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Designing multifunctional, cost-effective prairies for dry marginal lands

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Technical Report Update

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Introduction

In a preliminary report (Meissen 2019), we investigated how seed mix design, specifically the effect of species habitat matching to soils, affect plant establishment, ecosystem function, and cost-effectiveness in dry marginal lands. We found that key prairie species establish well even in dry conditions, and native warm and cool season grasses (along with important summer and fall flowering forbs) produce successful stands in marginal dry soil. Further, we showed that seed mixes customized for dry soils result in more ecological functionality at similar price. Dry adapted forb species established better than their medium to wet soil counterparts, resulting in more functional groups present— the entire spring forb functional group was missing in the non-customized mix. We also found that cost-effectiveness of native perennial vegetation was generally comparable in productive compared to marginal soils, with the number of plants produced from one dollar of seed similar for many native grass and forb species in medium and dry soils.

In this technical update, we build on our initial work by integrating an additional year of data into our overall study of the influence of seed mix design, specifically the effect of species habitat matching on dry soils. Our objective was to evaluate plant establishment, functional diversity, and cost-effectiveness for seed mixes that differed in composition of dry adapted species after two growing seasons.

Materials and Methods

Study site and data collection

We carried out a second year of data collection at the Wapsi-Fairbank Demonstration Site using the same methods as our initial 2018 vegetation survey. We measured density (plant genets) and used density estimates to calculate establishment and cost-effectiveness metrics. A complete description of study site, study design, and data collection methods used is found in our preliminary technical report, located online at the Tallgrass Prairie Center website (https://tallgrassprairiecenter.org/sites/default/files/wapsiprelimreport_2019.pdf).

Data analysis

To assess cost-effectiveness, we divided the cumulative number of observed genets (2018-2019) of each sown species in each plot by the cost of seed per plot for each species (plants/$1). To analyze the effects of seeding method on cost-effectiveness and native plant establishment, we used Welch's t-tests with 2020 data (excepting cumulative measures). We used t- tests to compare differences in vegetation and cost-effectiveness measures (both overall and within functional groups) with a significance threshold of $p < 0.05$ among seed mix treatments. For all analyses, we used R (R Core Team 2020).

Results and Discussion

Plant establishment and diversity

Overall, we found that both the mesic and dry adapted seed mixes produced similar plant densities after two years, though differences in functional group abundance between seed mixes remained. On average, the dry adapted mix produced 30 plants/m^2 (SE, 5 plants/m^2) while the mesic mix produced 33 plants/m^2 (SE, 2 plants/m^2); this small difference was not statistically significant. The dry adapted mix produced more spring forb plants (1 plants/m^2 (SE, 0.4 plants/m^2)) than the mesic mix (0.1 plants/m^2 (SE, 0.1 plants/m^2)), though this difference was only marginally significant ($t = 2.3$, $df = 3$, $p < 0.10$) (Fig. 1). The differences in spring forbs were characterized primarily by the establishment of *Zizia aptera* and *Penstemon grandiflorus* in the dry adapted mix, while *Tradescantia ohiensis* was only sparsely present in the mesic mix. Density of other functional groups were mostly similar among seed mixes, and no differences observed were statistically different (Fig. 1). Cool season grass density ranged from 2.0 plants/m^2 (SE, 0.2 plants/m^2) to 2.3 plants/m^2 (SE, 0.7 plants/m^2), and warm season grass density ranged from 11.4 plants/m^2 (SE, 1.3 plants/m^2) m^2 to 11.5 plants/m^2 (SE, 1.4 plants/m^2). Among summer forbs, densities ranged from 14.3 plants/m^2 (SE, 3.3 plants/m^2) to 16.4 plants/m^2 (SE, 2.8 plants/m^2). We found more fall forbs in the mesic mix (3.1 plants/m^2 (SE, 0.9 plants/m^2)) compared to the dry adapted mix (1.1 plants/m^2 (SE, 0.7 plants/m^2)).

