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Cost-effective seed mix design and first-year management

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Technical Report

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Introduction

Landscapes dominated by agriculture have experienced diminishing ecosystem services as land use continues to intensify and production inputs remain high. Declines in pollinator abundance (Cameron et al. 2011), deteriorating water quality (Jones et al. 2018), and continuing soil erosion (Wright and Wimberly 2013) have all become large-scale, significant stressors facing ecosystems in agricultural landscapes. In response, organizations have initiated targeted conservation programs to alleviate specific conservation challenges. In the North American Corn Belt, the United States Department of Agriculture (USDA) has created specific conservation initiatives intended to maximize single ecosystem services like upland game bird provision (CP-33 Habitat Buffers for Upland Birds), highly erodible land conservation (CP-2 Establishment of Permanent Native Grasses), and flood control (CP-23 Wetland Restoration) (USDA 2018a). In recent years, an especially popular conservation incentive has aimed for the restoration of pollinator habitat (CP-42 Pollinator Habitat), and approximately 160,000 ha in US Cornbelt states have been targeted for pollinator habitat plantings (USDA 2018b).

Restoring ecosystem services at scale requires executing conservation programs in a way that is resource and cost efficient as well as ecologically effective. Rather than pursuing programs that maximize single ecosystem services, conservation programs may achieve greater impact with limited resources (i.e. be more cost-effective) by working to balance multiple ecological benefits. A robust literature shows how diverse ecosystems in general can provide a wide variety of benefits simultaneously (e.g. Macfadyen et al. 2012; Wratten et al. 2012), and how ecological restoration can be largely self-sustaining (Miller et al. 2016). In the midwestern United States specifically, species rich tallgrass prairies provide a wide array of ecosystem services when restored on the landscape (Schulte et al. 2017). By strategically restoring prairie on 10% of farm fields, nitrogen and phosphorus losses to surface runoff can be reduced 73-82% (Zhou et al. 2014). Further, integrating prairie into farm fields and other parts of the rural landscape can practically eliminate sediment runoff (Helmers et al. 2012) and increase pollinator abundance (Ries et al. 2001). While the multiple benefits of tallgrass prairie are well known, no studies have investigated how to maximize ecological benefits of prairie reconstruction while minimizing cost.

Seed mix design is one of the largest determinants of project cost and ecological outcomes for prairie reconstructions. In particular, grass-to-forb seeding ratio affects cost since forb seed can be much more expensive relative to grass species (Prairie Moon Nursery 2012). Even for seed mixes with the same overall seeding rates, a mix with a low grass-to-forb seeding ratio is considerably more expensive than one with a high grass-to-forb ratio. Seeding rates for different plant functional groups that are too high or low may also adversely affect ecological outcomes. Grass seeding rates that are too low may promote too much bare ground, encouraging perennial weed species such as smooth brome (*Bromus inermis*) or Kentucky bluegrass (*Poa pratensis*) to quickly invade and dominate developing stands. The resulting lack of deep, fibrous rooted prairie grasses may also provide minimal soil and water quality benefits. Grass seeding rates that are too high may produce stands that are too competitive for forbs to persist (McCain et al. 2010), which would likely result in insufficient forage for pollinator habitat (Hopwood 2008). When designing seed mixes, species selection also influences establishment success. Customizing seed mixes by matching species moisture tolerances to site soil conditions may result in a reconstruction that establishes readily and persists long-term (Smith et al. 2010). However, rather than using customized seed mixes that match site conditions, many prairie reconstruction projects simply use "off-the shelf" mixes that reflect specific program goals (e.g. prioritizing short grasses for pollinator habitat provision (USDA 2011)), or seek to minimize costs. Ultimately, these pre-made seed mix choices may lead to poor cost effectiveness when considering high costs of seed and low potential stand establishment due to the seed mix not having been designed to match site conditions.

First-year management may also play a role in cost-effective prairie reconstruction. Post-agricultural sites where restoration typically occurs are often quickly dominated by fast-growing annual weeds by the time sown prairie seeds begin germinating (Smith et al. 2010). The resulting low-light, competitive conditions are not well suited to slow-growing prairie seedlings that require multiple growing seasons to reach maturity, and may result in poor seedling survival and low cost-effectiveness of purchased seed. Williams and others (2007) showed that prairie seedlings sown into established warm-season grasses were reliant on high light conditions created by frequently mowing tall vegetation in order to survive in subsequent years. After four years, the authors found that mowing vegetation while seedlings were establishing doubled the abundance of sown species. Since the cost of seed (and the resulting seedlings) can be over 15 times higher than the cost of post-seeding establishment mowing (Phillips-Mao et al. 2015), a significant improvement in survival of seedlings represents a large increase in cost-effectiveness. However, it remains unknown whether the large seedling survival increases from mowing observed in warm-season grass stands will also be present in the annual weed communities of post-agricultural lands.

Improving cost-effectiveness in prairie reconstruction requires an understanding of how key design and management decisions impact both costs and ecological outcomes. We assessed two factors- seed-mix design and establishment management- using experimental prairie reconstructions in field trials. Our objective was to compare native plant establishment and cost effectiveness with and without first-year mowing for three different seed mixes that differed in grass to forb ratio and soil type customization. With knowledge of plant establishment, cost effectiveness, and mowing management outcomes, conservation practitioners will be better equipped to restore prairie efficiently and successfully.

Materials and Methods

Study site

The study site is located at the Iowa State University Northeast Research and Demonstration Farm (42° 56´ N, 92° 34´ W) near Nashua, IA in Floyd County (Figure 1). The soils underlying the study site are primarily poorly drained Clyde clay loams, with a minor component of somewhat poorly drained Floyd loams in the northwest (NRCS 2016). Topographically, the study site is level, and slopes do not exceed 5% grade. Land use prior to this experiment was agricultural, with corn and soybeans consistently grown in rotation at the site.

We prepared the study site using tillage after crop production. The year before experiment establishment (2014), the farm manager planted the site with soybeans and applied pre-emergent herbicide (Zidua, application rate 3 oz/ac) in May. The manager applied a post-emergent herbicide (Roundup Weathermax, application rate unknown) in mid-July. To create a suitable seedbed before planting in the spring of 2015, the farm manager chisel plowed the site in March and field cultivated twice in April. The prepared seedbed was loose, with clods less than 6.4mm in diameter.

Experimental design

To assess cost effective seed mix design and establishment management, we installed a randomized complete block experiment with three replicates in May 2015 (Figure 2). We established two 40 x 253 ft strips as blocks, each consisting of eighteen 20 x 28 ft plots. In each plot, we randomly assigned a combination of mowing and seed mix treatments (n=36). We manipulated mowing at two levels: 1) unmowed and 2) mowed, and seed mix treatments at three levels: 1) economy grass mix, 2) diversity mix, and 3) pollinator mix.

We varied seed mix treatments based on grass to forb ratio and soil type customization. We designed three seed mixes to mimic typical NRCS approved mixes commonly planted in Iowa: 1) an economy grass mix ($130/ac) which included 21 species at a 3:1 grass to forb seeding rate ratio, 2) a diversity mix ($291/ac) which included 71 species at a 1:1 grass to forb seeding rate ratio, and 3) a pollinator mix ($368/ac) which included 38 species at a 1:3 grass to forb ratio (Appendix 1). We selected species for economy and pollinator mixes to mimic popular commercially available seed mixes, while we designed the diversity mix using species selected for mesic soil conditions at the experiment site. To ensure accuracy in seeding rates and seed purity, we calculated seeding rates for each species using pure live seed (PLS). We standardized the overall seeding rate among mixes at 430 PLS seeds per square meter. We purchased seed from native seed nurseries in Iowa and adjacent states in January 2017 and stored the seed in a temperature and humidity controlled (4°C, 45% RH) cooler until planting. We weighed, bagged, and mixed the seed for each plot separately. To ensure soils were stabilized as prairie seedlings established, we included a nurse crop of oats at a rate of 2.5 bu/ha.

We seeded the study site in late April of 2015. We used a Truax FLX-86U no-till drill with a John Deere JD-5325 tractor to seed each plot independently. To minimize seed contamination between treatments, we cleaned out the drill after seeding each plot. Because plot size was small, we used tube modifications connected to the seed cups to accommodate the small amounts of seed. The drill operator started at the west end of each strip and seeded each consecutive plot in the strip. Since there were no buffers between plots, drilling was unidirectional to eliminate seed contamination in adjacent plots.

For the mowing treatment, we mowed vegetation frequently throughout the 2015 growing season. We mowed plots to 11.4cm when vegetation height reached approximately 0.5m (4 total mowings: June 16, July 23, August 13, November 4), and left the resulting thatch on site. We did not mow plots in 2016 or 2017.

Data collection

We measured density (plants, stems, and seedlings) and canopy cover each September from 2015-2017. We sampled late in the year to allow seedlings to grow to a size that allowed confidence in seedling identification. To sample plant density and canopy cover, we used five 0.1m^2 quadrats spaced every 1m along a 5m transect established randomly in each plot. To reduce edge effects, we did not lay quadrats within 1m of plot borders. In each quadrat, we counted and identified all individual plants (genets) and stems (ramets) of planted species. We classified plants smaller than 10cm in height as seedlings. No planted seedlings were found in 2016 so we present only 2017 seedling data in this report. In 2016-2017, we recorded canopy cover values for annual weeds, perennial weeds, and native plants, and number of inflorescences on species rooted in the quadrat. We identified and recorded weed species and stem density in quadrats in 2016, but not in 2017. To assess cost effectiveness, we calculated the cost of seed per plot and divided by the number of 1000 established native stems in each plot (cost per thousand stems).

We measured selected species' biomass in September from 2015-2017 to assess differences in plant growth among mowing and seed mix treatments. We selected species common to all seed mixes, and measured biomass of *Ratibida pinnata* in 2015 and 2017, and *Monarda fistulosa* in 2016. We generated a randomized GPS point in each plot and sampled the closest plant to that point. In 2015-2016, we used a bulb planter 5cm in diameter and 10cm deep to extract a soil plug containing the plant, taking care to ensure no stems were damaged. To standardize plug size, we trimmed plugs to 7cm depth. In 2017 plants were too large to use the bulb planter on above-ground vegetation, so we clipped and removed plants at ground level. We then used the bulb planter to extract a soil plug from the center of the plant. After extraction, we washed plant plugs to remove soil and roots from other plants, separated roots and shoots, and each plant was dried individually in paper bags. To achieve constant mass, we oven dried plant material at 60°C for three days. We used an Ohaus PA313 electronic scale to measure resulting biomass.

Data analysis

To analyze the effects of seed mix and mowing on cost-effectiveness and native plant establishment, we used linear effects models and post-hoc Tukey HSD tests to compare means within treatment groups. We analyzed models in R using ANOVA (R Development Core Team 2015) to test for main effects and interactions. We modeled seed mix, mowing, block, and interactions as fixed effects ($p < 0.05$). In post-hoc analysis, we used Tukey HSD tests to compare differences in vegetation and cost-effectiveness measures ($p < 0.05$) among seed mix treatments at each level of mowing. To meet parametric assumptions for testing, we square-root-transformed plant density, stem density, and biomass values. We applied a log-transformation to cost-effectiveness values.

Results

Effects of seed mix

Seed mix consistently affected stem density in planted native species over all three years of the experiment (Table 1). Overall, forb and grass stem density increased through time regardless of seed mix, though increases in grass stem density were much more rapid than for forbs (Figure 3). We observed one exception in the economy mix; it decreased in grass stem density in the third year. Forb stem density was generally high (from 1.4 to 2.5 times higher) in the pollinator (2015: $t = 2.95$, $p < 0.05$; 2016: $t = 4.18$, $p < 0.001$; 2017: $t = 2.90$, $p < 0.05$) and diversity (2015: $t = 4.61$, $p < 0.001$; 2016: ns; 2017: $t = 2.23$, $p < 0.10$) mixes compared to the economy mix. The most prevalent forb species (in rank order) we found in the pollinator mix included *Rudbeckia hirta*, *Ratibida pinnata*, *Monarda fistulosa*, and *Zizia aurea*. The most prevalent forb species in both the diversity and economy grass mix was *Heliopsis helianthoides*, and other top species in the economy mix included *R. pinnata*, *R. hirta*, and *M. fistulosa*. Other common species in the diversity mix included *R. pinnata*, *R. hirta*, and *Helianthus grosseserratus*. Conversely, grass stem density in the pollinator mix was very low (from 8 to 17 times lower) compared to the diversity (2015: $t = 7.45$, $p < 0.001$; 2016: $t = 7.28$, $p < 0.001$; 2017: $t = 8.62$, $p < 0.001$) and economy mixes (2015: $t = 6.97$, $p < 0.001$; 2016: $t = 10.14$, $p < 0.001$; 2017: $t = 9.00$, $p < 0.001$). The most prevalent grass species (in rank order) we found in the pollinator mix included *Andropogon gerardii*, *Bouteloua curtipendula*, *Sporobolus compositus*, and *Koeleria macrantha*. Grass stem density was typically no different in the diversity and economy mixes, though the economy mix produced 1.47 times more grass stems in the second year ($t = 2.86$, $p < 0.05$). The most prevalent grass species in both the diversity and economy grass mix was *Elymus canadensis*, and other top species in the economy mix included *A. gerardii*, *Sorghastrum nutans*, and S*chizacyrium scoparium*. Other dominant species in the diversity mix included *Panicum virgatum*, *B. curtipendula*, and *S. nutans*.

