

Supplemental tables and figures

Includes all supplemental tables and figures to accompany “Precipitation moderates the effect of native shrubs on invasive buffelgrass (*Pennisetum ciliare*) growth in the Sonoran Desert while local topography has less influence” by Ossanna et al. (2026).

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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-averaged coefficients of the buffelgrass culm count model calculated from two top models (response variable: year-to-year change in total number of culms). Marginal R² = 0.144–0.147; conditional R² = 0.386–0.391.

| Coefficient | Estimate | Std. Error | Adjusted SE | z value | Pr(> z) |
|--|----------|------------|-------------|---------|-----------|
| Intercept | 9.9154 | 7.6168 | 7.6243 | 1.301 | 0.1934 |
| Aspect, N | -9.0486 | 13.5056 | 13.5188 | 0.669 | 0.5033 |
| Aspect, S | -5.2854 | 10.4379 | 10.4482 | 0.506 | 0.6129 |
| Aspect, SW | 18.6775 | 13.5127 | 13.5260 | 1.381 | 0.1673 |
| Aspect, W | 2.4818 | 10.3979 | 10.4081 | 0.238 | 0.8115 |
| Change in BG density | -8.0732 | 1.4381 | 1.4395 | 5.608 | <2e-16*** |
| Change in herb cover | 0.7489 | 1.1107 | 1.1118 | 0.674 | 0.5006 |
| Change in shrub cover | 5.8469 | 1.0880 | 1.0891 | 5.369 | 1e-07*** |
| Plot slope | -1.0905 | 1.5290 | 1.5302 | 0.713 | 0.4761 |
| Previous year precipitation | -3.5216 | 1.5449 | 1.5464 | 2.277 | 0.0228* |
| Change in BG density * Previous year precip | 3.9087 | 1.8024 | 1.8042 | 2.167 | 0.0303* |
| Change in herb cover * Previous year precip | 2.3452 | 1.1330 | 1.1341 | 2.068 | 0.0386* |
| Change in shrub cover * Previous year precip | -6.6136 | 1.1385 | 1.1396 | 5.803 | <2e-16*** |

Table S3. Reproductive culms model

Model-averaged coefficients of the buffelgrass reproductive culm count model calculated from five top models (response variable: year-to-year change in number of reproductive culms). Marginal $R^2 = 0.147\text{--}0.155$; conditional $R^2 = 0.318\text{--}0.333$.

| 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-averaged coefficients of the buffelgrass plot density model calculated from five top models (response variable: year-to-year change in plot density [individuals per m²]). Marginal $R^2 = 0.360\text{--}0.389$; conditional $R^2 = 0.423\text{--}0.458$.

| 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-averaged coefficients of the buffelgrass plot cover model calculated from six top models (response variable: year-to-year-change in plot cover [%]). Marginal $R^2 = 0.243$ – 0.246 ; conditional $R^2 = 0.284$ – 0.289 .

| 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-averaged coefficients of the buffelgrass seedling survival model calculated from 15 top models (response variable: seedling survival [%]). Marginal $R^2 = 0.666$ – 0.695 ; conditional $R^2 = 0.779$ – 0.800 .