Species richness generally did not differ between seed mixes. Overall species richness in year two in the dry adapted mix (16.8 species (SE, 2.2 species)) was about the same as in the mesic mix (16.2 species (SE, 1.5 species)).The dry adapted mix produced more spring forb species 1.0 species (SE, 0.6 species) than the mesic mix 0.2 species (SE, 0.2 species) though this difference was not statistically significant. The number of warm and cool season grass species produced by each mix was practically identical, with 5.5 species for warm season grasses and 1.2 species for cool season grasses. We observed a similar amount of summer forb species in the dry adapted mix (7.0 species (SE, 0.9 species)) as in the mesic mix (6.2 species (SE, 0.6 species)). Richness of fall species was greater in the mesic mix (3.0 species (SE, 0.9 species)) compared to the dry adapted mix (1.0 species (1.8 species (SE, 0.8 species)) though this difference was not statistically significant.

Compared to our preliminary results, trends in plant establishment and diversity that we observed after two years were much the same. The two mixes established about equally well, with the dry adapted mix producing more spring forbs than the mesic mix (though the difference in spring forb abundance became less important after the second year). Species richness both overall and for individual functional groups remained about the same from year one to year two.

Cost-effectiveness

After the second growing season, cost-effectiveness was not different between mixes. Both mixes were similarly cost-effective, with the cost to produce 1000 plants over two years at \$1.90 /1000 plants (SE, \$0.20 /1000 plants) in the mesic mix and \$2.20 /1000 plants (SE, \$0.50 /1000 plants) in the dry mix (Fig. 2). Of species we observed to establish, partridge pea (*Chamaecrista fasciculata*), black-eyed susan (*Rudbeckia hirta*), and big bluestem (*Andropogon gerardii*) were the top three most cost-effective species with plants/\$1 values ranging from 13694 plants/\$1 (SE, 2959 plants/\$1) to 2418 plants/\$1 (SE, 539 plants/\$1) (Table 1). Species with low (but not zero) cost-effectiveness included compass plant (*Silphium laciniatum*), purple prairie clover (*Dalea purpurea*), and Ohio spiderwort (*Tradescantia ohiensis*) with plants/$1 values ranging from 11 plants/$1 (SE, 11 plants/$1) to 19 plants/$1 (SE, 19 plants/$1).

While we initially expected cost-effectiveness to diverge between seed mixes as plantings matured and weather conditions normalized to more average, drier years, our results show each mix remains about equally cost-effective. It remains to be seen whether the mesic mix will continue to perform well during or after a drought. We expect that particularly drought tolerant species like junegrass and little bluestem may become more common while species typically more common in wet-mesic prairies like flat topped goldenrod and great blue lobelia will decrease in abundance, though long term monitoring is necessary for further investigation.

Conclusion

Our study continues to show that when planted on dry soils, prairie reconstructions are effective and tolerate a degree of seed mix and site soil mismatch. Our advice to service providers and conservation practitioners remains unchanged- utilizing prairie on dry marginal lands can be successful. Any long-term effects of soil and seed mix matching still remain unknown, and follow up study is needed. Additional surveys, especially once the stands are well matured (7-10 years old) are warranted before final conclusions can be drawn about seed mix- soil matching at the Wapsi-Fairbank Demonstration Site.

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Literature Cited

Meissen JC. 2019. Designing multifunctional, cost-effective prairies for dry marginal lands. Preliminary Technical Report. Tallgrass Prairie Center, University of Northern Iowa. Cedar Falls, IA. [accessed 2021 Jun 1]. https://tallgrassprairiecenter.org/sites/default/files/wapsiprelimreport_2019.pdf

Table 1. Number of plants produced from $1 of seed. Values reflect 2019 plants per dollar for each species among all plots where it was planted.