During years two and three of establishment, seed mix affected canopy cover of native species and weeds (Table 1). In general, the pollinator mix had high weed cover but low native cover, while the diversity and economy mixes had low weed cover but high native cover (Figure 4). Annual weeds consisted of mainly *Setaria* spp., *Ambrosia artemesifolia*, and *Conyza canadensis*. *Cirsium arvense* and *Elymus repens* were the most common perennial weeds. Annual weed cover decreased with planting age in all mixes, but by the third year, the pollinator mix still had relatively high annual weed cover (19.1%) relative to the diversity ($t = 6.00$, $p < 0.001$) or economy ($t = 6.53$, $p < 0.001$) mixes. Annual weed cover was uniformly very low (from 0.6% to 2.1%) in the diversity and economy mixes. Perennial weed cover was overall low in year 2 (from

1.1% to 3.6%), but by year three it was high (23%) in the pollinator mix compared to the diversity ($t = 4.93$, $p < 0.001$) or economy ($t = 5.35$, $p < 0.001$) mixes. Perennial weed cover was no different in the diversity and economy mixes, and remained low in year three (< 5.1%). Native cover in the pollinator mix was distinctly low (from 1.5 to 2.1 times lower) compared to the diversity (2016: $t = 2.59$, $p < 0.05$; 2017: $t = 7.52$, $p < 0.001$) and economy mixes (2016: $t = 3.87$, $p < 0.01$; 2017: $t = 7.54$, $p < 0.001$). Native cover did not differ between the diversity and economy mixes.

Seed mix showed a consistent effect on native species richness (Table 1). Richness generally increased over time regardless of seed mix, though it did not increase in the pollinator mix in year three (Figure 5). The diversity mix had the highest species richness in all years of the study (from 32.3 to 93.1% higher) compared to the pollinator (2015: $t = 5.22$, $p < 0.001$; 2016: $t = 3.66$, $p < 0.01$; 2017: $t = 7.80$, $p < 0.001$) and economy mixes (2015: $t = 3.21$, $p < 0.01$; 2016: $t = 2.44$, $p = 0.05$; 2017: t 3.85, $p < 0.01$). Species richness was not different in the economy and pollinator mixes except in the third year, where richness in the economy mix was 46.2% greater than in the pollinator mix ($t = 5.35$, $p < 0.001$).

Native seedlings from natural seed regeneration were more abundant in some seed mixes than others (Table 1). The economy mix had the fewest seedlings, and the diversity and pollinator mixes had on average 1.6 times as many seedlings ($t = 3.20$, $p < 0.01$; $t = 3.30$, $p < 0.01$) (Figure 6). We found no differences in seedling abundance between the diversity and pollinator mixes. The species composition of seedlings generally reflected key flowering species from previous years, and three species composed the overwhelming majority of seedlings found: *Ratibida pinnata*, *Rudbeckia hirta*, and *Heliopsis helianthoides* (Figure 7). While the pollinator and diversity mixes both produced similar amounts of seedlings, the diversity mix was composed of more *H. helianthoides*, and the pollinator mix was composed of more *R. hirta*.

We did not detect an effect of seed mix on flowering density. Cumulative flower density (sum of flower density per square meter over three growing seasons) was highly variable from plot to plot (Figure 8). However, there was marginal evidence to suggest that in mowed plots, the pollinator mix produced more flowers than the economy mix ($t = 2.31$, $p < 0.10$).

Cost effectiveness differed among seed mixes (Table 1). The cost to produce 1000 native stems was lowest in the economy mix ($0.07 ± 0.01) compared to the diversity ($0.13 ± 0.01) or pollinator ($0.41 ± 0.09) mixes ($t = 4.02$ $p < 0.01$; $t = 10.51$, $p < 0.001$) (Figure 9). Though 46% less cost effective than the economy mix, the diversity mix was more than 67.3% more cost effective than the pollinator mix ($t = 6.49$, $p < 0.001$).

The effect of seed mix on biomass was unique among vegetation measures, as it was more predictive after the first two years of establishment (Table 1). For *Monarda fistulosa* in year two, neither root nor shoot biomass differed among seed mixes (Figure 10). For *Ratibida pinnata* in year three, root biomass was 34 to 40% greater in the pollinator mix compared to the diversity ($t = 3.35$ $p < 0.01$) or economy mixes ($t = 3.565$, $p < 0.01$), and shoot biomass was 63% greater in the pollinator mix compared to the diversity ($t = 4.80$ $p < 0.001$) or economy mixes ($t = 4.13$, $p < 0.001$) (Figure 11).

Effects of mowing

Establishment mowing increased stem density in most planted native species in the first two years, but showed little effect by the third year (Table 1). Overall, stem density increased through time for both forbs and grasses regardless of mowing, though maximum densities were reached a year earlier with mowing (Figure 12). Compared to unmowed plots, forb stem density in mowed plots was higher in the first year ($t = 3.15$, $p < 0.01$), and there was marginal evidence that it was also higher in the second year ($t = 1.88$, $p < 0.10$). Forb stem density was not affected by mowing in year three. Grass stem density was greater in mowed plots in year one ($t = 7.10$, $p < 0.001$) and year two ($t = 4.66$, $p < 0.001$), but there was only marginal evidence that it was greater in year three ($F_{1,29} = 1.75$, $p < 0.10$).

Mowing had a strong effect on native and weed cover while stands were establishing, but the effect dissipated as stands matured (Table 1). Annual weeds were nearly three times less abundant during the second growing season when stands were mowed the first year ($t = 3.89$, $p < 0.001$), but by the third growing season, annual weed abundance was low regardless of mowing treatment (Figure 14). Perennial weed cover was unaffected by mowing. First-year mowing roughly doubled the canopy cover of planted native species in the second growing season (35% in unmowed plots, 61% in mowed plots) ($t = 5.22$, $p < 0.001$), but native cover increased to ~60% in year three regardless of mowing treatment.

Mowing increased native species richness in year one and two, but by year three, mow and no-mow plots were equally species rich (Table 1). In general, richness increased with time regardless of whether plots were mowed or not (Figure 15). The effect of mowing was strongest in year one where mowed plots had nearly twice as many species as unmowed plots ($t = 4.65$, $p < 0.001$). In year two, mowed plots had 20% more species ($t = 2.16$, $p < 0.05$). By the third year we did not detect differences in species richness between mowed and unmowed plots.

After three years, native seedlings from natural seed regeneration were much more abundant in prairie plantings that were mowed. Compared to unmowed plots, mowed plots had on average 2.4 times as many seedlings ($t = 4.24$, $p < 0.001$) (Table 1, Figure 6). The species composition of seedlings was generally similar regardless of mowing, and few trends in individual species could be discerned (Figure 7). In particular, the abundance of *Ratibida pinnata* seedlings increased markedly with mowing, but mowing had no clear effect in the other dominant seedling species (*Rudbeckia hirta* and *Heliopsis helianthoides*).

Flowering was highly variable during all three years of establishment and differences between mowing treatments were not readily apparent. Averaged across seed mixes, mowing did not have an effect on cumulative flower density (sum of flower density per square meter over three growing seasons) (Figure 8). However, we found some evidence ($t = 1.71$, $p < 0.10$) that mowing increased flowering density in the pollinator mix (540 ± 209 vs. 246 ± 113 flowers/m^2), and we observed greater but statistically insignificant cumulative floral resource provisioning in mowed compared to unmowed plots for the diversity mix (285 ± 76 vs. 139 ± 66 flowers/m^2).

The increase in flowering was visually apparent in the pollinator mix, especially in the second growing season (Figure 15), but the effect was no longer obvious in the third growing season.

First-year mowing increased cost-effectiveness (Table 1). Averaged over all mixes, the cost to produce 1000 native stems was twice as low when establishment mowing was carried out (t = 3.76, $p < 0.001$) (Figure 9). Mowing had the largest effect on the pollinator mix, with cost per thousand stems nearly three times lower in mowed compared to unmowed plots (t = 4.22, $p < 0.001$). We found cost effectiveness to be greater in mowed plots compared to unmowed plots in the diversity (36% more) and economy mixes (14% more) as well, though these differences were not statistically significant.

Similar to other vegetative measures, mowing increased biomass while stands were establishing, but the effect faded by the third growing season (Table 1). For *Monarda fistulosa* in year two, root biomass was over two times greater (t = 2.85 $p < 0.01$), and shoot biomass was three times greater (t = 4.35, $p < 0.001$) in mowed compared to unmowed plots (Figure 10). For *Ratibida pinnata* in year three, first year mowing did not have an effect on either root or shoot biomass (Figure 11).

Discussion

Diverse, functionally balanced seed mixes improve ecological performance while remaining cost effective. Our results showed that planting a diverse, 1:1 grass to forb prairie seed mix resulted in a stand that outperformed a grass dominated (3:1 grass to forb) seed mix on forb plant density and native species richness. At the same time, the diverse balanced mix also outperformed a forb dominated (1:3 grass to forb) pollinator seed mix on native cover, weed cover, native stem density, and native species richness metrics while matching performance with the pollinator mix in forb plant density and floral resources at a lower cost. Though the grass dominated economy mix was cheapest of all mixes we compared, the substantial increase in ecosystem service provisioning of the diversity mix makes the modestly increased costs a reasonable trade-off.

Over the long-term, diverse and functionally balanced seed mixes may be best suited to the sustained provision of ecosystem services. Our finding that the economy mix produced very few forb seedlings compared to other mixes suggests that seed reproduction of forbs is not viable in these mixes. Ultimately, the prevention of seed reproduction can lead to population declines in many important prairie forb species (Meissen et al. 2015, 2017b), which may lead to strong dominance by a few competitive C4 grasses over time and an overall loss of ecosystem service provisioning (McCain et al. 2010). In contrast, we found high abundances of forb seedlings in the diversity and pollinator mixes, suggesting population growth is viable in forb species in those stands (Meissen et al. 2017a). Though both diversity and pollinator mixes showed successful reproduction, we found fewer invasive species (perennial weeds) in the diversity mix. The poorly competitive nature of the pollinator stand that consisted of substantial bare ground and annual species likely allowed the expansion of invasive species like Canada thistle (*Cirsium arvense*) and quackgrass (*Elymus repens*), while a dense matrix of diverse native grasses and forbs in the diversity mix probably prevented their establishment. The importance of ensuring native cover to reduce bare ground and light to increase invasion resistance has also been observed in Kansas (Foster et al. 2015). Over the long-term, these highly competitive weed species may eventually exclude the seeded plant community, severely limiting ecosystem service provisioning in these pollinator stands.

Unexpectedly, *Ratibida pinnata* biomass was highest in the pollinator mix after three years. We did not anticipate seed mix to play a role in determining plant size. This result is likely due to the relatively low cover of other species, the high abundance of bare ground, and the resulting lack of competition from those conditions. Because larger plants typically produce more robust flowers (Galen 1999) and more bare ground creates nesting space, the pollinator mix appears to be successful at providing optimized pollinator ecosystem services. However, this situation may only be temporary, given our finding that perennial weeds also grew well under these conditions. If the trend of increasing perennial weed cover continues, we may eventually find forbs with reduced biomass in pollinator mixes as invasive species more strongly compete with native forbs.

Land managers can accelerate prairie establishment by conducting first-year mowing. Without mowing, the ecosystem services that tallgrass prairies provide (floral resources, perennial cover) are "lost" in the second year after seeding as the plant community remains mostly annual weeds. While the loss of one year of service provision is trivial for long-term restorations on protected lands, one year may represent a significant loss for some conservation programs on private lands. For example, typical contracts that dictate land use for the Conservation Reserve Program are 10 years long (USDA 2018a), and thus failure to mow during establishment represents a 10% loss of the potential ecosystem service provision for a stand enrolled in such a program. Vegetation outcomes are similar after 3 years regardless of mowing, so while stands may take an extra year to establish, failure to mow does not result in stand failure.

By mowing first-year prairie plantings, land managers can increase cost-effectiveness and the likelihood of forb population persistence. We found that mowing increased cost-effectiveness primarily by promoting regeneration from seed. Mowing more than doubled seedling production, which generated "free" plants (and hence stems) when calculating cost per stem in the study prairies. By creating a large pool of seedlings that can recruit to new reproductive adults, mowing ensures that these forb populations are able to take advantage of new gaps in the vegetation and continue population growth and persistence. Ultimately, mowing creates the conditions necessary in tallgrass prairies to ensure a self-sustaining ecosystem- one of the key components of ecological restoration (SERI 2004).

