Minnesota Advisory Team Recommendations for Native Vegetation and Biodiversity Establishment and Management

February 2025

Acknowledgements

The recommendations in this report are a result of thoughtful input from Advisory Sub-committee members listed below, as well as a wide range of conservation partners from tribal governments, non-profit organizations, federal and state agencies, local governments, seed vendors, and consulting companies that are motivated to protect Minnesota's native plants and biodiversity.

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Introduction

Monarch Butterfly on Showy Goldenrod
Image: BWSR

Native vegetation in Minnesota provides a wide range of benefits to ecosystems, wildlife and human populations, and the economy. However, Minnesota is experiencing declines of native plant communities and decreasing diversity levels of native plants and associated organisms, threatening ecosystems and human food systems. These declines are due to a combination of factors, including development, fragmentations, climate change, invasive species, pollutants and excess nutrients, and changes in land management practices. Only around 1% of Minnesota's native prairie land remains from pre-European settlement levels and forested land has decreased from 32 million acres to 18 million acres. Around 50 percent of Minnesota's wetland acreage, and 50 percent of natural shorelines have also been lost. The Minnesota DNR lists 90 plant species as endangered or threatened and additional species are being considered for listing.

In the spring of 2023, state legislation directed the Minnesota Board of Water and Soil Resources (BWSR) to work with state and federal agencies, Tribal Nations, academic institutions, local governments, and stakeholders to foster mutual understanding and provide recommendations for standardized specifications for establishing and enhancing native vegetation in order to provide benefits for water quality, soil conservation, energy conservation and climate adaptation, resiliency or mitigation.

103B.101 BOARD OF WATER AND SOIL RESOURCES.

Subd. 18. **Guidelines for establishing and enhancing native vegetation.**

(a) The board must work with state and federal agencies, Tribal Nations, academic institutions, local governments, practitioners, and stakeholders to foster mutual understanding and to provide recommendations for standardized specifications to establish and enhance native vegetation to provide benefits for:

(1) water quality;

(2) soil conservation;

(3) habitat enhancement;

(4) energy conservation; and

(5) climate adaptation, resiliency, or mitigation.

(b) The board may convene working groups or work teams to develop information, education, and recommendations.

This project was initiated in response to this legislation. While many agencies, tribal governments and other conservation partners are providing effective models for the establishment and management of native plants and plant communities, it's important to recognize the diversity of views and approaches to this topic.

An intent of this project is to identify areas of common agreement, but also areas with differing opinions where more discussion is needed. We emphasize the need to continue sharing perspectives and experience moving ahead, particularly as we face impacts from climate change and the loss of biodiversity. This report provides a structure for ongoing discussions about native vegetation policy, protection, restoration and management.

A large advisory team of over 100 conservation professionals have been part of discussions throughout this project, and members interested in providing more detailed recommendations participated in a project advisory sub-committee.

Key goals of this effort include:

- Build collaboration and mutual understanding between conservation partners about the protection, establishment, and management of native vegetation and associated biodiversity.
- Incorporate perspectives from tribal nations and other groups whose perspectives may not have been part of past discussions.
- Recognize the diversity of views about the establishment and management of biodiverse landscapes across Minnesota, while emphasizing topics where there is common agreement.
- identify specific barriers to restoration projects statewide and developing strategies to address those barriers.
- Develop recommendations that will lead to landscape benefits for water quality, soil conservation, habitat enhancement, energy conservation, and climate adaptation, resiliency, and mitigation.
- Support decision making by local teams of experts related to native vegetation establishment and management.
- Create a foundation for inclusive and ongoing discussions about native vegetation policy, protection, establishment and management.

Audience and Use of this document

The intended audience for this document includes natural resource professionals, conservation program managers, agency policy directors and legislators. The recommendations included in this document will be used to guide state funded grant programs and conservation programs that protect, establish and manage native vegetation. The recommendations and discussions started as part of this effort will need to continue, in order to adapt to changing environmental needs and to aid the evolution of conservation programs. Partners involved in this process have expressed interest in having a yearly meeting to update recommendations and further collaboration.