| 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

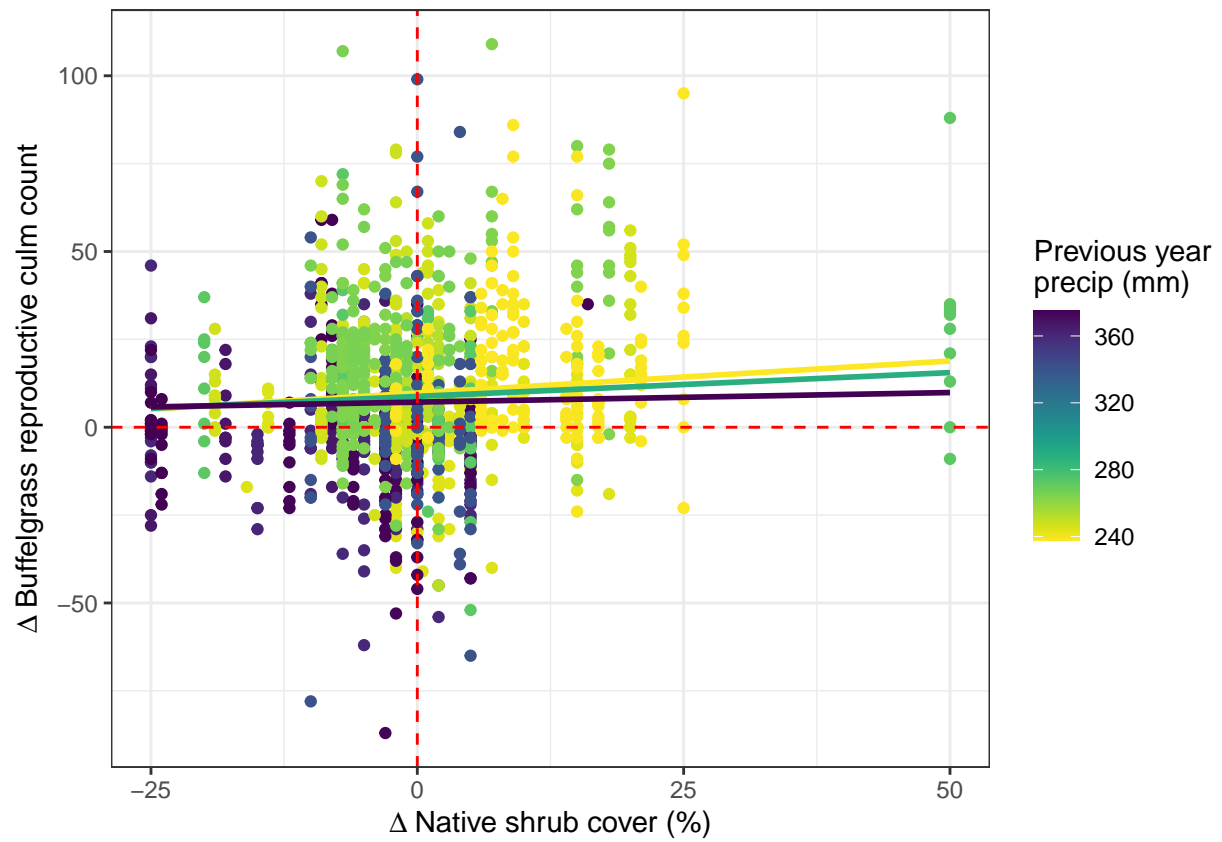


Figure S1. Relationship between year-to-year change in native shrub cover and year-to-year change in reproductive buffelgrass culm count, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (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