The benefits that mowing provides to native plant vigor appear to be temporary. An earlier report showed how the large increase in light at ground level increased greatly from mowing to drive improved establishment (Williams 2015), a result that accords with other studies (Williams et al. 2007, McCain et al. 2010). Since no mowing occurred in the second or third year, the light levels reaching growing species were likely not sufficiently different to result in changes between treatments. Ultimately, our findings suggest that mowing increases native plant vigor for an additional year after mowing, but then fades. Though we were only able to sample shorter lived, fast growing species due to the length of our study, the positive effect of mowing may persist longer in slower growing, long-lived species. Longer lived, slower growing species tend to be sensitive to competition early on (Silvertown et al. 1993) so the competitive release that mowing provides from fast growing annual weeds during the establishment phase may have a more significant effect on these species compared to others.

Conclusions

Our study showed that highly functional and cost-effective stands of native vegetation can be created by planting a diverse seed mix with a balance of forbs and grasses well suited to site soil conditions. With proper first-year mowing management, land managers can further improve cost effectiveness and accelerate stand establishment. While optimizing conservation plantings for single ecosystem services may result in slightly better outcomes in that service, our study demonstrated that conservation plantings designed to balance multiple ecological benefits at once (e.g. diversity seed mix) provided much of the same benefits, and were often indistinguishable from the optimized single benefit plantings. Further study should investigate other means of increasing cost effectiveness in prairie establishment, including the predictability and generalizability of our results. In particular, experiments that identify species responses to other key management choices such as planting time or seed mix design under different soil conditions can increase our understanding of successful outcomes.

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Literature Cited

Cameron, S. A., J. D. Lozier, J. P. Strange, J. B. Koch, N. Cordes, L. F. Solter, and T. L. Griswold. 2011. Patterns of widespread decline in North American bumble bees. Proceedings of the National Academy of Sciences 108:662–667.

Foster, B. L., G. R. Houseman, D. R. Hall, and S. E. Hinman. 2015. Does tallgrass prairie restoration enhance the invasion resistance of post-agricultural lands? Biological Invasions 17:3579–3590.

Galen, C. 1999. Why Do Flowers Vary? BioScience 49:631–640.

Helmers, M. J., X. Zhou, H. Asbjornsen, R. Kolka, M. D. Tomer, and R. M. Cruse. 2012. Sediment Removal by Prairie Filter Strips in Row-Cropped Ephemeral Watersheds. Journal of Environment Quality 41:1531.

Hopwood, J. L. 2008. The contribution of roadside grassland restorations to native bee conservation. Biological Conservation 141:2632–2640.

Jones, C. S., J. K. Nielsen, K. E. Schilling, and L. J. Weber. 2018. Iowa stream nitrate and the Gulf of Mexico. PLOS ONE 13:e0195930.

Macfadyen, S., S. A. Cunningham, A. C. Costamagna, and N. A. Schellhorn. 2012. Managing ecosystem services and biodiversity conservation in agricultural landscapes: are the solutions the same ? Journal of Applied Ecology 49:690–694.

McCain, K. N. S., S. G. Baer, J. M. Blair, and G. W. T. Wilson. 2010. Dominant Grasses Suppress Local Diversity in Restored Tallgrass Prairie. Restoration Ecology 18:40–49.

Meissen, J. C., S. M. Galatowitsch, and M. W. Cornett. 2015. Risks of overharvesting seed from native tallgrass prairies. Restoration Ecology 23:882–891.

Meissen, J. C., S. M. Galatowitsch, and M. W. Cornett. 2017a. Meeting seed demand for landscape-scale restoration sustainably: the influence of seed harvest intensity and site management. Ecoscience 24:145–155.

Meissen, J. C., S. M. Galatowitsch, and M. W. Cornett. 2017b. Assessing long-term risks of prairie seed harvest: what is the role of life-history? Botany 95:1081–1092.

Miller, B. P., E. A. Sinclair, M. H. M. Menz, C. P. Elliott, E. Bunn, L. E. Commander, E. Dalziell, E. David, B. Davis, T. E. Erickson, P. J. Golos, S. L. Krauss, W. Lewandrowski, C. E. Mayence, L. Merino-Martín, D. J. Merritt, P. G. Nevill, R. D. Phillips, A. L. Ritchie, S. Ruoss, and J. C. Stevens. 2016. A framework for the practical science necessary to restore sustainable, resilient, and biodiverse ecosystems. Restoration Ecology:1–13.

NRCS [Natural Resources Conservation Service]. 2016. Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/.

Phillips-Mao, L., J. M. Refsland, and S. M. Galatowitsch. 2015. Cost-Estimation for landscape-scale restoration planning in the Upper Midwest, U.S. Ecological Restoration 33:135–146.

Prairie Moon Nursery. 2012. Catalog and cultural guide. http://www.prairiemoon.com/catalog-download.html.

Ries, L., D. M. Debinski, and M. L. Wieland. 2001. Conservation Value of Roadside Prairie Restoration to Butterfly Communities. Conservation Biology 15:401–411.

Schulte, L. A., J. Niemi, M. J. Helmers, M. Liebman, J. G. Arbuckle, D. E. James, K. Randall, M. E. O. Neal, M. D. Tomer, J. C. Tyndall, P. Drobney, J. Neal, G. Van Ryswyk, L. A. Schulte, J. Niemi, M. J. Helmers, M. Liebman, J. G. Arbuckle, and D. E. James. 2017. Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands. Proceedings of the National Academy of Sciences 114:11247–11252.

Silvertown, J., M. Franco, I. Pisanty, and A. Mendoza. 1993. Comparative plant demography--relative importance of life-cycle components to the finite rate of increase in woody and herbaceous perennials. The Journal of Ecology 81:465.

Smith, D., D. Williams, G. Houseal, and K. Henderson. 2010. The Tallgrass Prairie Center guide to prairie restoration in the Upper Midwest. First edition. University of Iowa Press, Iowa City, IA.

Society for Ecological Restoration International (SERI) Science & Policy Working Group. 2004. The SER International primer on ecological restoration. Page Ecological Restoration. Second edition. Society for Ecological Restoration International, Tuscon.

United States Department of Agriculture (USDA). 2011. Pollinator habitat Iowa job sheet. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1077265.pdf.

United States Department of Agriculture (USDA). 2018a. Conservation Reserve Program. https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/.

United States Department of Agriculture (USDA). 2018b. Conservation Reserve Program Monthly Summary. https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Conservation/PDF/September2017Summary.pdf.

Williams, D. W., L. L. Jackson, and D. D. Smith. 2007. Effects of frequent mowing on survival and persistence of forbs seeded into a species-poor grassland. Restoration Ecology 15:24–33.

Wratten, S. D., M. Gillespie, A. Decourtye, E. Mader, and N. Desneux. 2012. Pollinator habitat enhancement: Benefits to other ecosystem services.

Wright, C. K., and M. C. Wimberly. 2013. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. Proceedings of the National Academy of Sciences 110:4134–4139.

Zhou, X., M. J. Helmers, H. Asbjornsen, R. Kolka, M. D. Tomer, and R. M. Cruse. 2014. Nutrient removal by prairie filter strips in agricultural landscapes. Journal of Soil and Water Conservation 69:54–64.

Table 1. ANOVA results showing the effect of seed mix and mowing on ten vegetation measures in the first three years of prairie establishment (*N*=36).

Vegetation metric	Seed Mix (*df* = 2)		Mow (*df* = 1)		Seed Mix : Mow (*df* = 2)	
	F	*p*	*F*	*p*	*F*	*p*
Year 1						
Native forb stem density	10.90	<0.001	9.91	<0.01	1.81	ns
Native grass stem density	34.75	<0.001	50.37	<0.001	4.73	<0.05
Native species richness	19.84	<0.001	24.42	<0.001	0.91	ns
Year 2						
Native forb stem density	8.76	<0.001	3.27	ns	1.97	ns
Native grass stem density	54.64	<0.001	21.70	<0.001	1.94	ns
Native species richness	7.97	<0.01	4.67	<0.05	1.72	ns
Annual weed cover	5.21	<0.01	15.14	<0.001	0.47	ns
Perennial weed cover	8.79	<0.001	0.14	ns	0.12	ns
Native species cover	7.78	<0.01	27.29	<0.001	1.22	ns
Root biomass (*Monarda fistulosa*)	0.07	ns	8.48	<0.01	2.32	ns
Shoot biomass (*Monarda fistulosa*)	1.03	ns	19.20	<0.001	0.21	ns
Year 3						
Native forb stem density	4.62	<0.05	0.16	ns	0.65	ns
Native grass stem density	51.86	<0.001	3.06	ns	0.29	ns
Native species richness	30.43	<0.001	0.01	ns	0.10	ns
Annual weed cover	26.30	<0.001	3.23	ns	4.21	<0.05
Perennial weed cover	17.70	<0.001	0.01	ns	0.28	ns
Native species cover	37.83	<0.001	1.48	ns	0.64	ns
Root biomass (*Ratibida pinnata*)	7.99	<0.01	0.39	ns	2.32	ns
Shoot biomass (*Ratibida pinnata*)	13.38	<0.001	2.42	ns	3.25	ns
Native seedling density	7.06	<0.01	18.01	<0.001	2.56	ns
Cumulative native flower density	1.69	ns	1.88	ns	1.05	ns
Cost per 1000 native stems	56.23	<0.001	14.10	<0.001	3.21	ns

Figure 1. Regional map showing the general location of the study site within the Tallgrass Prairie Region.

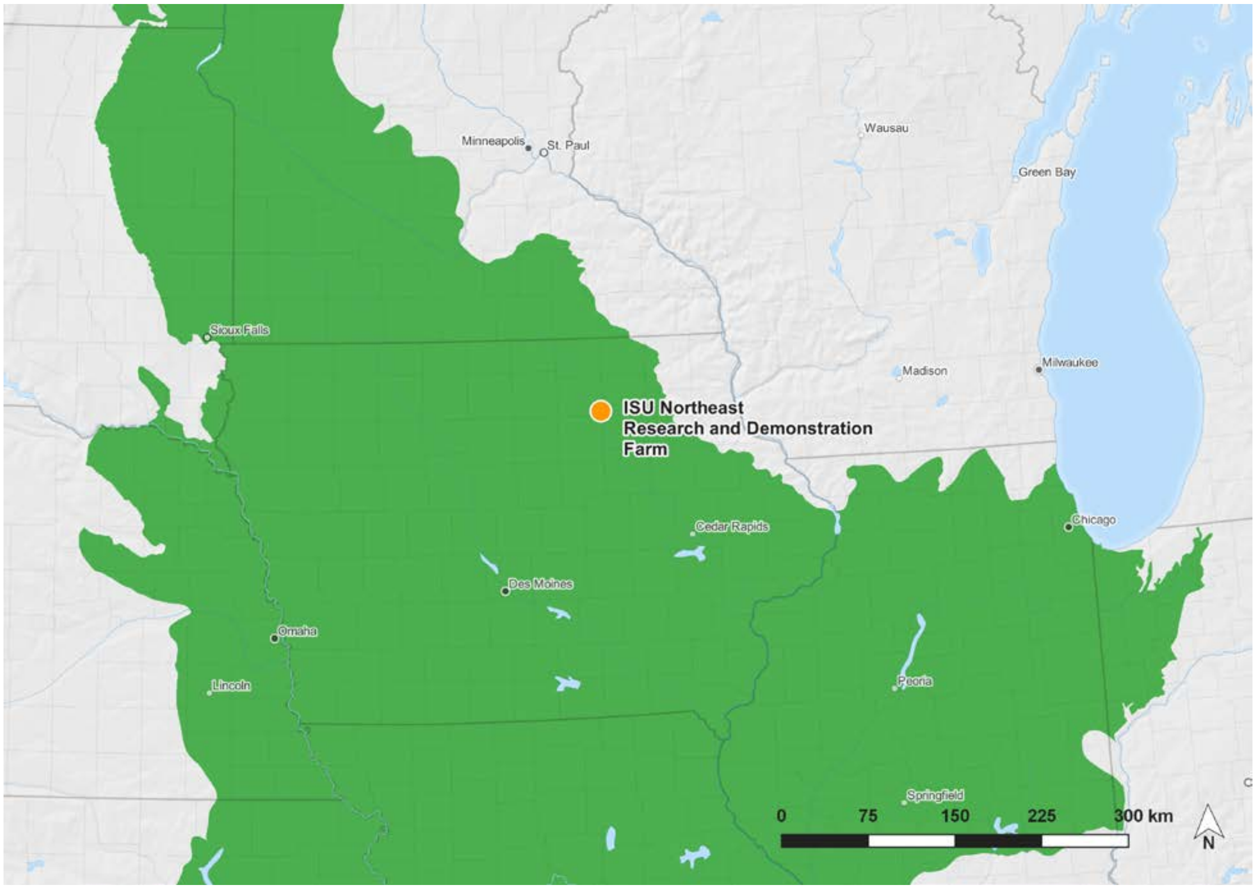


Figure 2. Experimental layout at the Iowa State University Northeast Research and Demonstration Farm near Nashua, Iowa.

