5.4989	19.3003	0.788	0.4405
Plot slope	-2.0952	1.4049	147.2300	-1.491	0.1380
Change in BG density	-7.6271	1.4079	1080.9177	-5.417	7.45e-08***
Change in shrub cover	5.7765	1.0774	1189.1395	5.362	9.90e-08***
Change in herb cover	0.3447	1.0772	998.0276	0.320	0.7490
Change in BG density * Previous year precip	2.8213	1.6240	242.3700	1.737	0.0836
Change in shrub cover * Previous year precip	-6.7540	1.1241	1190.4146	-6.008	2.49e-09***
Change in herb cover * Previous year precip	2.7597	1.1026	923.9022	2.503	0.0125*

Table S3. Reproductive culms model

Model coefficients of the buffelgrass reproductive culm count model (response variable: year-to-year change in number of reproductive culms). Marginal $R^2 = 0.098$; conditional $R^2 = 0.295$.

Coefficient	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)
Intercept	11.9587	3.7727	3.7764	3.167	0.00154**
Aspect, N	-6.9282	6.6088	6.6152	1.047	0.29495
Aspect, S	-9.2787	5.0959	5.1009	1.819	0.06890
Aspect, SW	14.1600	6.6084	6.6149	2.141	0.03230*
Aspect, W	-3.2396	5.0709	5.0759	0.638	0.52332
Change in BG density	-2.5706	0.8613	0.8621	2.982	0.00286**
Change in herb cover	2.7259	0.6647	0.6653	4.097	4.18e-05***
Change in shrub cover	1.3680	0.6467	0.6473	2.113	0.03458 *
Plot slope	1.4751	0.9336	0.9345	1.578	0.11447
Previous year precipitation	-0.8645	0.8951	0.8960	0.965	0.33463
Change in BG density * Previous year precip	-1.4539	1.1143	1.1151	1.304	0.19231
Change in herb cover * Previous year precip	-0.4236	0.6304	0.6308	0.672	0.50188
Change in shrub cover * Previous year precip	-0.1940	0.4939	0.4943	0.392	0.69476

Table S4. Plot density model

Model coefficients of the buffelgrass plot density model (response variable: year-to-year change in plot density [individuals per m²]). Marginal $R^2 = 0.381$; conditional $R^2 = 0.427$.

Coefficient	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)
Intercept	5.82503	1.50245	1.51693	3.840	0.000123***
Aspect, N	-2.41140	2.51069	2.53560	0.951	0.341594
Aspect, S	-5.92643	2.03290	2.05289	2.887	0.003891**
Aspect, SW	-3.04473	2.66856	2.69492	1.130	0.258559
Aspect, W	-5.18841	1.94872	1.96798	2.636	0.008379**
Change in herb cover	0.31353	0.53761	0.54133	0.579	0.562468
Change in shrub cover	0.90282	0.59483	0.60077	1.503	0.132900
Plot slope	0.03471	0.35617	0.35966	0.097	0.923116
Previous year precipitation	4.80511	0.66377	0.67028	7.169	< 2e-16***
Change in herb cover * Previous year precip	0.10806	0.34178	0.34354	0.315	0.753096
Change in shrub cover * Previous year precip	1.33254	0.60515	0.61121	2.180	0.029243*

Table S5. Plot cover model

Model coefficients of the buffelgrass plot cover model (response variable: year-to-year-change in plot cover [%]). Marginal R² = 0.248; conditional R² = 0.295.

Coefficient	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)
Intercept	11.12057	3.64886	3.68561	3.017	0.002550**
Aspect, N	-10.44430	6.00828	6.06872	1.721	0.085250
Aspect, S	-12.62234	4.91518	4.96467	2.542	0.011008*
Aspect, SW	-8.89160	6.52070	6.58642	1.350	0.177019
Aspect, W	-12.82015	4.67915	4.72628	2.713	0.006677**
Change in herb cover	0.61479	1.47871	1.49280	0.412	0.680459
Change in shrub cover	-3.48090	1.59733	1.61343	2.157	0.030970*
Plot slope	2.85609	1.63323	1.64969	1.731	0.083400
Previous year precipitation	6.77803	1.74402	1.76150	3.848	0.000119***
Change in herb cover * Previous year precip	-0.06964	1.01416	1.02438	0.068	0.945797
Change in shrub cover * Previous year precip	-0.22906	1.24320	1.25544	0.182	0.855228

Table S6. Seedling survival model

Model coefficients of the buffelgrass seedling survival model (response variable: seedling survival [%]). Marginal R² = 0.819.

Coefficient	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)
Intercept	-1.26536	0.16964	0.17120	7.391	<2e-16***
BG density	0.23192	0.13779	0.13878	1.671	0.0947
Herb cover	0.18024	0.14112	0.14196	1.270	0.2042
Plot slope	0.04850	0.10134	0.10183	0.476	0.6338
Previous year precipitation	1.35339	0.15445	0.15586	8.683	<2e-16 ***
Shrub cover	-0.13375	0.11613	0.11673	1.146	0.2519
BG density * Previous year precip	0.03340	0.08605	0.08641	0.387	0.6991
Herb cover * Previous year precip	-0.15459	0.13977	0.14026	1.102	0.2704
Shrub cover * Previous year precip	-0.09849	0.10459	0.10493	0.939	0.3479