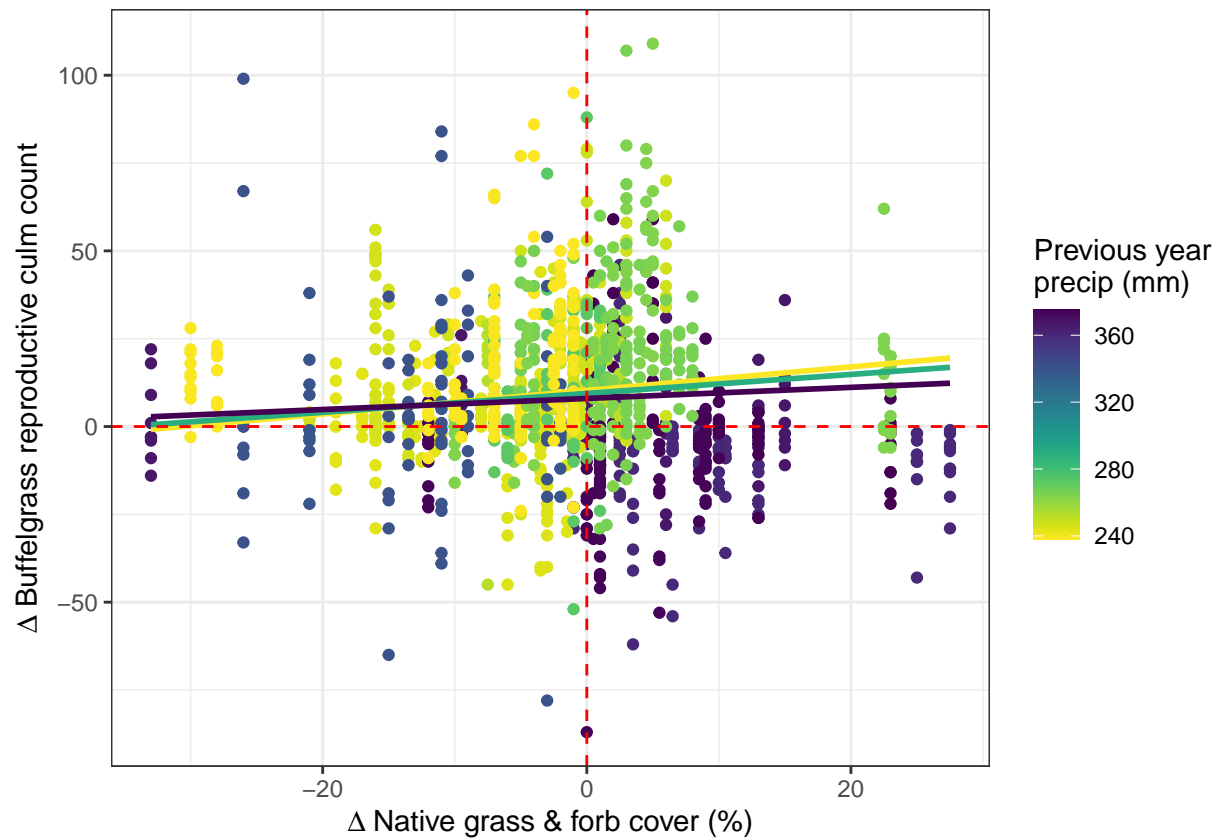


Figure S2. Relationship between year-to-year change in native herbaceous (grass and forb) cover and year-to-year change in reproductive buffelgrass culm count, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), 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

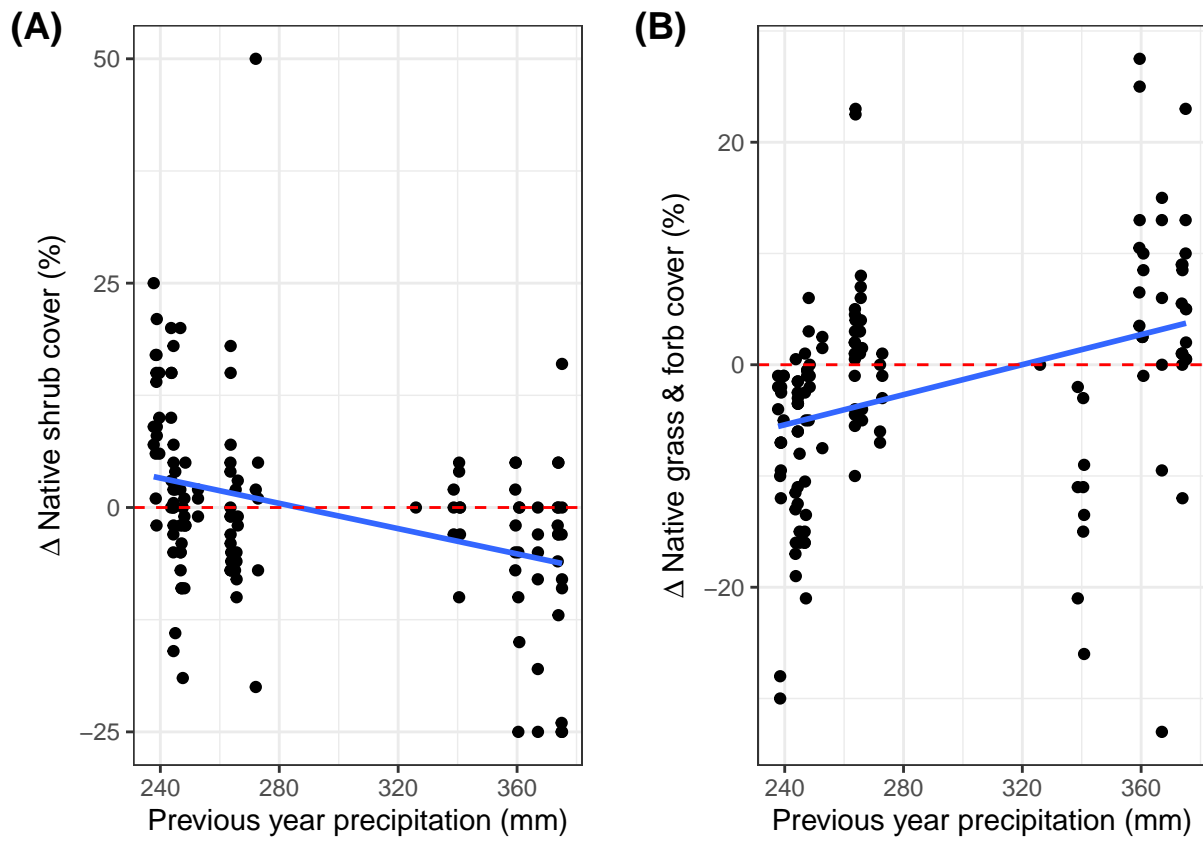


Figure S3. Simple linear regression of (A) year-to-year change in native shrub cover and (B) year-to-year change in native herbaceous cover as a function of the previous year's precipitation, pooling all sampling locations and times. Horizontal red dashed lines indicate no change in shrub or herbaceous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