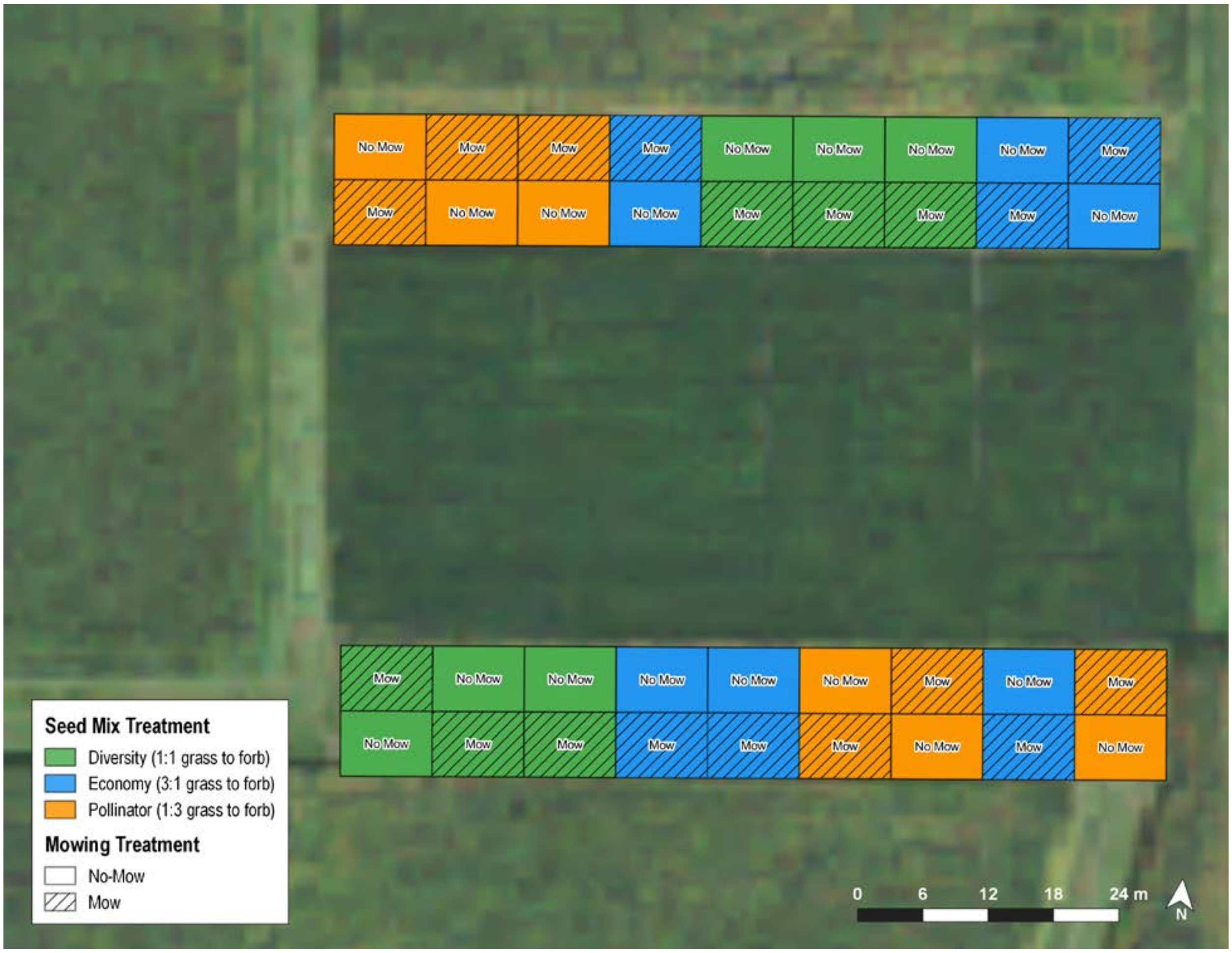


Figure 3. Mean stem density per square meter in a) planted forb species and b) planted grass species during three growing seasons of prairie establishment for three seed mixes. Values are averaged over both mowing treatments. Error bars represent standard error.

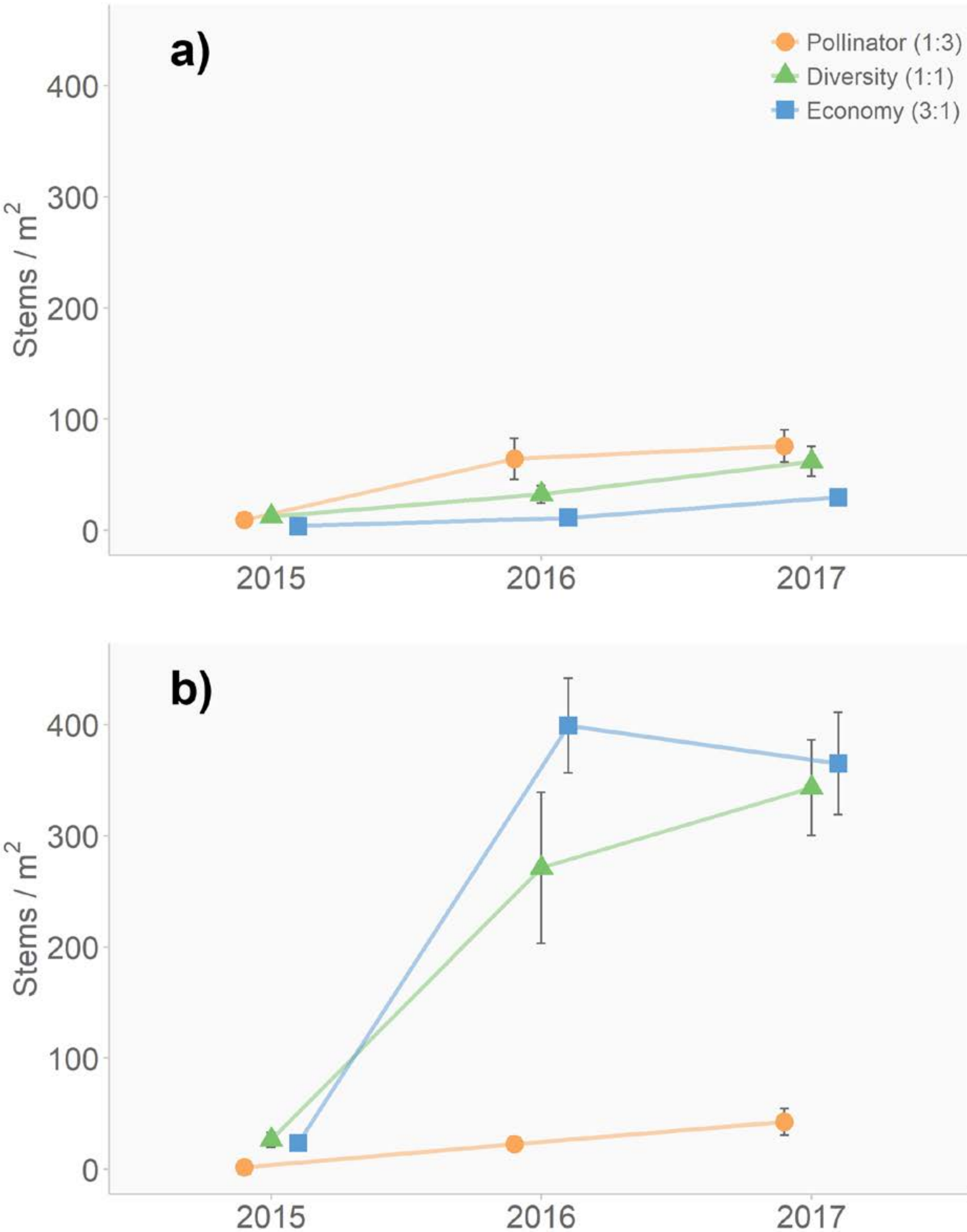


Figure 4. Canopy cover of a) annual weeds, b) perennial weeds, and c) planted native species during three growing seasons of prairie establishment for three seed mixes. Values are averaged over both mowing treatments. Error bars represent standard error.

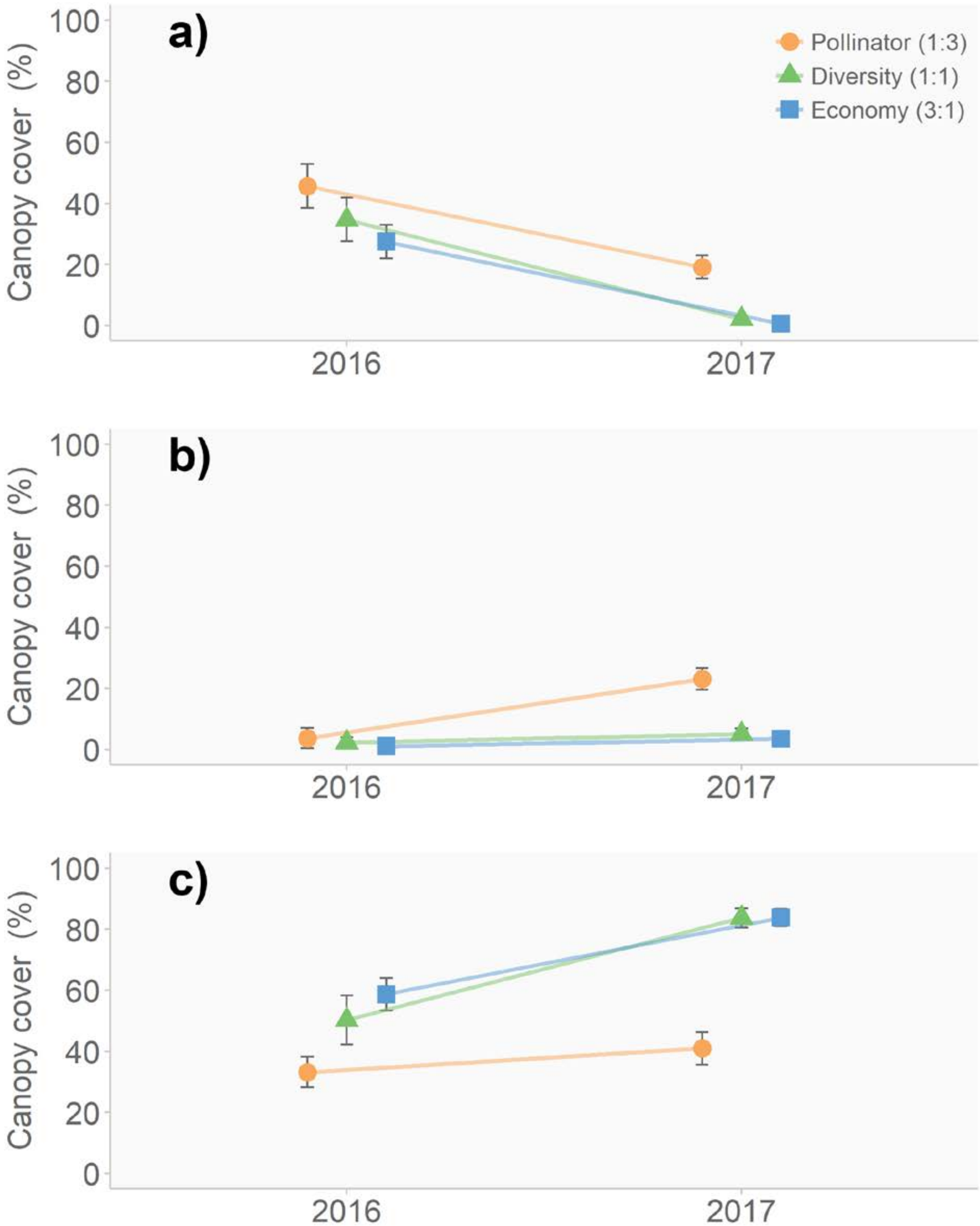


Figure 5. Native planted species richness per $0.5m^2$ during three growing seasons of prairie establishment for three seed mixes. Values are averaged over both mowing treatments. Error bars represent standard error.