Common Name	**Scientific Name**	**n**	**Plants/$1**	**SE**
partridge pea	*Chamaecrista fasciculata*	8	13693.79	2958.80
blackeyed Susan	*Rudbeckia hirta*	8	4389.63	1950.60
big bluestem	*Andropogon gerardii*	8	2417.94	538.85
Canada wildrye	*Elymus canadensis*	8	1727.98	285.52
Indiangrass	*Sorghastrum nutans*	8	1661.92	289.04
little bluestem	*Schizachyrium scoparium*	8	1554.66	336.33
sideoats grama	*Bouteloua curtipendula*	8	1098.26	136.96
switchgrass	*Panicum virgatum*	8	696.77	247.67
composite dropseed	*Sporobolus compositus*	8	592.25	105.83
wild bergamot	*Monarda fistulosa*	8	476.38	156.09
pinnate prairie coneflower	*Ratibida pinnata*	8	455.69	64.19
sweet coneflower	*Rudbeckia subtomentosa*	4	372.85	201.36
great blue lobelia	*Lobelia siphilitica*	4	329.34	190.14
Illinois ticktrefoil	*Desmodium illinoense*	4	299.61	99.87
New England aster	*Symphyotrichum novae-angliae*	8	292.64	146.32
pale purple coneflower	*Echinacea pallida*	8	194.51	38.25
sawtooth sunflower	*Helianthus grosseserratus*	8	186.46	115.53
common milkweed	*Asclepias syriaca*	8	139.35	30.41
sedge	*Carex*	8	137.82	67.30
tall cinquefoil	*Drymocallis arguta*	4	131.69	84.06
meadow zizia	*Zizia aptera*	4	119.45	51.40
white sagebrush	*Artemisia ludoviciana*	8	111.98	63.54
tall thoroughwort	*Eupatorium altissimum*	8	103.22	103.22
roundhead lespedeza	*Lespedeza capitata*	4	86.71	86.71
stiff tickseed	*Coreopsis palmata*	4	82.37	82.37
large beardtongue	*Penstemon grandiflorus*	4	81.55	81.55
flat-top goldentop	*Euthamia graminifolia*	4	79.71	79.71
candle anemone	*Anemone cylindrica*	4	60.39	60.39
whorled milkweed	*Asclepias verticillata*	4	51.10	51.10
button eryngo	*Eryngium yuccifolium*	4	29.03	29.03
showy ticktrefoil	*Desmodium canadense*	4	28.90	28.90
smooth oxeye	*Heliopsis helianthoides*	8	21.34	21.34
purple prairie clover	*Dalea purpurea*	8	19.04	19.04
bluejacket	*Tradescantia ohiensis*	4	18.12	18.12
compassplant	*Silphium laciniatum*	8	10.79	10.79

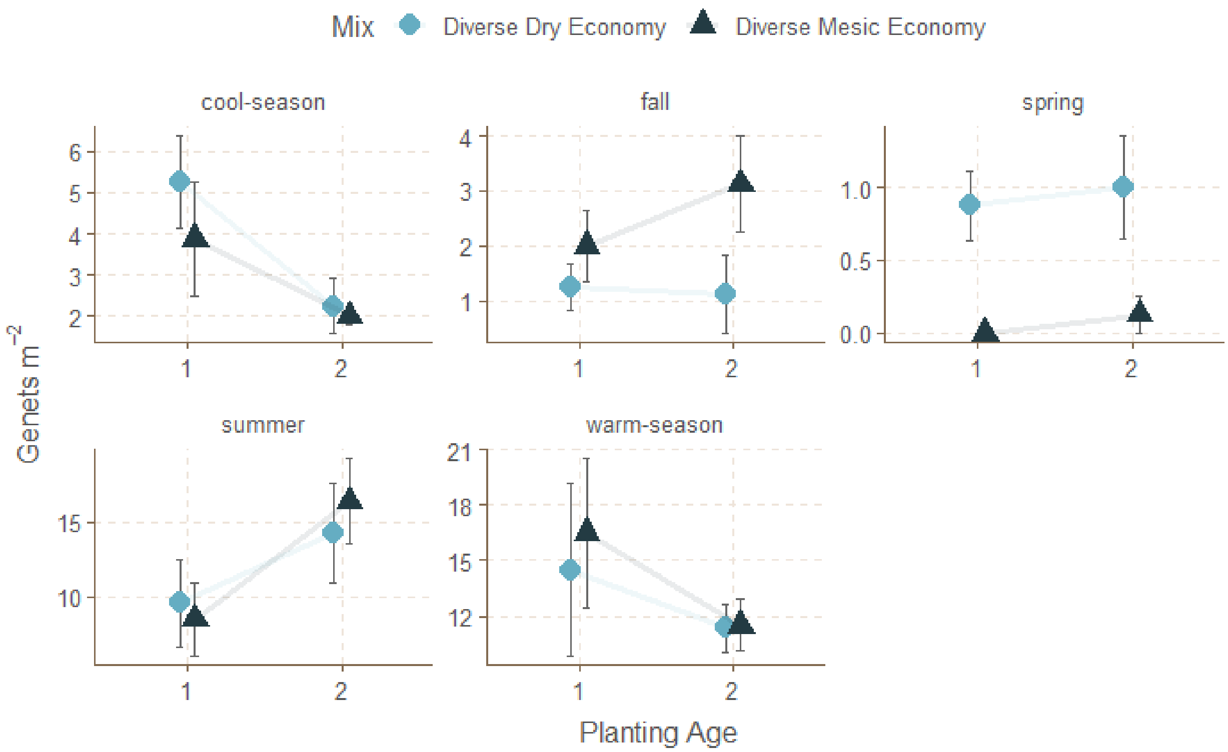

Figure 1. Density of planted native species among plant functional groups (based on phenology) observed in dry and mesic seed mixes planted on dry marginal lands.