Figures

Figure S1

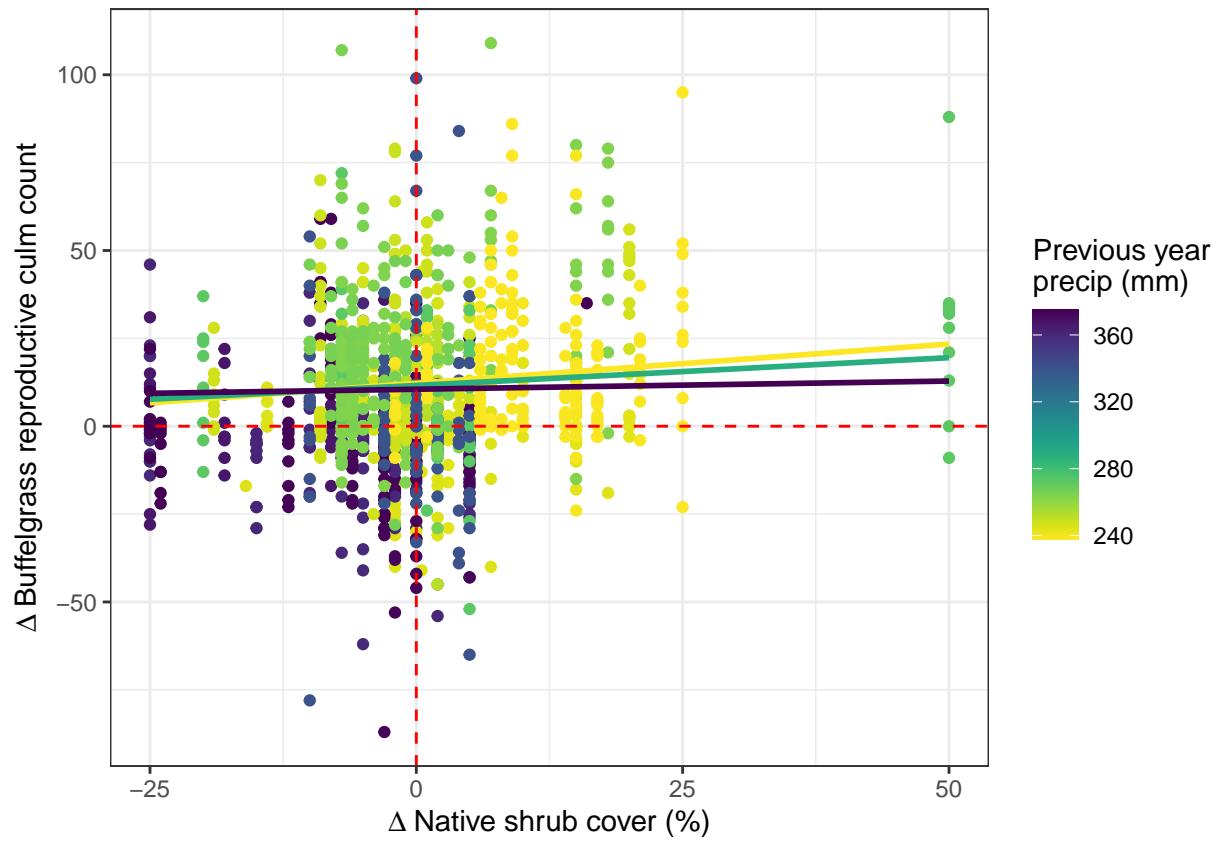


Figure S1. Relationship between year-to-year change in native shrub cover and year-to-year change in reproductive buffelgrass culm count, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (yellow line), and average conditions (green line). Vertical red dashed line indicates no change in shrub cover while horizontal line indicates no change in the number of reproductive buffelgrass culms.

Figure S2

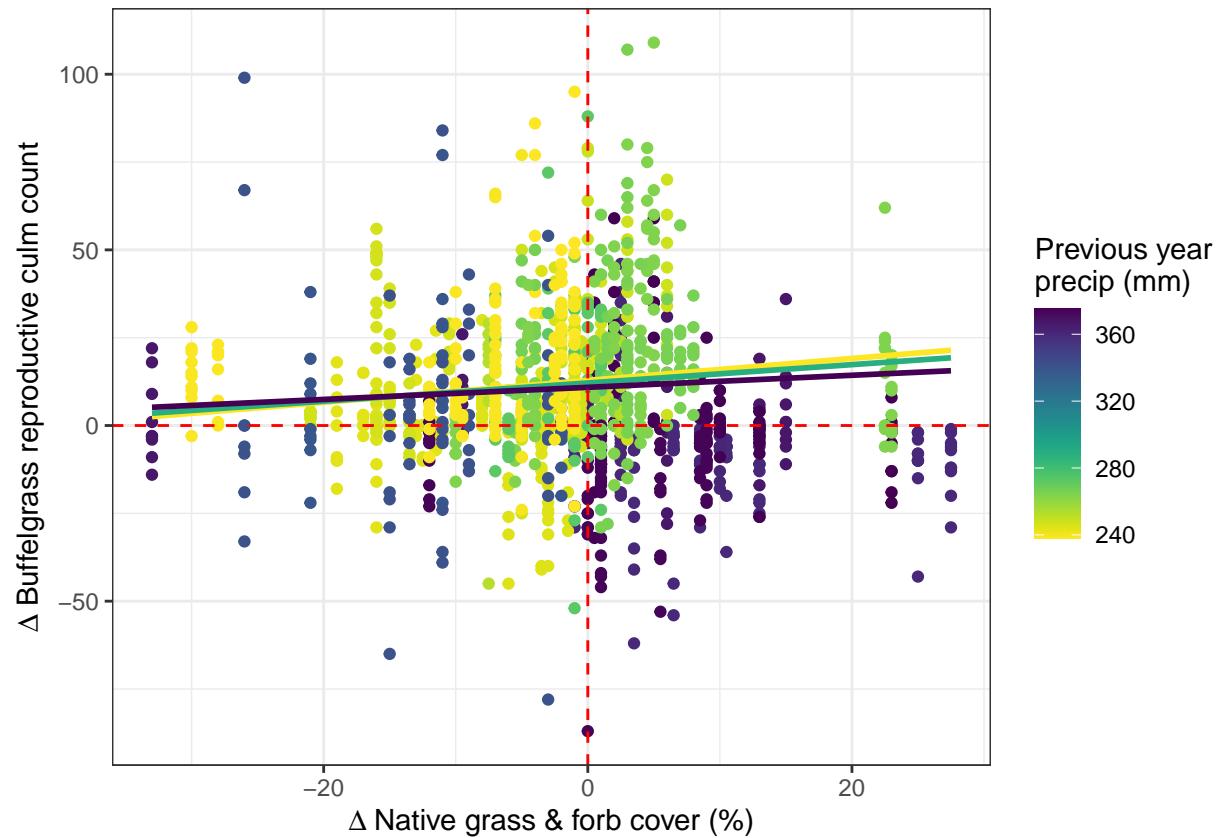


Figure S2. Relationship between year-to-year change in native herbaceous (grass and forb) cover and year-to-year change in reproductive buffelgrass culm count, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (yellow line), and average conditions (green line). Vertical red dashed line indicates no change in herb cover while horizontal line indicates no change in the number of reproductive buffelgrass culms.