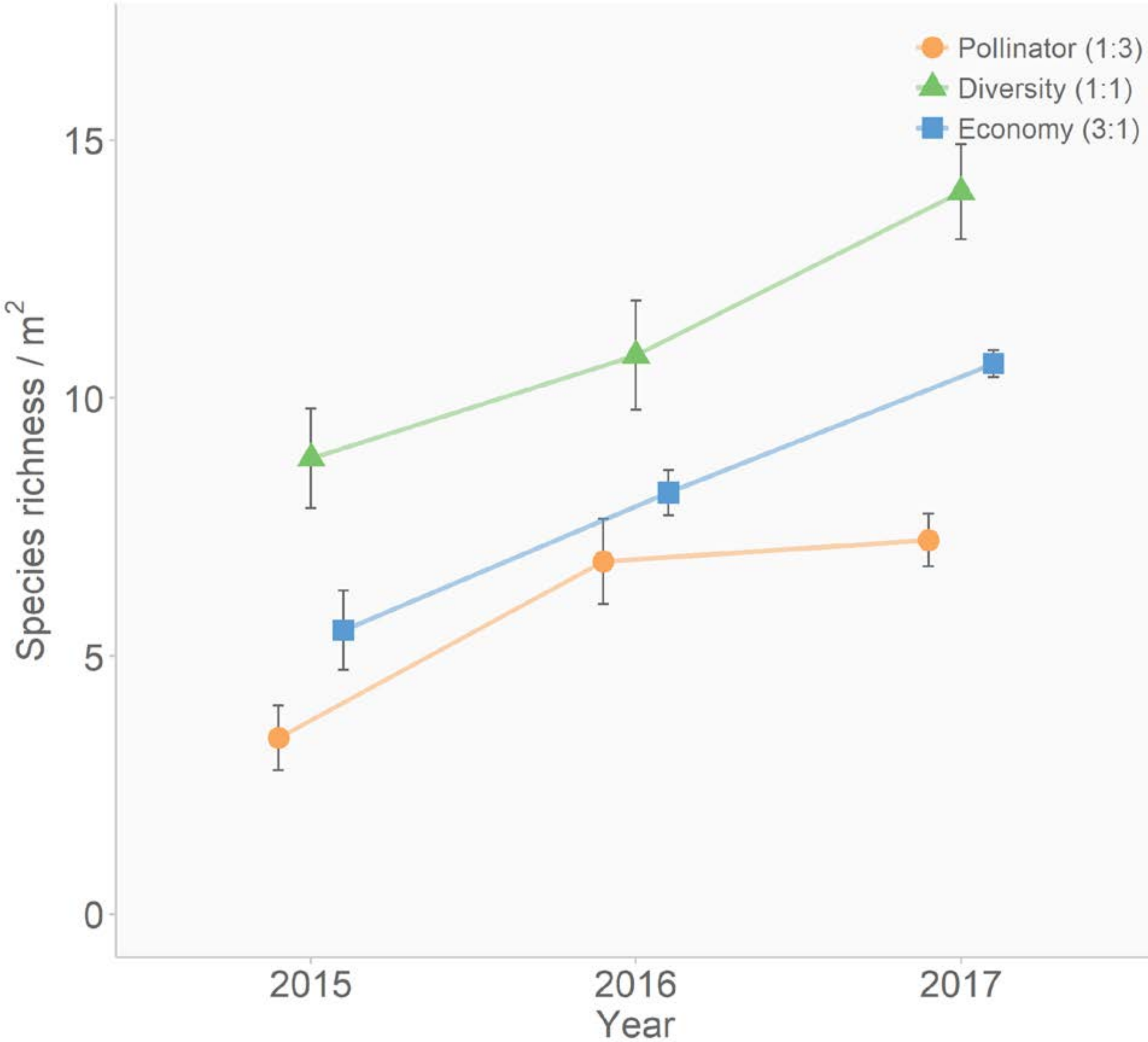


Figure 6. Average native seedling density per square meter in the third growing season (2017) for three seed mixes with and without establishment mowing. Error bars represent standard error.

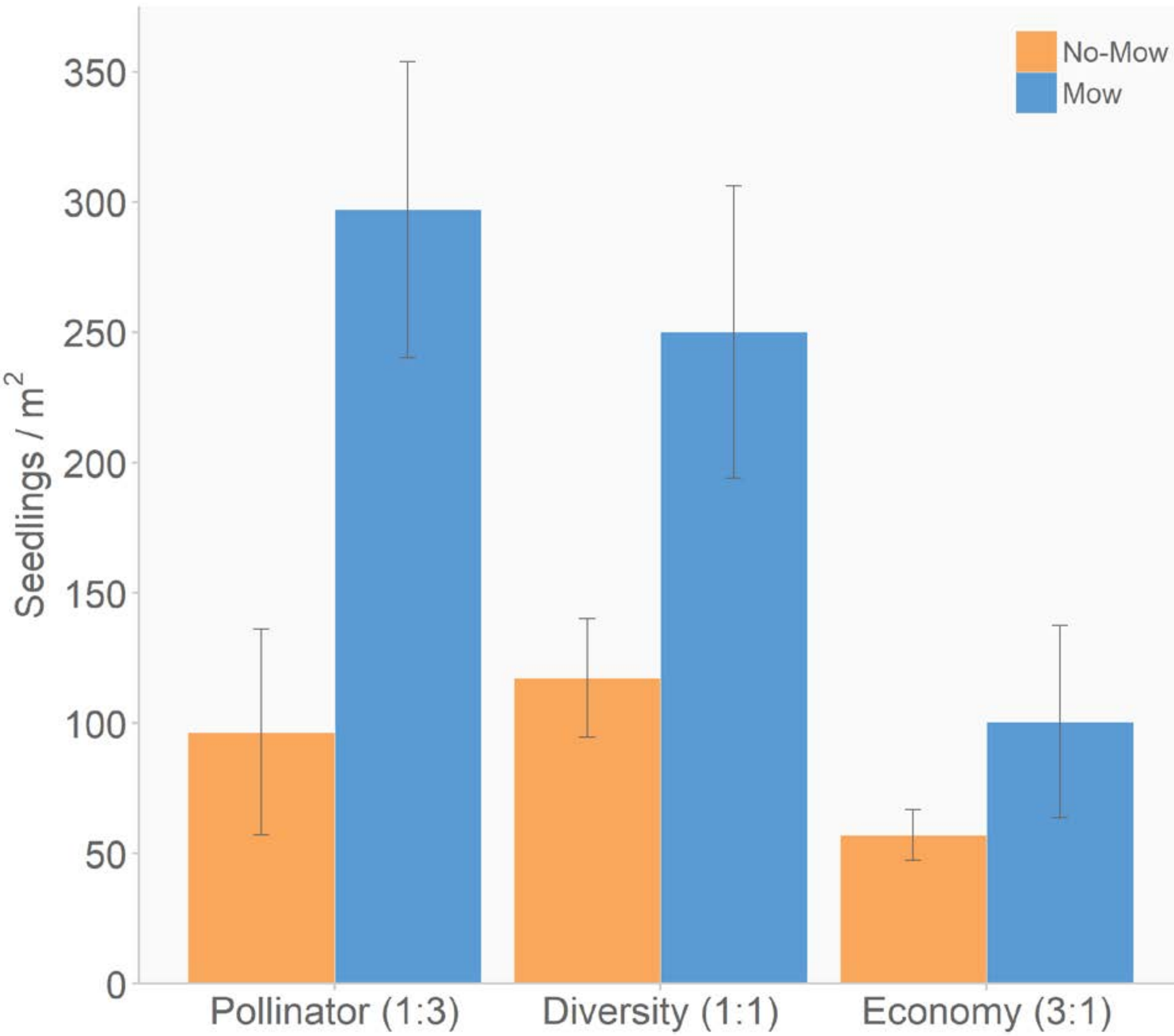


Figure 7. Average native forb seedling density per species per square meter in the third growing season (2017) for three seed mixes with and without establishment mowing. Species abbreviations: descan=*Desmodium canadense*, desill=*Desmodium illinoensis*, echpal=*Echinacea pallida*, helgro=*Helianthus grosseserratus*, helhel=*Heliopsis helianthoides*, monfis=*Monarda fistulosa*, oilrig=*Oligoneuron rigida*, ratpin=*Ratibida pinnata*, rudhir=*Rudbeckia hirta*, symlae=*Symphyotrichum lavae*, sympil=*Symphyotrichum pilosa*, zizaur=*Zizia aurea*.

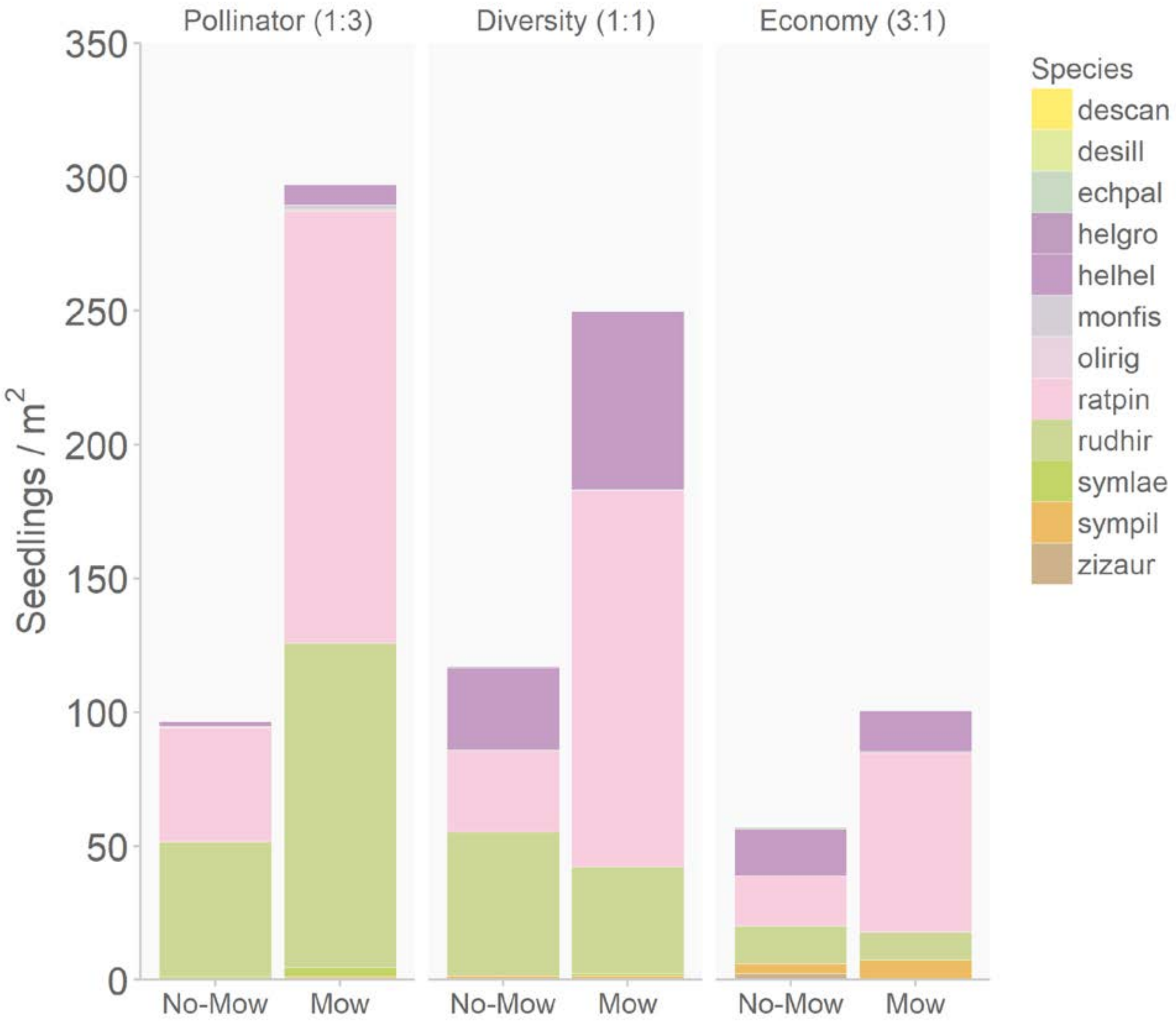


Figure 8. Cumulative floral resource provisioning (sum of flower density per square meter) after three growing seasons of prairie establishment for three seed mixes with and without establishment mowing.