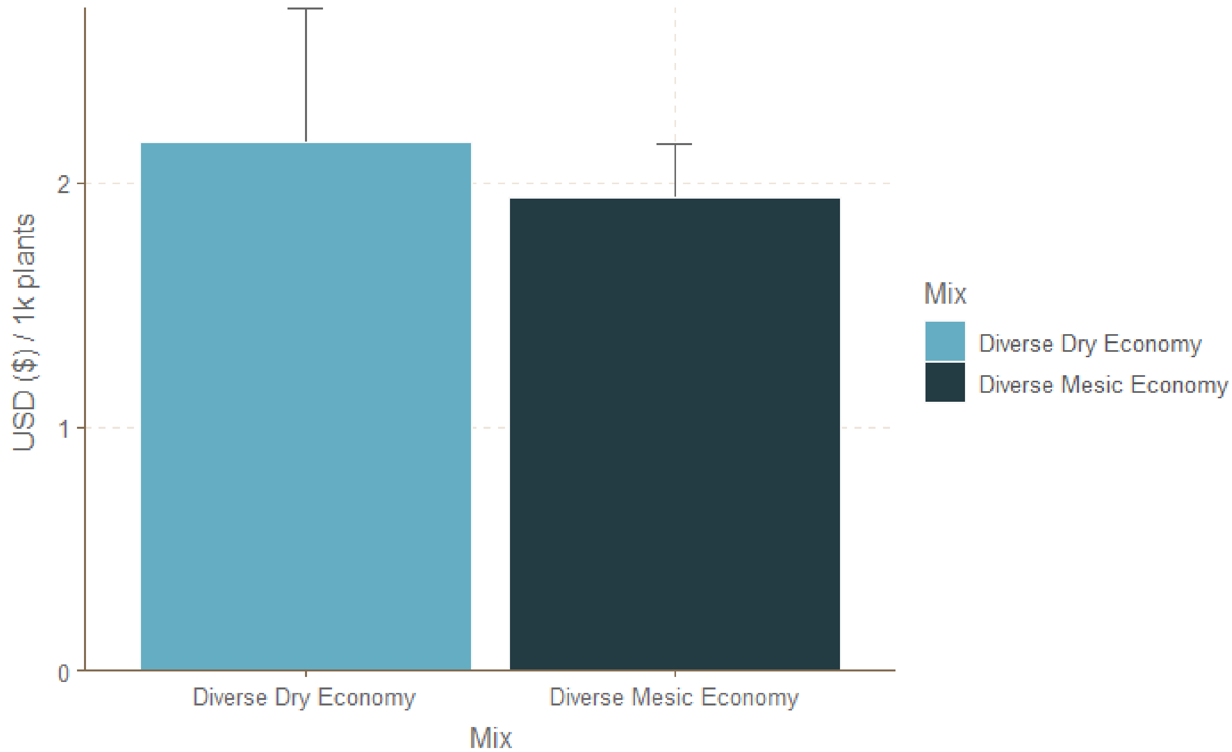

Figure 2. Cost (US dollars) to produce one thousand plants among dry and mesic seed mixes planted on dry marginal lands. Costs reflect the price of seed mix.

Appendix 1. Seed mixes planted as treatments at the Wapsi-Fairbank Demonstration Site.