Figure S4

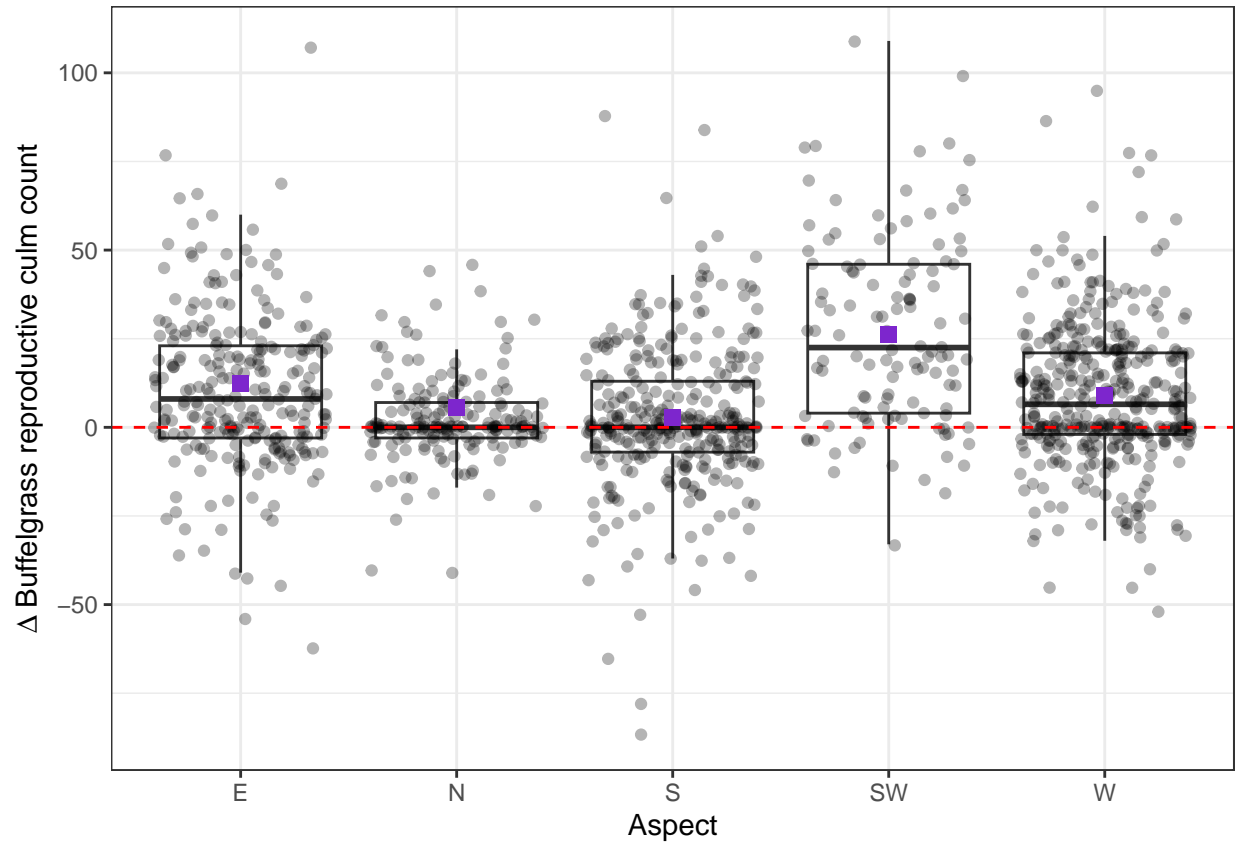


Fig. S4. Effects of aspect on year-to-year change in buffelgrass reproductive culm count. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in the number of reproductive buffelgrass culms.