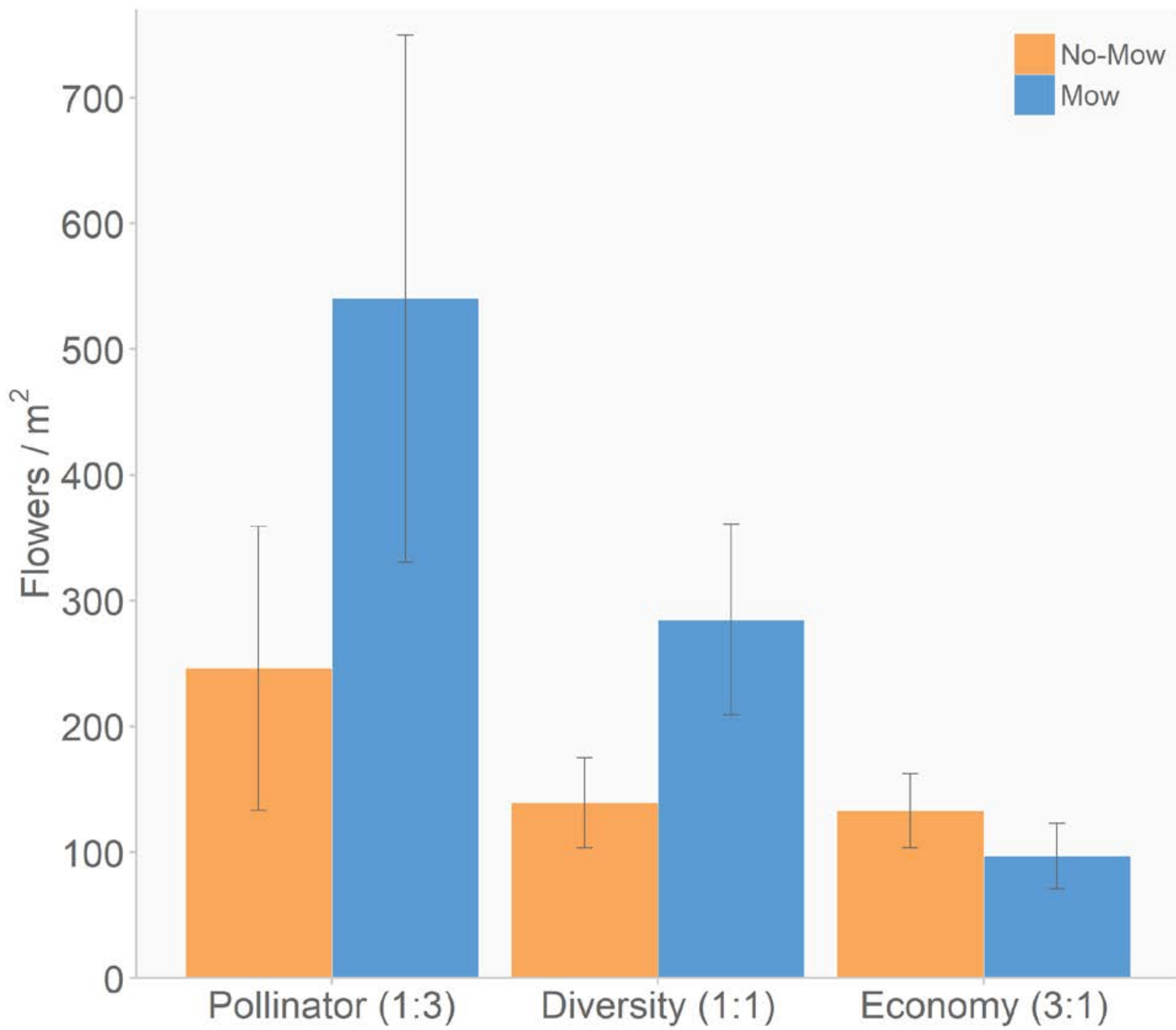


Figure 9. Mean cost to produce 1000 native plant stems after three growing seasons of prairie establishment for three seed mixes with and without establishment mowing.

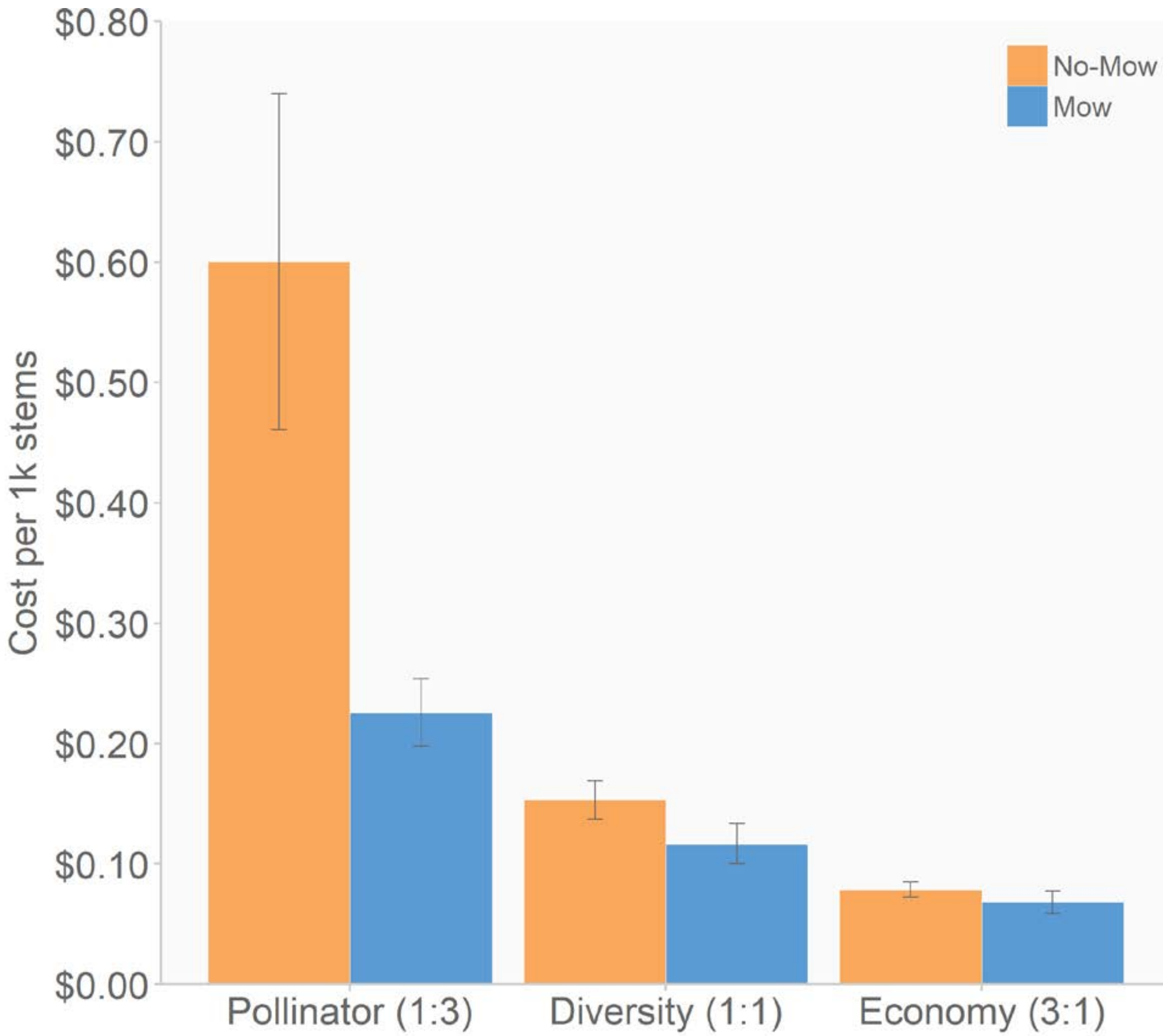


Figure 10. Mean biomass of *Monarda fistulosa* a) roots and b) shoots during the second year (2016) of prairie establishment for three seed mixes with and without establishment mowing.

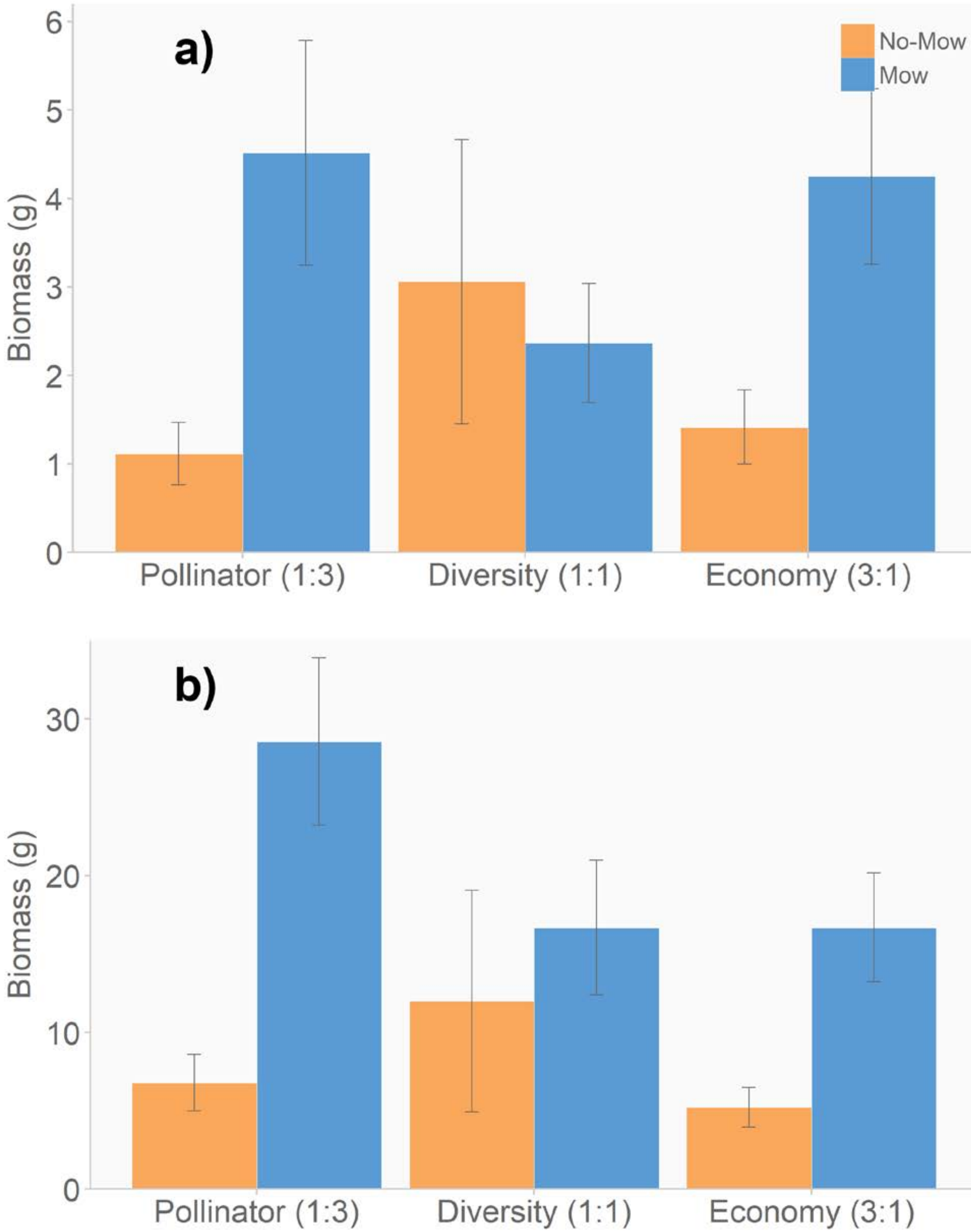


Figure 11. Mean biomass of *Ratibida pinnata* a) roots and b) shoots during the third year (2017) of prairie establishment for three seed mixes with and without establishment mowing.