Figure S3

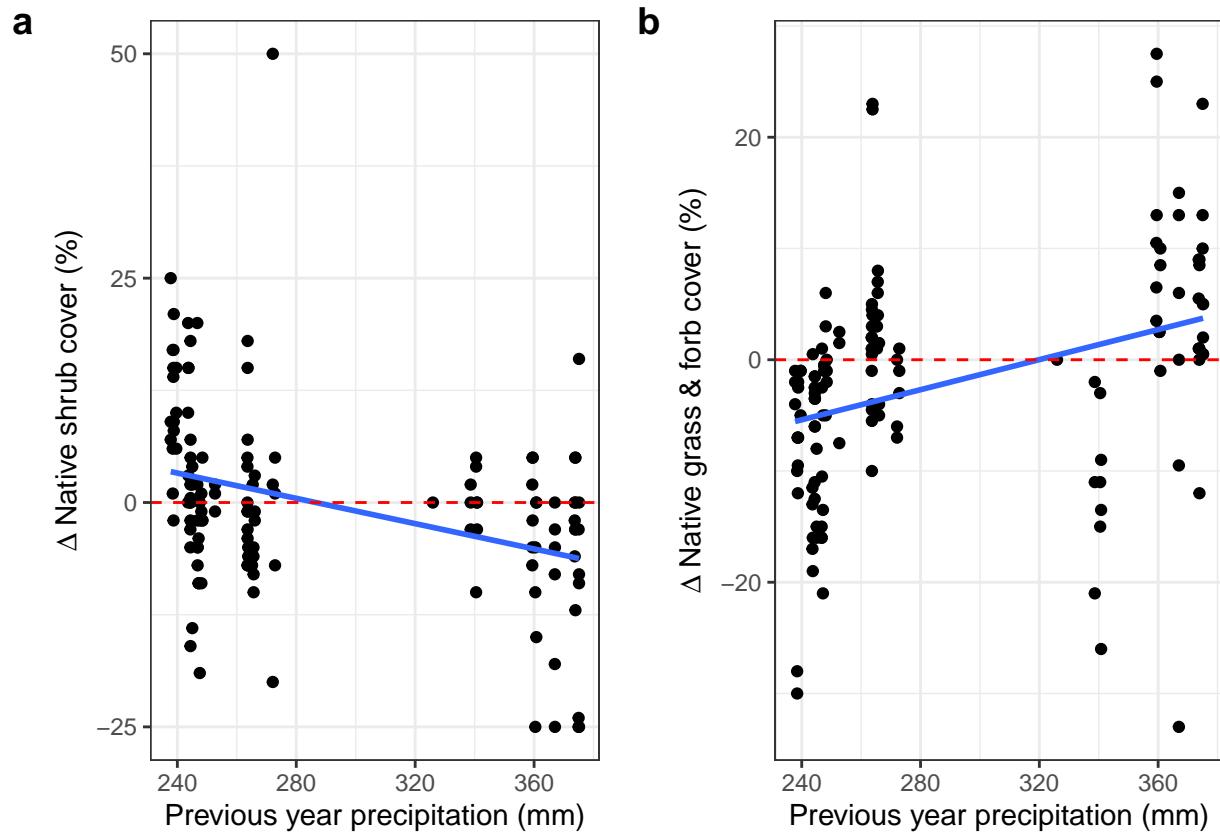


Figure S3. Simple linear regression of (A) year-to-year change in native shrub cover and (B) year-to-year change in native herbaceous cover as a function of the previous year's precipitation, pooling all sampling locations and times. Horizontal red dashed lines indicate no change in shrub or herbaceous cover.