Figure S5

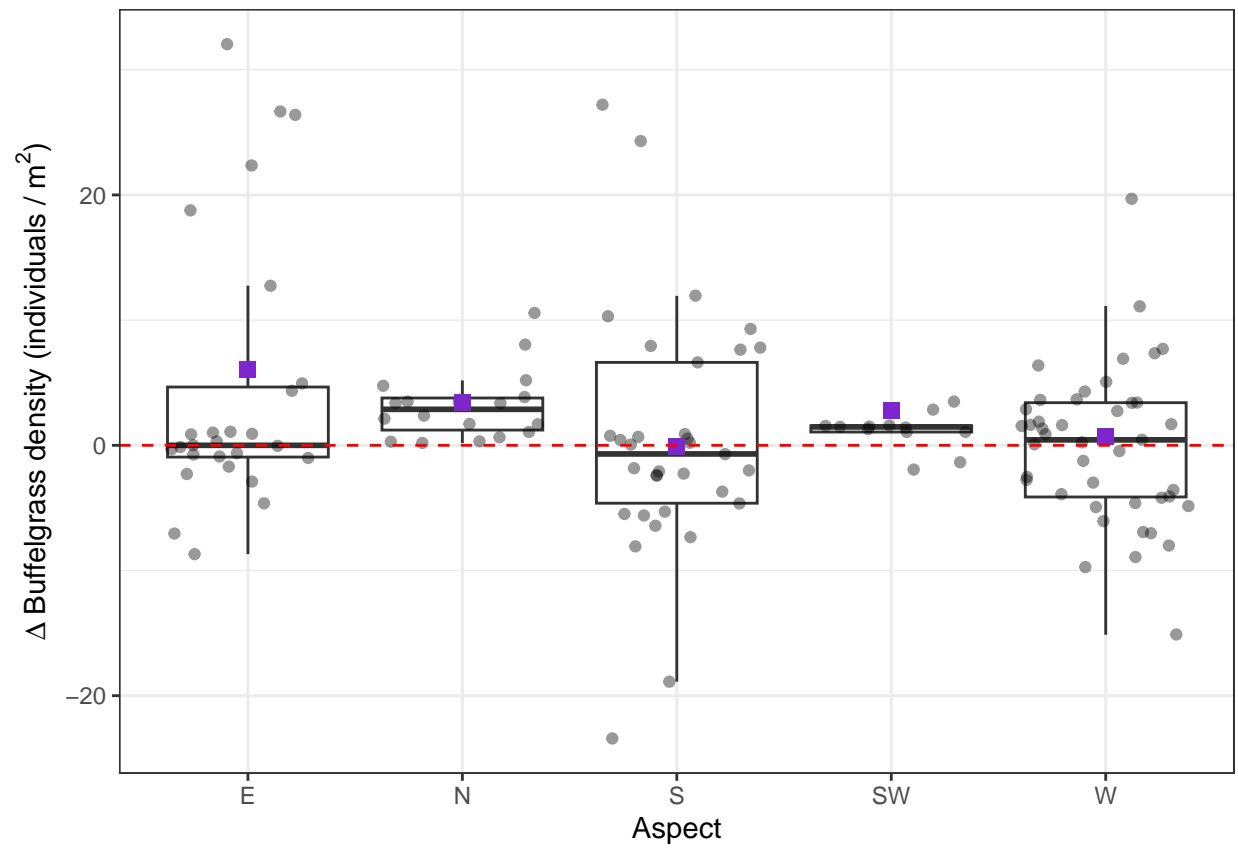


Fig. S5. Effects of aspect on year-to-year change in buffelgrass plot density. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in buffelgrass density.