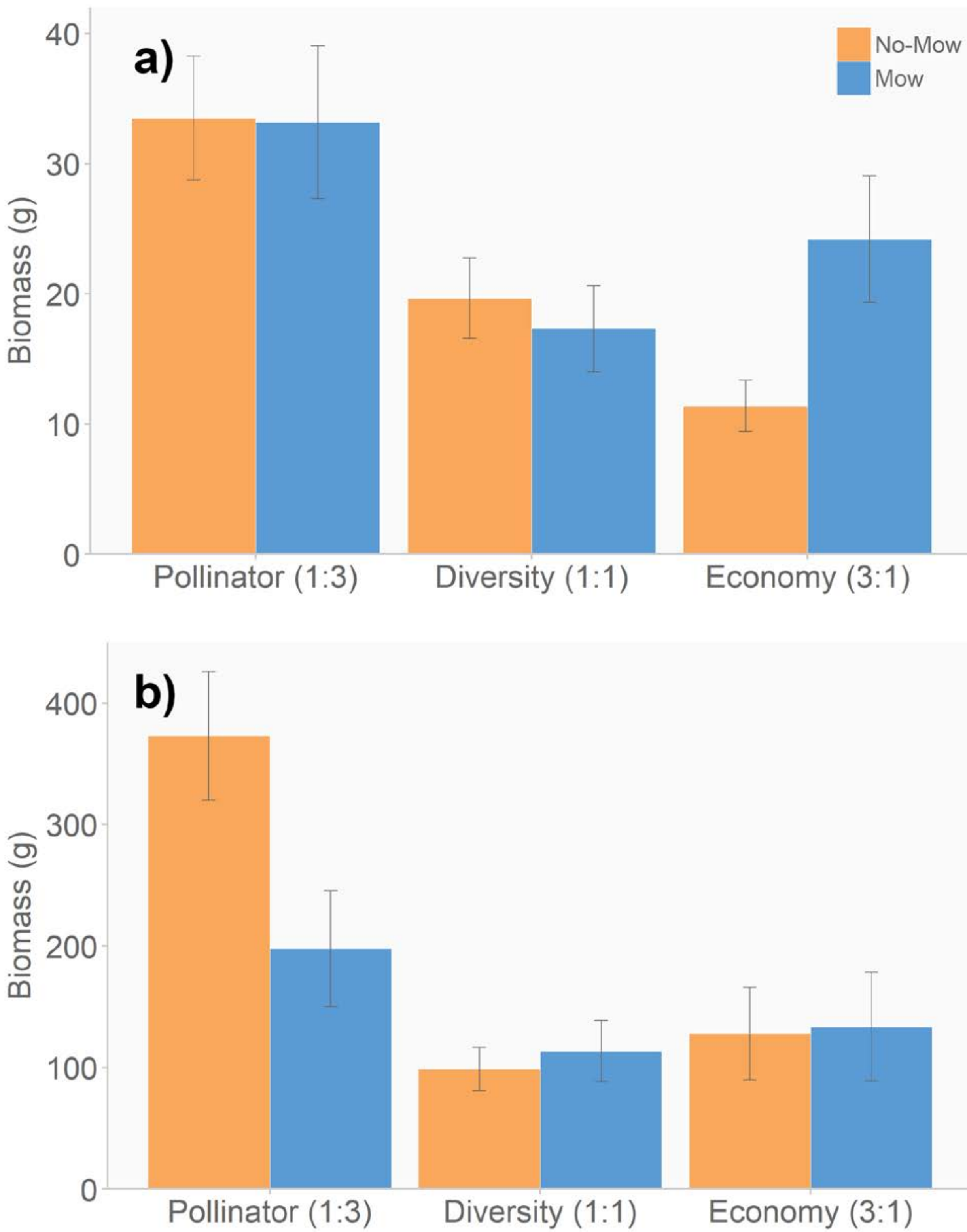


Figure 12. Typical view of the study site. Photos show the same pollinator plot in August of a) 2016 and b) 2017.

Figure 13. Mean stem density per square meter in a) planted forb species and b) planted grass species during three growing seasons of prairie establishment with and without establishment mowing. Values are averaged over all seed mix treatments. Error bars represent standard error.

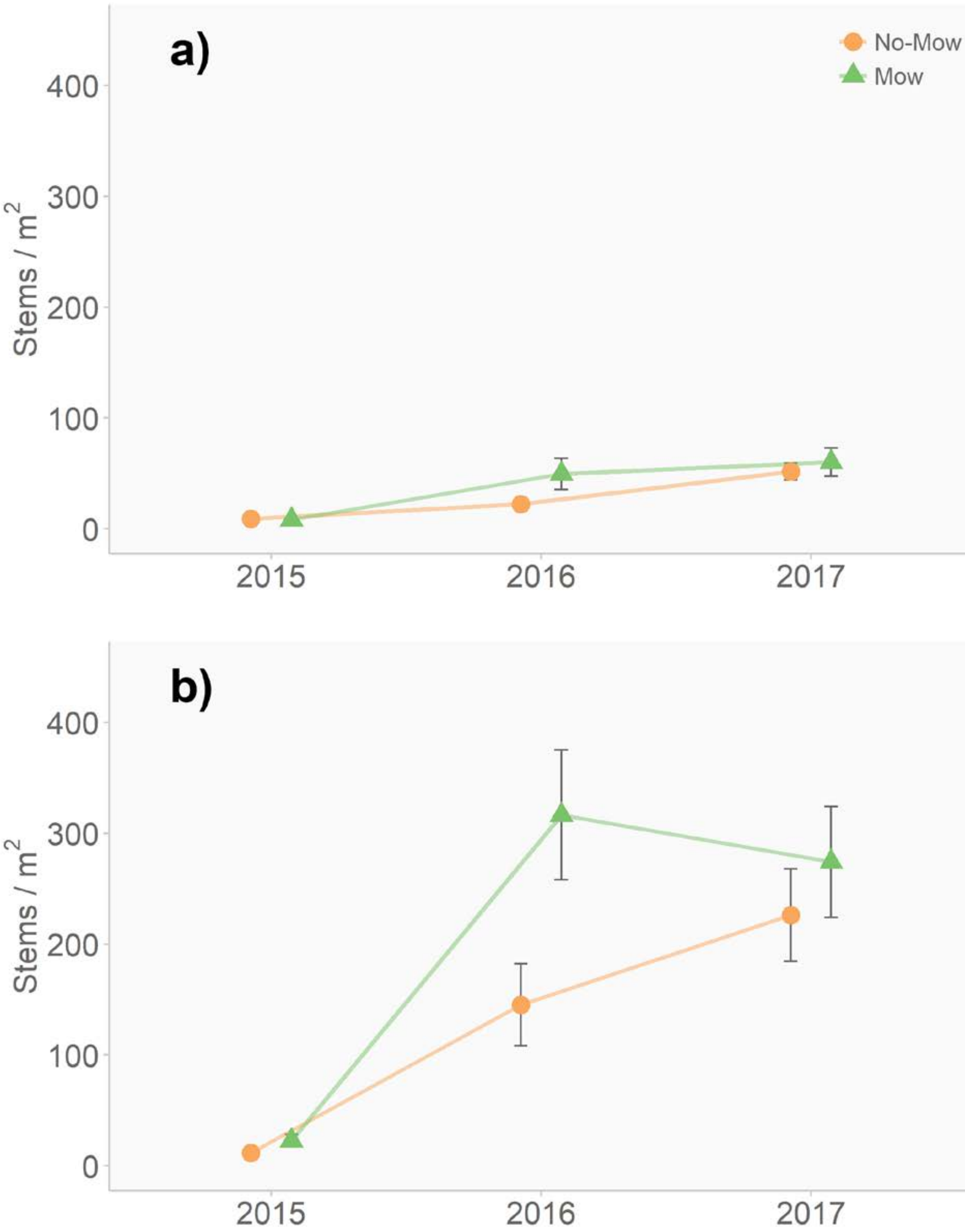


Figure 14. Canopy cover of a) annual weeds, b) perennial weeds, and c) planted native species during the second and third growing seasons of prairie establishment with and without establishment mowing. Values are averaged over all seed mix treatments. Error bars represent standard error.

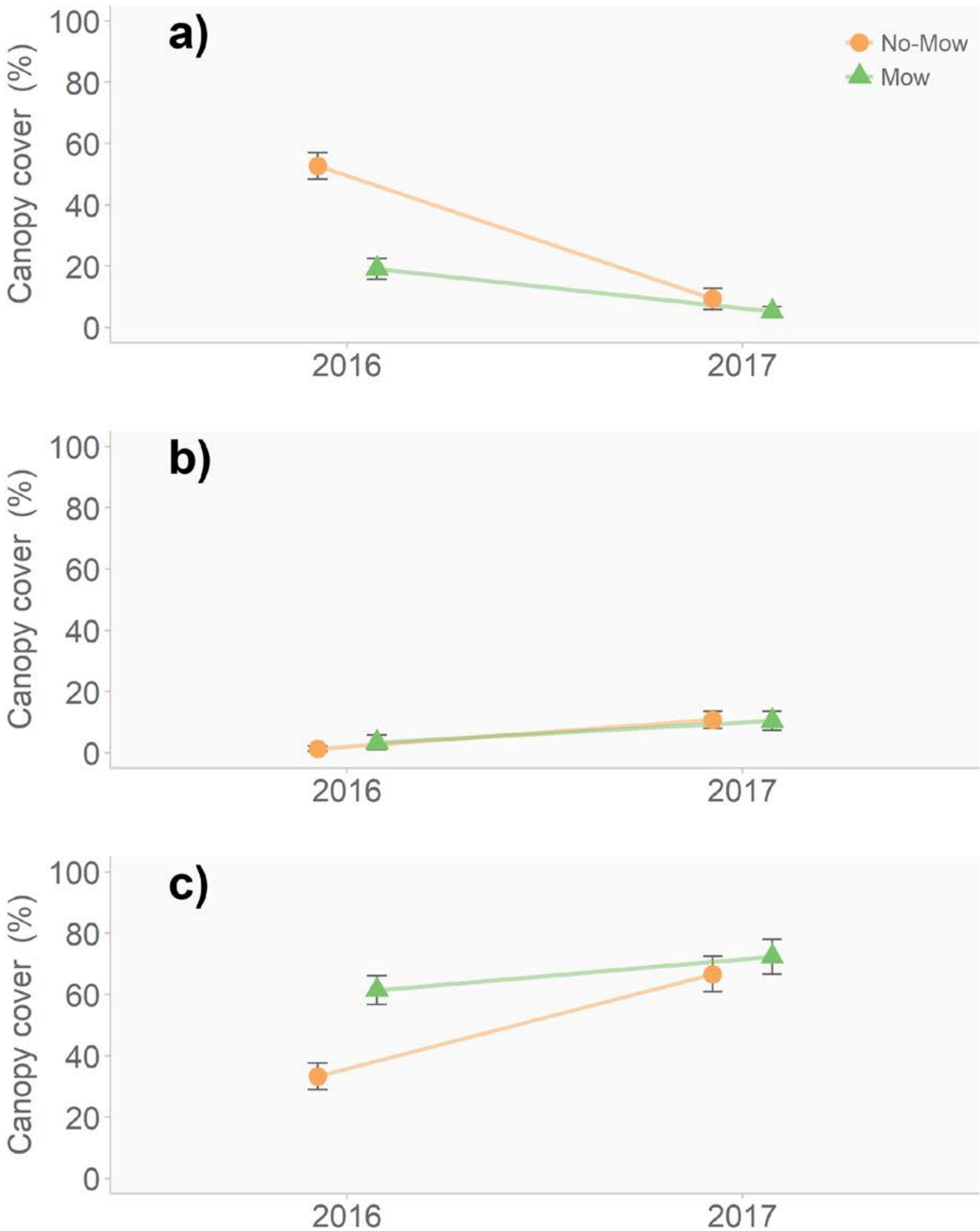
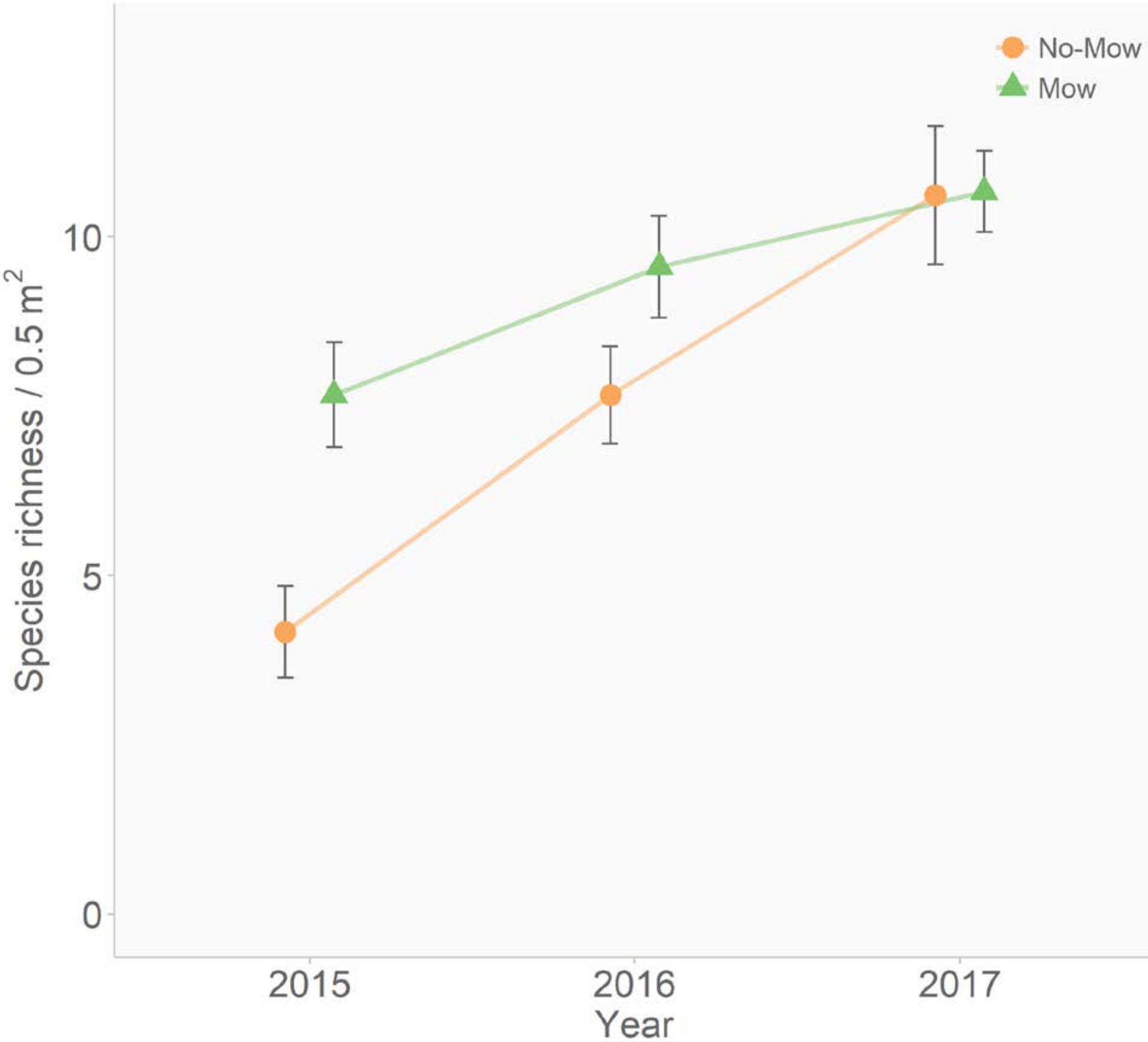


Figure 15. Planted native species richness per $0.5m^2$ during three growing seasons of prairie establishment for three seed mixes. Values are averaged over both mowing treatments. Error bars represent standard error.