Figure S4

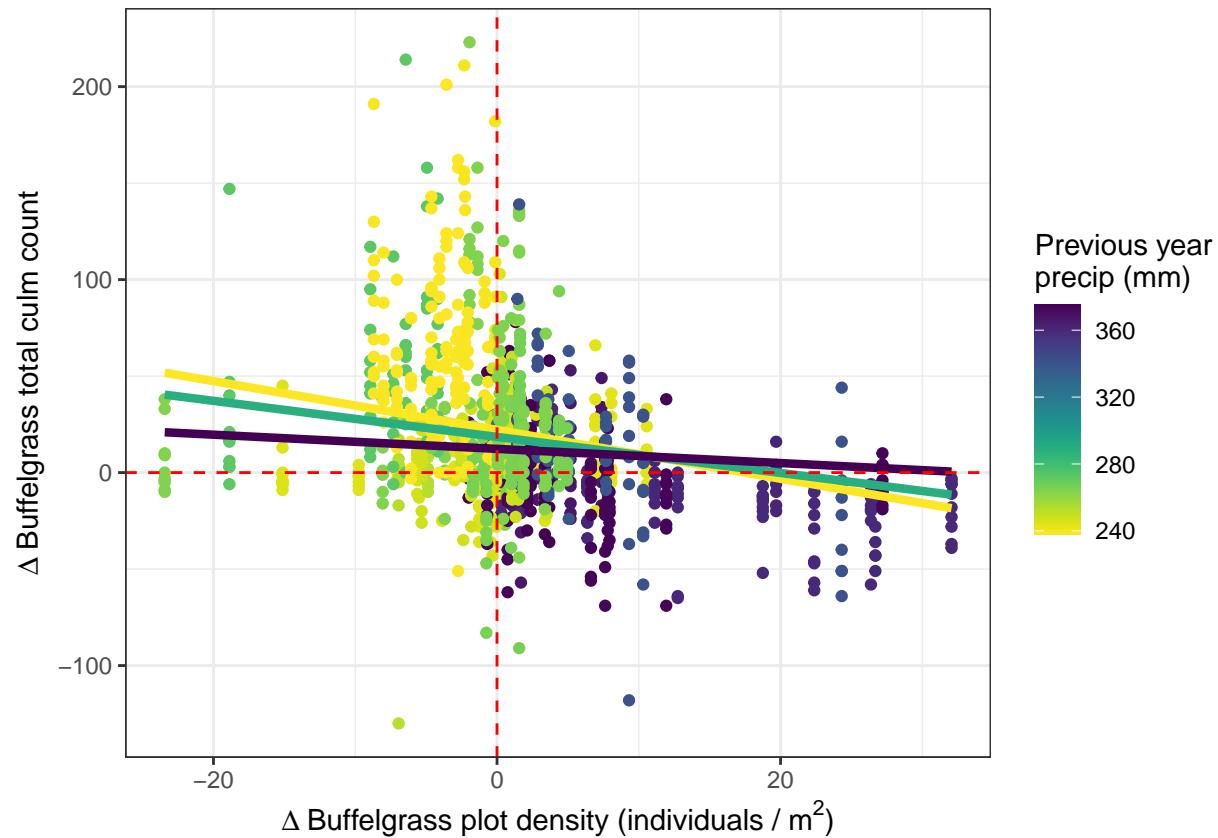


Figure S4. Relationship between year-to-year change in buffelgrass plot density and year-to-year change in total buffelgrass culm count, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (yellow line), and average conditions (green line). Vertical red dashed line indicates no change in buffelgrass plot density while horizontal line indicates no change in the number of buffelgrass culms.

Figure S5

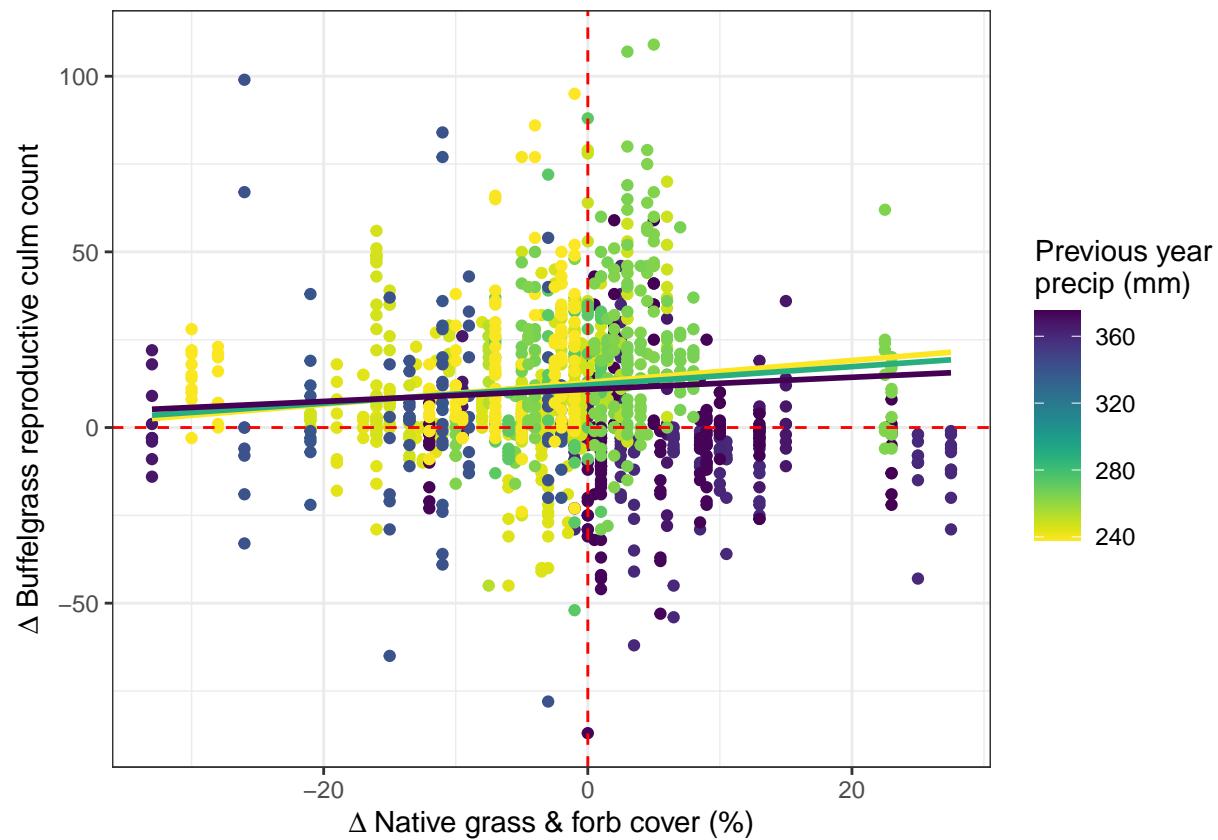


Figure S5. Relationship between year-to-year change in buffelgrass plot density and year-to-year change in reproductive buffelgrass culm count, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (yellow line), and average conditions (green line). Vertical red dashed line indicates no change in buffelgrass plot density while horizontal line indicates no change in the number of reproductive buffelgrass culms.