Common Name	Scientific Name	Diverse Dry Economy (seeds/ m^2)	Diverse Mesic Economy (seeds/ m^2)
Cool season grasses			
Kalm's brome	*Bromus kalmii*	NA	5.38
yellowfruit sedge	*Carex annectens*	NA	2.69
Bicknell's sedge	*Carex bicknellii*	NA	2.69
shortbeak sedge	*Carex brevior*	2.69	NA
heavy sedge	*Carex gravida*	0.54	NA
troublesome sedge	*Carex molesta*	NA	2.69
Canada wildrye	*Elymus canadensis*	10.76	10.76
fowl mannagrass	*Glyceria striata*	NA	10.76
junegrass	*Koeleria macrantha*	21.53	NA
Warm season grasses			
big bluestem	*Andropogon gerardii*	10.76	32.29
sideoats grama	*Bouteloua curtipendula*	32.29	32.29
switchgrass	*Panicum virgatum*	10.76	21.53
little bluestem	*Schizachyrium scoparium*	32.29	21.53
Indiangrass	*Sorghastrum nutans*	21.53	32.29
composite dropseed	*Sporobolus compositus*	53.82	43.06
sand dropseed	*Sporobolus cryptandrus*	21.53	NA
prairie dropseed	*Sporobolus heterolepis*	2.69	2.69
Spring forbs			
thimbleweed	*Anemone cylindrica*	1.08	NA
ground-plum	*Astragalus crassicarpus*	0.11	NA
New Jersey tea	*Ceanothus americanus*	0.54	NA
Richardson's alumroot	*Heuchera richardsonii*	21.53	NA
large beardtongue	*Penstemon grandiflorus*	1.08	NA
prairie phlox	*Phlox pilosa*	NA	0.22
bracted spiderwort	*Tradescantia bracteata*	1.08	NA
smooth spiderwort	*Tradescantia ohiensis*	NA	2.15
heartleaf golden alexander	*Zizia aptera*	2.69	NA
golden alexander	*Zizia aurea*	NA	2.69
Summer forbs			
leadplant	*Amorpha canescens*	2.69	2.69
swamp milkweed	*Asclepias incarnata*	NA	1.61
common milkweed	*Asclepias syriaca*	1.08	1.08
butterfly milkweed	*Asclepias tuberosa*	0.43	0.32
whorled milkweed	*Asclepias verticillata*	0.54	NA
Canadian milkvetch	*Astragalus canadensis*	10.76	10.76
white wild indigo	*Baptisia alba*	NA	0.54
showy partridge pea	*Chamaecrista fasciculata*	2.69	2.69

stiff tickseed	*Coreopsis palmata*	0.54	NA
white prairieclover	*Dalea candida*	10.76	NA
purple prairie clover	*Dalea purpurea*	10.76	21.53
showy ticktrefoil	*Desmodium canadense*	NA	2.69
Illinois ticktrefoil	*Desmodium illinoense*	2.69	NA
pale purple coneflower	*Echinacea pallida*	2.15	2.69
rattlesnake master	*Erynigium yuccifolium*	NA	2.15
flowering spurge	*Euphorbia corollata*	1.08	NA
smooth oxeye	*Heliopsis helianthoides*	2.69	5.38
round-head bushclover	*Lespedeza capitata*	1.61	NA
wild beebalm	*Monarda fistulosa*	10.76	10.76
prairie cinquefoil	*Drymocallis arguta*	21.53	NA
common mountain mint	*Pycnanthemum virginianum*	NA	21.53
yellow coneflower	*Ratibida pinnata*	21.53	21.53
black-eyed susan	*Rudbeckia hirta*	10.76	10.76
rosinweed	*Silphium integrifolium*	0.22	0.32
compass plant	*Silphium laciniatum*	0.11	0.22
Fall forbs			
prairie sage	*Artemisia ludoviciana*	21.53	18.84
false boneset	*Brickellia eupatoriodes*	2.69	NA
tall boneset	*Eupatorium altissimum*	2.69	1.61
grass-leaved goldenrod	*Euthamia graminifolia*	NA	10.76
sawtooth sunflower	*Helianthus grosseserratus*	1.08	1.61
prairie sunflower	*Helianthus laetiflorus*	0.32	NA
rough blazingstar	*Liatris aspera*	1.61	NA
prairie blazingstar	*Liatris pycnostachya*	NA	1.61
great blue lobelia	*Lobelia siphilitica*	NA	10.76
sweet coneflower	*Rudbeckia subtomentosa*	NA	10.76
stiff goldenrod	*Solidago rigida*	8.07	8.07
showy goldenrod	*Solidago speciosa*	10.76	10.76
smooth blue aster	*Symphyotrichum laeve*	16.15	8.07
New England aster	*Symphyotrichum novae-angliae*	8.07	8.07
prairie ironweed	*Vernonia fasciculata*	NA	2.69