Figure S6

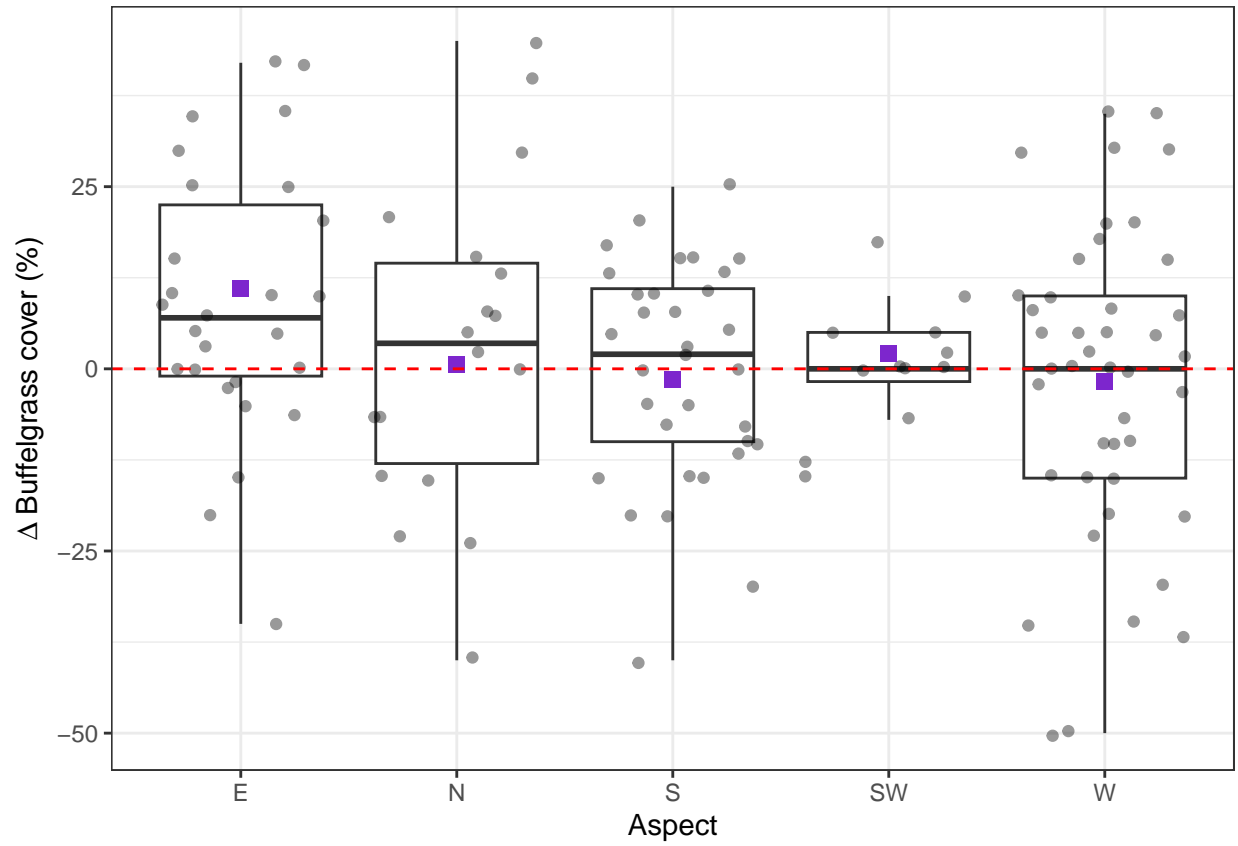


Fig. S6. Effects of aspect on year-to-year change in buffelgrass plot cover. Purple squares represent model-predicted averages. Horizontal red dashed line indicates no change in buffelgrass cover.