Figure S6

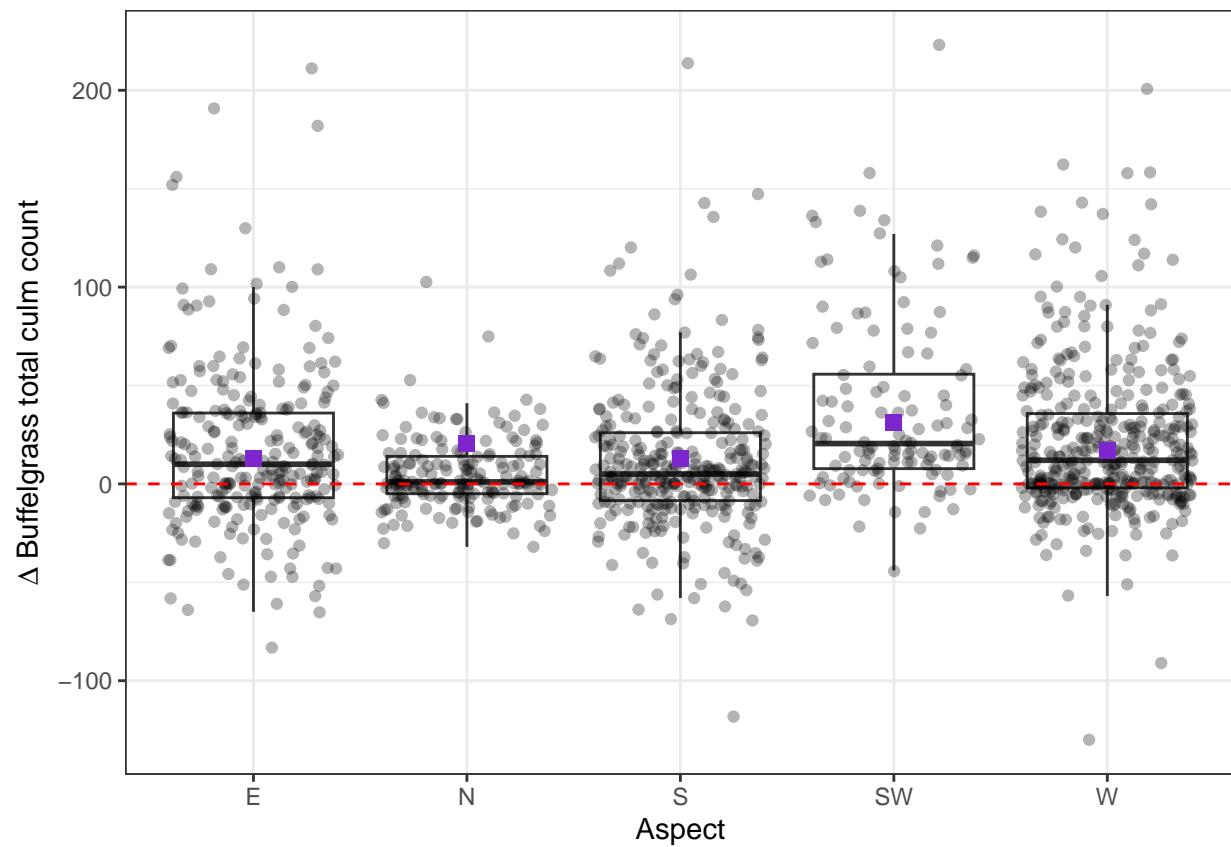


Fig. S6. Effects of aspect on year-to-year change in total buffelgrass culm count. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in the number of buffelgrass culms.

Figure S7

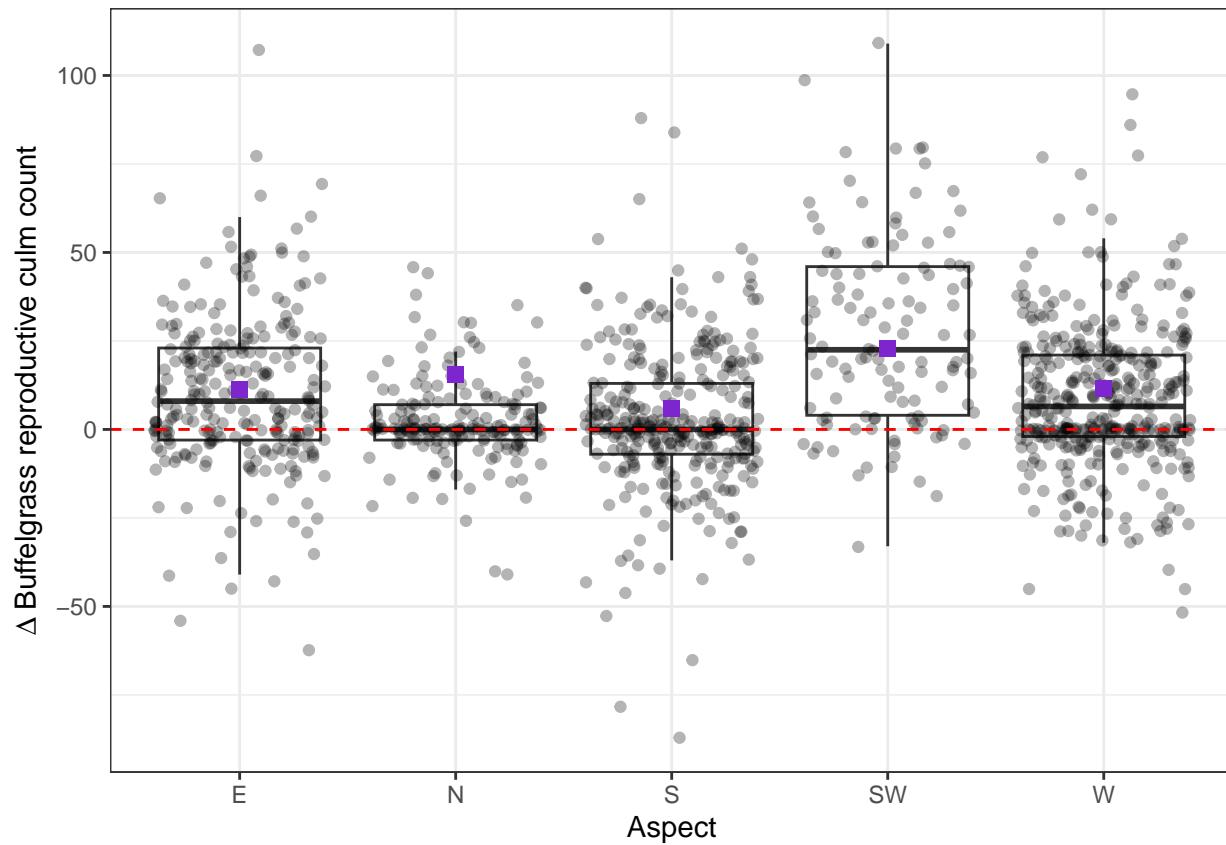


Fig. S7. Effects of aspect on year-to-year change in buffelgrass reproductive culm count. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in the number of reproductive buffelgrass culms.