Appendix A. Seed mixes planted as treatments at the Northeast Research and Demonstration Farm.

Pollinator Mix (1:3 grass-to-forb seeding rate ratio)

Common Name	*Scientific Name*	*Functional group*	*Seeds/m²*	*% mix*
Junegrass	*Koeleria macrantha*	grass (cool season)	31.6	7.32%
big bluestem	*Andropogon gerardii*	grass (warm season)	3.6	0.82%
side-oats grama	*Bouteloua curtipendula*	grass (warm season)	3.4	0.80%
little bluestem	*Schizachyrium scoparius*	grass (warm season)	29.1	6.72%
tall dropseed	*Sporobolus compositus*	grass (warm season)	17.8	4.11%
prairie dropseed	*Sporobolus heterolepis*	grass (warm season)	3	0.70%
yellow fox sedge	*Carex vulpinoidea*	sedge	19.8	4.58%
Canada milkvetch	*Astragalus canadensis*	forb (legume)	3.3	0.77%
white wild indigo	*Baptisia alba*	forb (legume)	0.6	0.15%
white prairie clover	*Dalea candida*	forb (legume)	22.5	5.20%
purple prairie clover	*Dalea purpurea*	forb (legume)	25.2	5.82%
common milkweed	*Asclepias syriaca*	forb	1.6	0.37%
butterfly milkweed	*Asclepias tuberosa*	forb	3.4	0.80%
pale purple coneflower	*Echinacea pallida*	forb	6.2	1.44%
rattlesnake master	*Erynigium yuccifolium*	forb	8.9	2.07%
Sneezeweed	*Helenium autumnale*	forb	20.6	4.75%
Alumroot	*Heuchera richardsonii*	forb	27.7	6.39%
prairie blazingstar	*Liatris pycnostachya*	forb	8.7	2.02%
wild bergamot	*Monarda fistulosa*	forb	19.7	4.55%
stiff goldenrod	*Oligoneuron rigidum*	forb	8.1	1.87%
foxglove beardtongue	*Penstemon digitalis*	forb	10.3	2.39%
prairie phlox	*Phlox pilosa*	forb	0.3	0.07%
prairie cinquefoil	*Potentilla arguta*	forb	9.0	2.09%
common mountain mint	*Pycnanthemum virginianum*	forb	8.7	2.02%
yellow coneflower	*Ratibida pinnata*	forb	11.8	2.74%
black-eyed susan	*Rudbeckia hirta*	forb	25.5	5.90%
Rosinweed	*Silphium integrifolium*	forb	0.4	0.10%
compass plant	*Silphium laciniatum*	forb	0.8	0.17%
showy goldenrod	*Solidago speciosa*	forb	3.8	0.87%
heath aster	*Symphyotrichum ericoides*	forb	7.9	1.82%
smooth blue aster	*Symphyotrichum laeve*	forb	4.3	1.00%
New England aster	*Symphyotrichum novae-angliae*	forb	15.9	3.68%
sky-blue aster	*Symphyotrichum oolentangiense*	forb	3.1	0.72%
Ohio spiderwort	*Tradescantia ohiensis*	forb	4.7	1.09%
Ironweed	*Vernonia fasciculata*	forb	14.2	3.28%
Culver's root	*Veronicastrum virginicum*	forb	31.6	7.32%
prairie violet	*Viola pedatifida*	forb	1.1	0.25%
golden alexander	*Zizia aurea*	forb	14.1	3.26%
	Overall Total:		432.4	

Diversity Mix (1:1 grass-to-forb seeding rate ratio)

Common Name	*Scientific Name*	*Functional group*	*Seeds/ft²*	*% mix*
prairie brome	*Bromus kalmii*	grass (cool season)	2.7	0.63%
Canada wildrye	*Elymus canadensis*	grass (cool season)	10.8	2.54%
fowl mannagrass	*Glyceria striata*	grass (cool season)	10.8	2.54%
big bluestem	*Andropogon gerardii*	grass (warm season)	21.5	5.07%
side-oats grama	*Bouteloua curtipendula*	grass (warm season)	32.3	7.61%
Switchgrass	*Panicum virgatum*	grass (warm season)	21.5	5.07%
little bluestem	*Schizachyrium scoparius*	grass (warm season)	21.5	5.07%
Indiangrass	*Sorghastrum nutans*	grass (warm season)	21.5	5.07%
tall dropseed	*Sporobolus compositus*	grass (warm season)	53.8	12.68%
prairie dropseed	*Sporobolus heterolepis*	grass (warm season)	2.7	0.63%
yellow fox sedge	*Carex annectens*	sedge	10.8	2.54%
Bicknell's sedge	*Carex bicknellii*	sedge	1.1	0.25%
plains oval sedge	*Carex brevior*	sedge	2.7	0.63%
heavy sedge	*Carex gravida*	sedge	0.2	0.05%
field oval sedge	*Carex molesta*	sedge	2.7	0.63%
Leadplant	*Amorpha canescens*	forb (legume)	2.2	0.51%
Canada milkvetch	*Astragalus canadensis*	forb (legume)	10.8	2.54%
white wild indigo	*Baptisia alba*	forb (legume)	0.2	0.05%
partridge pea	*Chamaecrista fasiculata*	forb (legume)	3.2	0.76%
purple prairie clover	*Dalea purpurea*	forb (legume)	10.8	2.54%
showy tick trefoil	*Desmodium canadense*	forb (legume)	1.6	0.38%
Illinois tick trefoil	*Desmodium illinoense*	forb (legume)	2.7	0.63%
round-headed bushclover	*Lespedeza capitata*	forb (legume)	0.5	0.13%
wild garlic	*Allium canadense*	forb	1.1	0.25%
Canada anemone	*Anemone canadensis*	forb	0.2	0.05%
Thimbleweed	*Anemone cylindrica*	forb	0.5	0.13%
prairie sage	*Artemisia ludoviciana*	forb	10.8	2.54%
swamp milkweed	*Asclepias incarnata*	forb	1.1	0.25%
common milkweed	*Asclepias syriaca*	forb	2.2	0.51%
butterfly milkweed	*Asclepias tuberosa*	forb	0.3	0.08%
whorled milkweed	*Asclepias verticillata*	forb	0.5	0.13%
New Jersey tea	*Ceanothus americanus*	forb	0.5	0.13%
prairie coreopsis	*Coreopsis palmata*	forb	0.4	0.10%
shootingstar	*Dodecatheon media*	forb	1.1	0.25%
pale purple coneflower	*Echinacea pallida*	forb	2.2	0.51%
rattlesnake master	*Erynigium yuccifolium*	forb	2.2	0.51%
tall boneset	*Eupatorium altissimum*	forb	2.7	0.63%
flowering spurge	*Euphorbia corollata*	forb	1.1	0.25%
grass-leaved goldenrod	*Euthamia graminifolia*	forb	10.8	2.54%
northern bedstraw	*Galium boreale*	forb	1.1	0.25%
bottle gentian	*Gentiana andrewsii*	forb	5.4	1.27%

bigtooth sunflower	*Helianthus grosseserratus*	forb	1.6	0.38%
prairie sunflower	*Helianthus laetiflorus*	forb	0.2	0.05%
ox-eye sunflower	*Heliopsis helianthoides*	forb	5.4	1.27%
prairie blazingstar	*Liatris pycnostachya*	forb	1.1	0.25%
Michigan lily	*Lilium michiganense*	forb	0.1	0.03%
great blue lobelia	*Lobelia siphilitica*	forb	10.8	2.54%
wild bergamot	*Monarda fistulosa*	forb	8.1	1.90%
stiff goldenrod	*Oligoneuron rigidum*	forb	8.1	1.90%
wild quinine	*Parthenium integrifolium*	forb	1.1	0.25%
foxglove beardtongue	*Penstemon digitalis*	forb	10.8	2.54%
prairie phlox	*Phlox pilosa*	forb	0.2	0.05%
prairie cinquefoil	*Potentilla arguta*	forb	10.8	2.54%
hairy mountain mint	*Pycnanthemum pilosum*	forb	8.1	1.90%
slender mountain mint	*Pycnanthemum tenuifolium*	forb	10.8	2.54%
common mountain mint	*Pycnanthemum virginianum*	forb	10.8	2.54%
yellow coneflower	*Ratibida pinnata*	forb	10.8	2.54%
black-eyed susan	*Rudbeckia hirta*	forb	8.1	1.90%
sweet coneflower	*Rudbeckia subtomentosa*	forb	8.1	1.90%
rosinweed	*Silphium integrifolium*	forb	0.2	0.05%
compass plant	*Silphium laciniatum*	forb	0.1	0.03%
showy goldenrod	*Solidago speciosa*	forb	8.1	1.90%
smooth blue aster	*Symphyotrichum laeve*	forb	5.4	1.27%
New England aster	*Symphyotrichum novae-angliae*	forb	5.4	1.27%
sky-blue aster	*Symphyotrichum oolentangiense*	forb	2.7	0.63%
purple meadow rue	*Thalictrum dasycarpum*	forb	0.5	0.13%
prairie spiderwort	*Tradescantia bracteata*	forb	0.5	0.13%
Ohio spiderwort	*Tradescantia ohiensis*	forb	1.1	0.25%
ironweed	*Vernonia fasciculata*	forb	2.7	0.63%
Culver's root	*Veronicastrum virginicum*	forb	5.4	1.27%
golden alexander	*Zizia aurea*	forb	2.7	0.63%
	Overall Total:		441.8	

Economy Mix (3:1 grass-to-forb seeding rate ratio)

Common Name	*Scientific Name*	*Functional group*	*Seeds/m²*	*% mix*
Canada wildrye	*Elymus canadensis*	grass (cool season)	46.3	10.75%
big bluestem	*Andropogon gerardii*	grass (warm season)	46.3	10.75%
side-oats grama	*Bouteloua curtipendula*	grass (warm season)	46.3	10.75%
switchgrass	*Panicum virgatum*	grass (warm season)	32.3	7.50%
little bluestem	*Schizachyrium scoparius*	grass (warm season)	46.3	10.75%
Indiangrass	*Sorghastrum nutans*	grass (warm season)	46.3	10.75%
tall dropseed	*Sporobolus compositus*	grass (warm season)	59.2	13.75%
Canada milkvetch	*Astragalus canadensis*	forb (legume)	10.8	2.50%
purple prairie clover	*Dalea purpurea*	forb (legume)	10.8	2.50%
prairie sage	*Artemisia ludoviciana*	forb	10.8	2.50%
tall boneset	*Eupatorium altissimum*	forb	5.4	1.25%
ox-eye sunflower	*Heliopsis helianthoides*	forb	5.4	1.25%
wild bergamot	*Monarda fistulosa*	forb	10.8	2.50%
stiff goldenrod	*Oligoneuron rigidum*	forb	5.4	1.25%
prairie cinquefoil	*Potentilla arguta*	forb	10.8	2.50%
yellow coneflower	*Ratibida pinnata*	forb	10.8	2.50%
black-eyed susan	*Rudbeckia hirta*	forb	5.4	1.25%
sweet coneflower	*Rudbeckia subtomentosa*	forb	8.1	1.88%
showy goldenrod	*Solidago speciosa*	forb	5.4	1.25%
New England aster	*Symphyotrichum novae-angliae*	forb	5.4	1.25%
golden alexander	*Zizia aurea*	forb	2.7	0.63%
	Overall Total:		430.4	