Figure S7

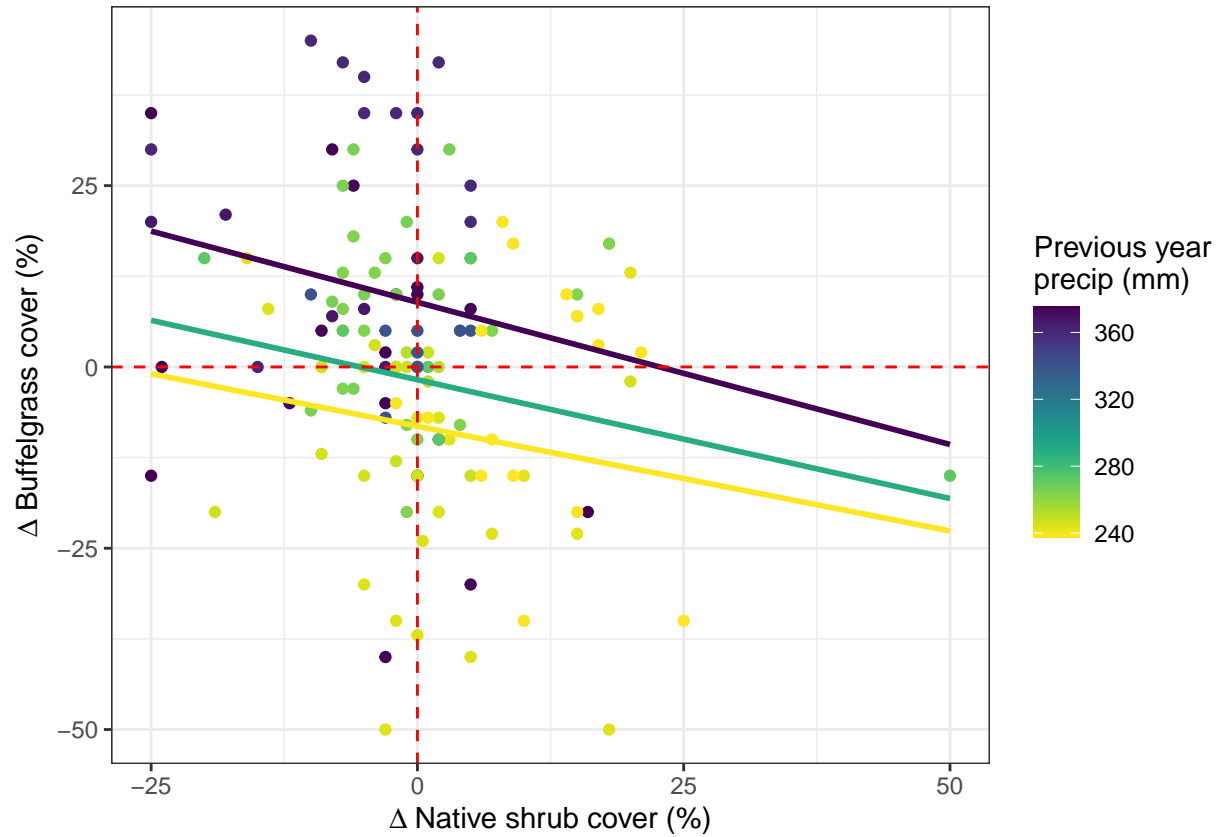


Figure S7. Relationship between year-to-year change in native shrub cover and year-to-year change in buffelgrass plot cover, moderated by precipitation. Colored lines represent model-predicted values under the wettest precipitation conditions experienced (purple line), the driest conditions (yellow line), 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 S8