Figure S8

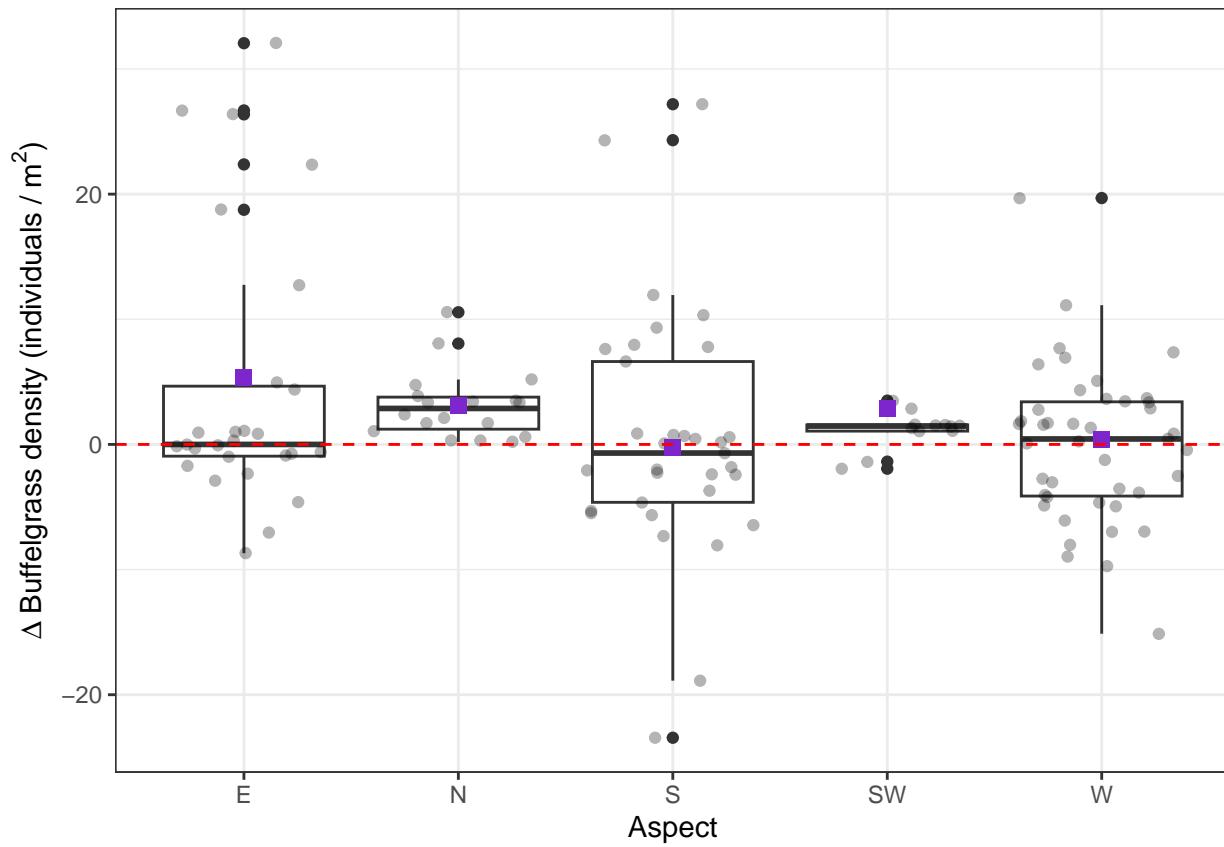


Fig. S8. Effects of aspect on year-to-year change in buffelgrass plot density. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in buffelgrass density.

Figure S9

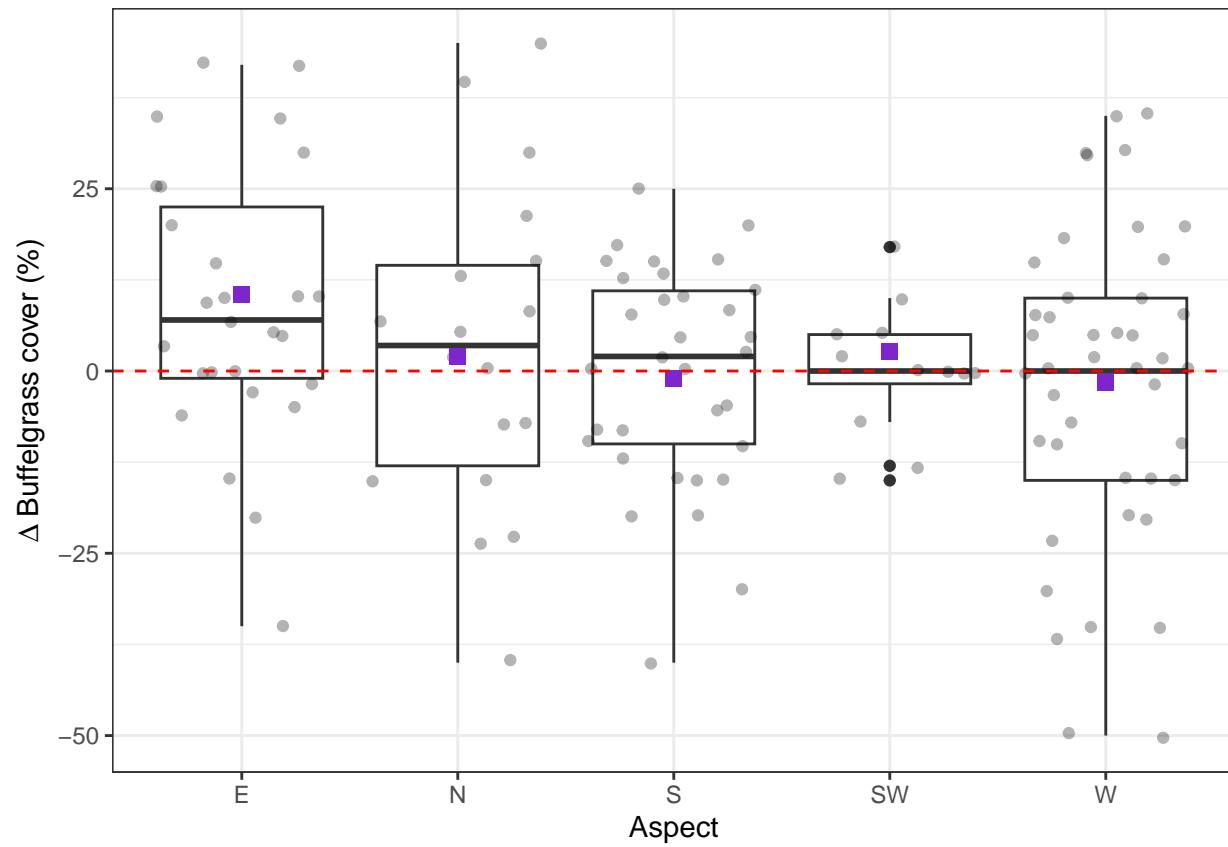


Fig. S9. Effects of aspect on year-to-year change in buffelgrass plot cover. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in buffelgrass cover.

Figure S10

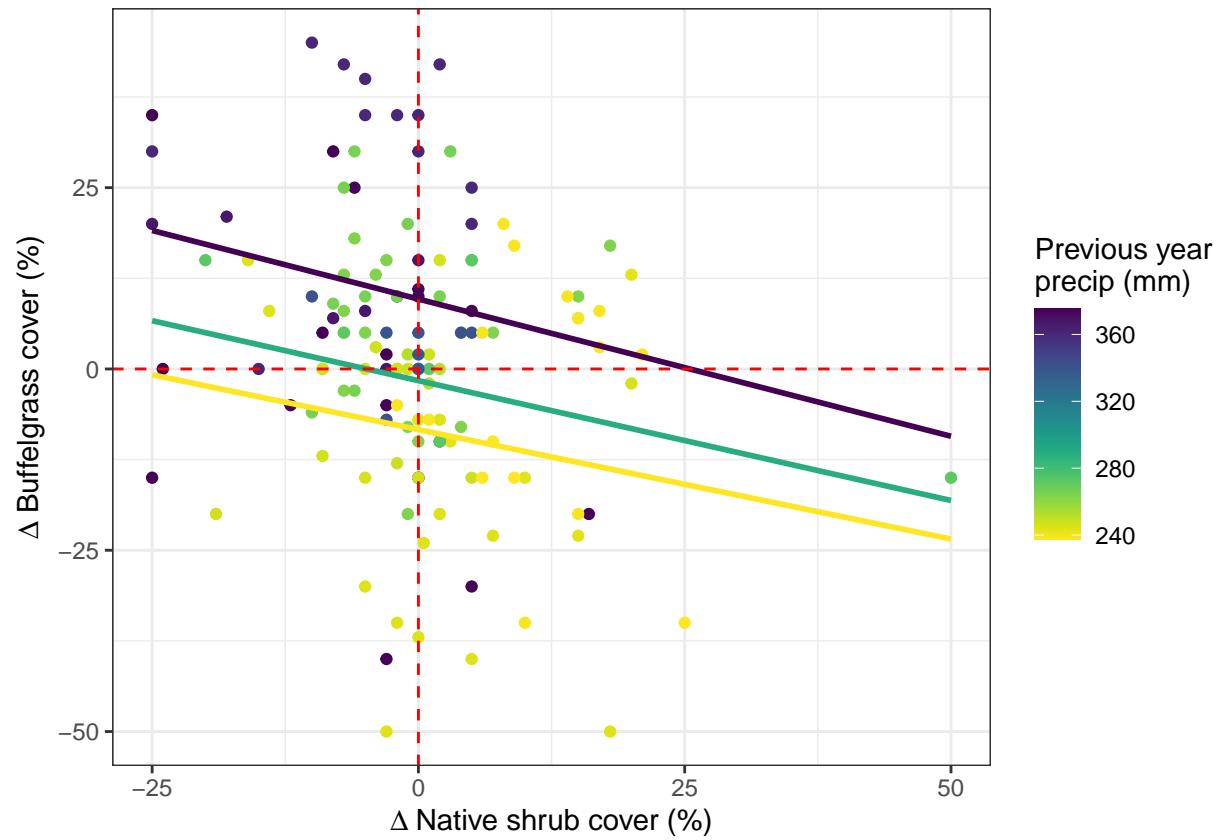


Figure S10. Relationship between year-to-year change in native shrub cover and year-to-year change in buffelgrass plot cover, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (yellow line), and average conditions (green line). Vertical red dashed line indicates no change in shrub cover while horizontal line indicates no change in buffelgrass cover.