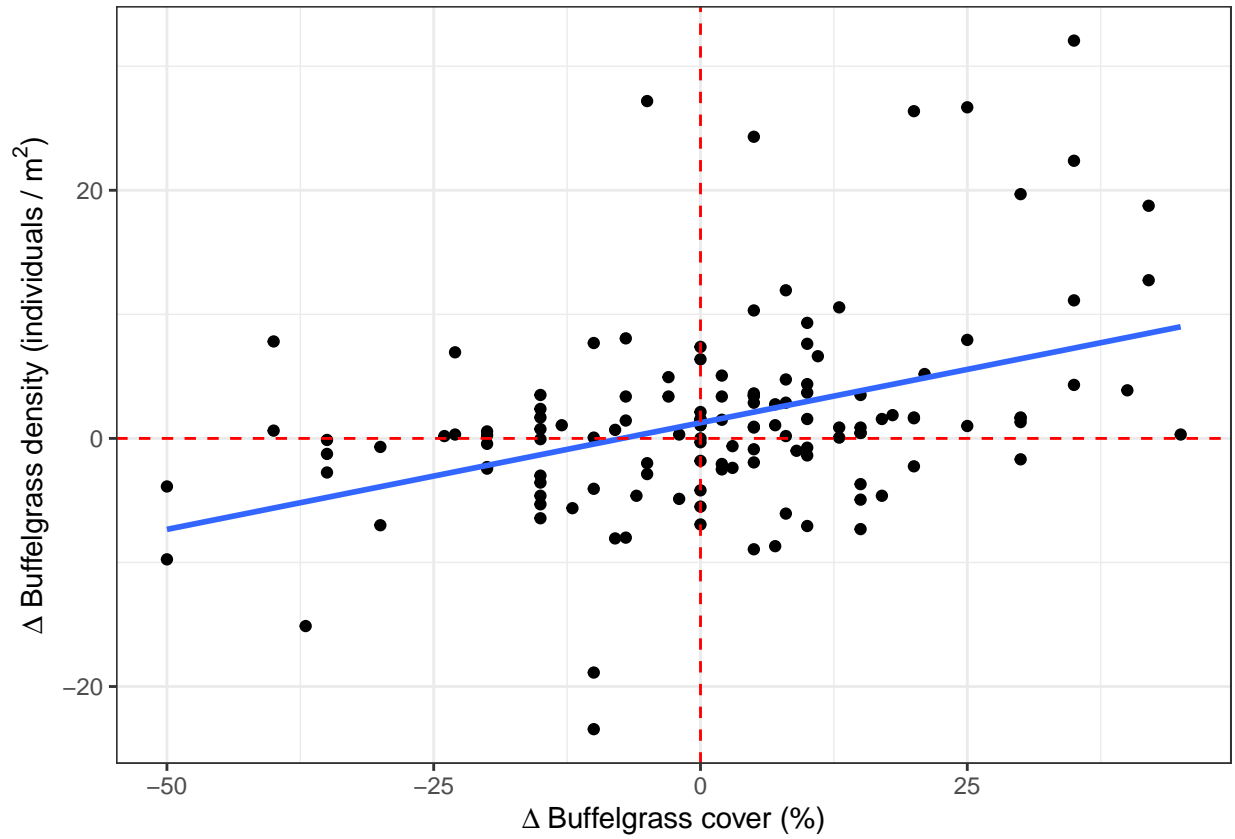


Figure S8. Simple linear regression of year-to-year change in buffelgrass plot density as a function of year-to-year change in buffelgrass plot cover, pooling all sampling locations and times. Vertical red dashed line indicates no change in buffelgrass cover while horizontal line indicates no change in buffelgrass density.

Figure S9

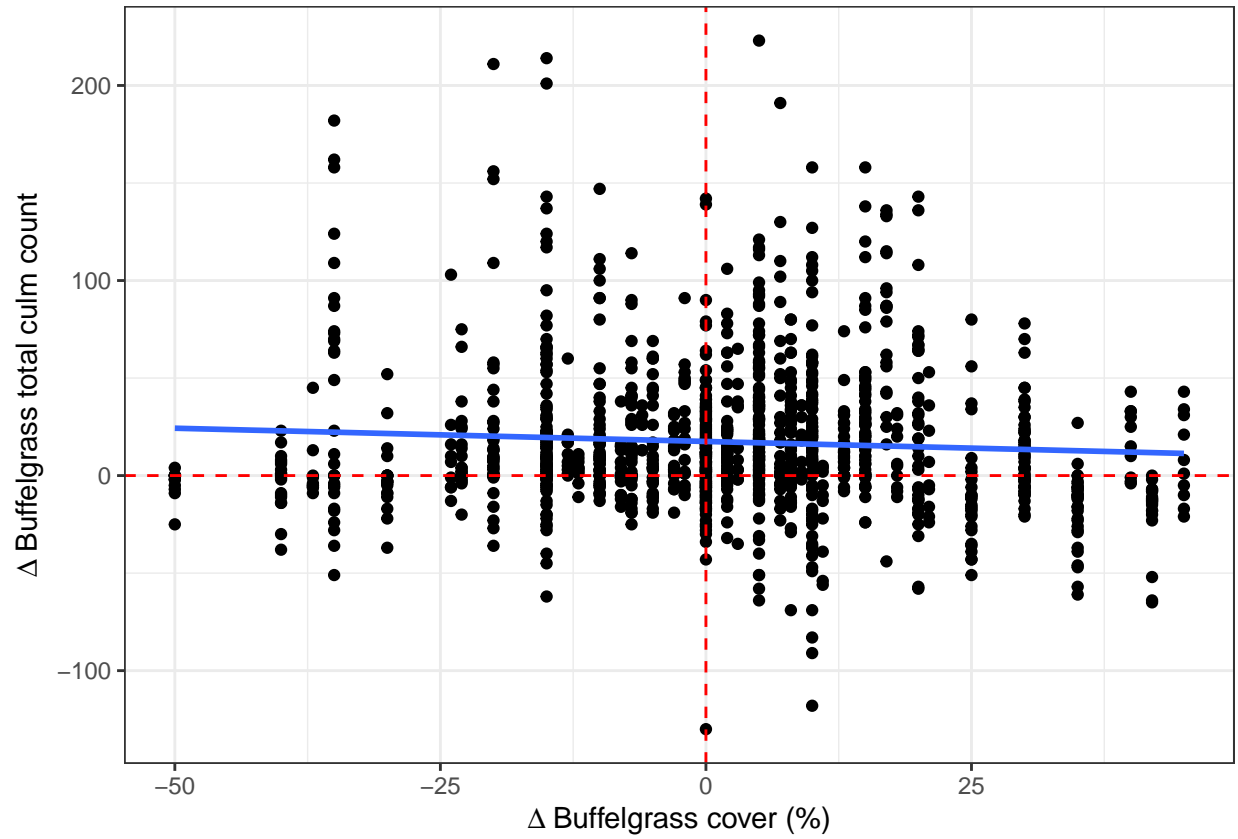


Figure S9. Simple linear regression of year-to-year change in buffelgrass total culm count as a function of year-to-year change in buffelgrass plot cover, pooling all sampling locations and times. Vertical red dashed line indicates no change in buffelgrass cover while horizontal line indicates no change in buffelgrass total culm count.