Figure S11

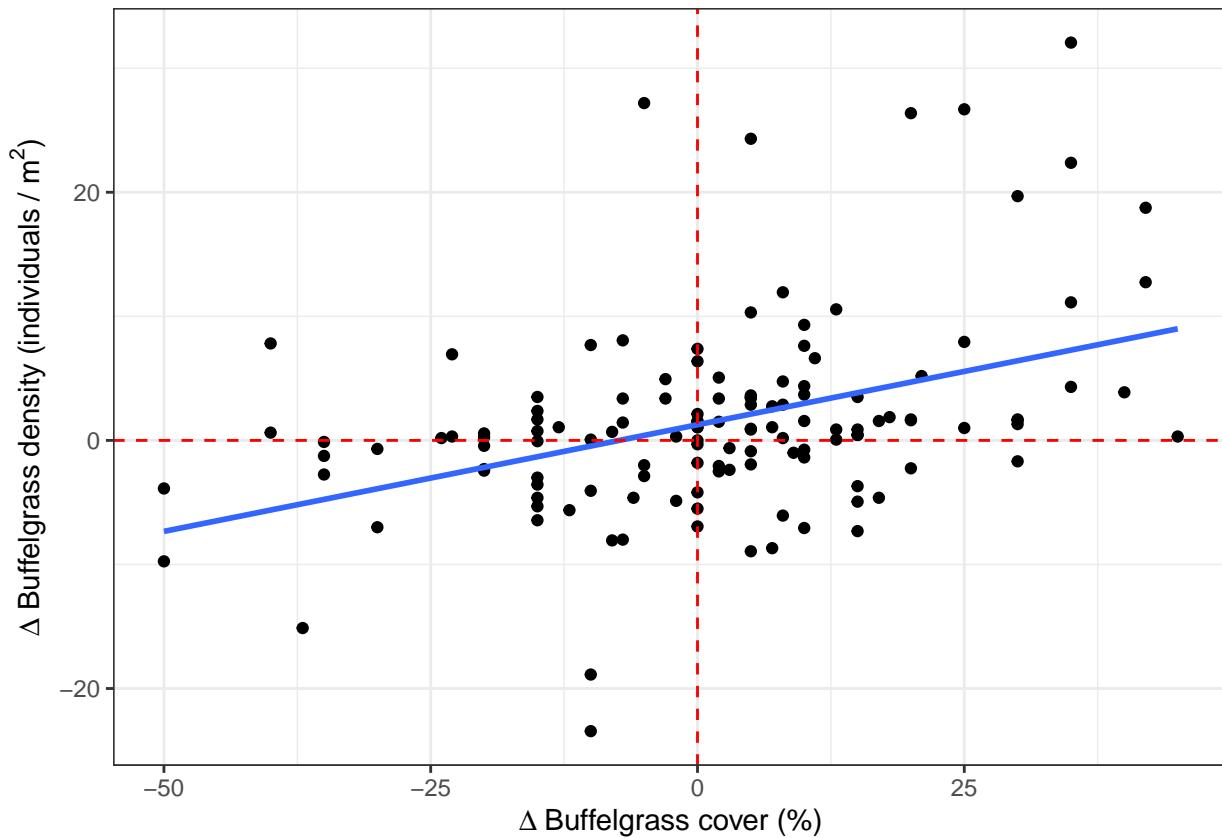


Figure S11. Simple linear regression of year-to-year change in buffelgrass plot density as a function of year-to-year change in buffelgrass plot cover, pooling all sampling locations and times. Vertical red dashed line indicates no change in buffelgrass cover while horizontal line indicates no change in buffelgrass density.

Figure S12

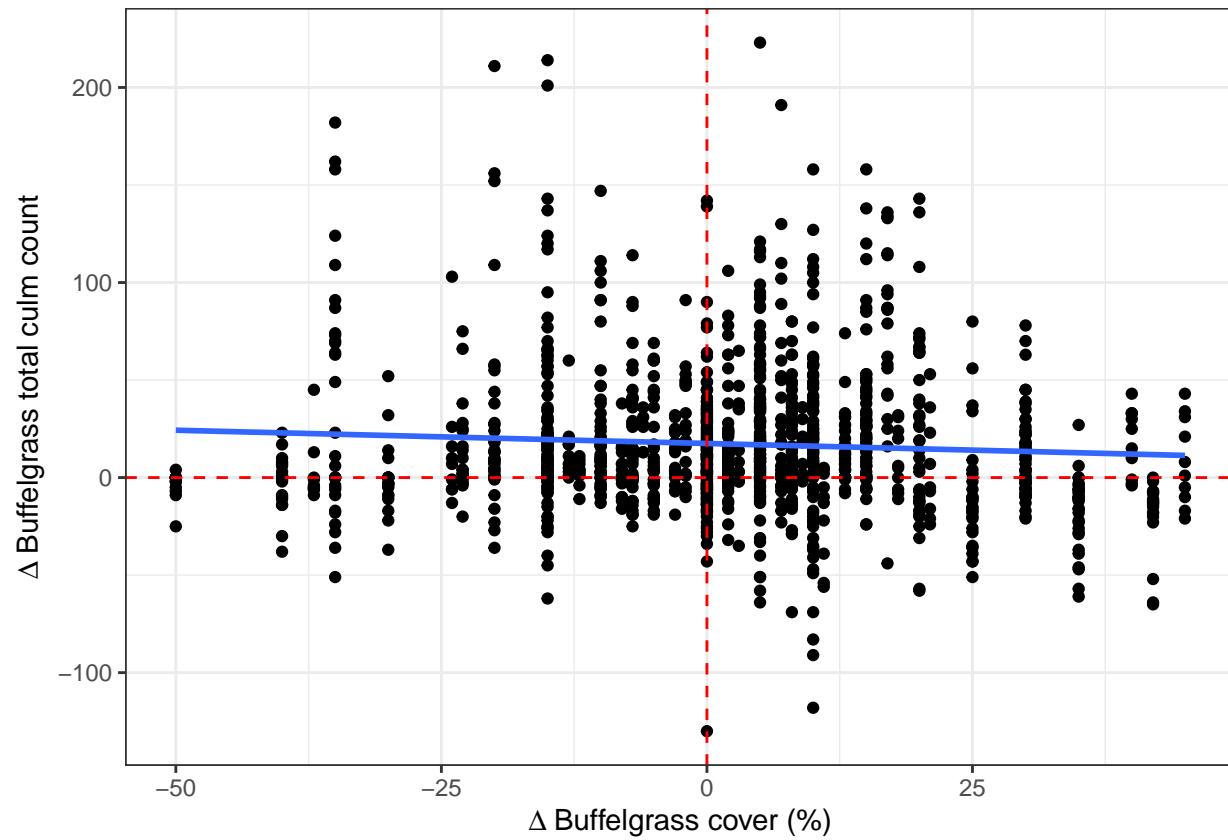


Figure S12. Simple linear regression of year-to-year change in buffelgrass total culm count as a function of year-to-year change in buffelgrass plot cover, pooling all sampling locations and times. Vertical red dashed line indicates no change in buffelgrass cover while horizontal line indicates no change in buffelgrass total culm count.