This document contains three primary sections:

Section 1: An Introduction that includes the following three topics:

- A Summary of the Benefits of Native Vegetation
- Principles for Establishment and Management of Resilient and Biodiverse Landscapes
- Definitions

Section 2: Advisory Team Recommendations organized under the following headings:

- General Concepts
- Vegetation Sourcing and Movement
- Outreach
- Guidance and Standard Specifications
- Culturally Specific Considerations
- Research and Record Keeping
- Topics that Need Ongoing Discussion

Section 3: Appendices

- Definitions
- Inventory of Seed Source Standards and Technical Resources Used for Ecological Restoration in Minnesota
- State Programs Related to Ecological Restoration and Native Vegetation Establishment
- References

Maple-Basswood forest
Image: Dan Shaw

Section 1: Overview of Concepts and Principles

1.1. Benefits of Native Vegetation

Native plants and the plant communities that they evolved in and support, provide a wide range of ecological and human services. In this document we are using the following definitions for the terms native plant and native plant community. Additional terms used in the document are found in Appendix 3.1.

Native Plant – Native plants are plant species that were growing in Minnesota's biomes when European immigrants first arrived in this state. These plant species, along with the mammals, birds, fish, insects, and other living things, help to make each biome unique (MNDNR).

Native Plant Community - a group of native plants that interact with each other and with their environment in ways not greatly altered by modern human activity or by introduced organisms**.** These groups of native plant species form recognizable units, such as oak savannas, pine forests, or marshes, that tend to repeat over space and time.

The following information is a summary of key benefits of native vegetation.

Environmental Quality Benefits:

- Providing the base of food webs and nutrient cycles
- Removal of nutrients and pollutants, providing protection for air and water resources
- Carbon sequestration by drawing carbon into aboveground biomass, as well as below ground into root systems and the soil
- Providing fuels for biochar creation
- Water infiltration and groundwater recharge through the creation of pore space within soil
- Water interception, absorption, and filtration by leaves, stems and roots
- Slope stabilization provided by extensive root systems
- Prevention of soil erosion and sedimentation caused by water and wind
- Soil heath promoted by stabilizing soils, adding organic content through root and vegetative decomposition, and by supporting diverse microorganism populations
- Evapotranspiration (releasing excess water through stems and leaves to decease water volume within stormwater practices)
- Cooling and temperature moderation of air, soil and water
- Limiting flood impacts by slowing flood waters
- Healthy nutrient cycling and food chain support

Native Wildlife Habitat Benefits:

- Energy and nutrients for entire food webs via energy flows and nutrient cycles
- Pollinator habitat and food sources, supporting hummingbirds, bees, moths, butterflies, and other insects
- Host plants for a wide variety of insects
- Food sources (nectar, fruit, seed, forage, etc.) for mammals, birds, arthropods, and other animals
- Shelter and nesting habitat for insects, birds, and other animals

- Aquatic habitat for a wide range of insects, fish, birds and other animals in lakes, rivers and wetlands

Resiliency Benefits

- Preservation of biodiversity (the variety of life and its processes)
- Suitability to local conditions
- Providing connectivity between essential habitats
- Adapt to climate extremes e.g., drought and flooding
- Ability to adapt through genetic adaptation, succession and dispersal
- Creating competition for invasive species (displaced plants)

Human Services Benefits

- Regional character and identity (sense of place)
- Climate cooling from landscape cover e.g., tree and shrub canopies, grassland
- Landscape aesthetics
- Human physical and mental health benefits from experiencing and interacting with healthy ecosystems
- Low maintenance once established
- Educational opportunities
- Medicinal needs
- Food security

Cultural Values

- Build reciprocity into land stewardship (e.g., acknowledgement of plants and animals as relatives and living beings)
- Focus on relationship building with one another and other living beings, be a good relative.
- Restoration of plants for traditional uses
- Community-based and Tribal involvement (e.g., seek and respect Tribal input, make resources available for Tribal entities)
- Cultural revitalization of traditional land-based practices (e.g., cultural burning, harvesting and propagating plants)
- Provide more opportunities and access for hunting, fishing, and gathering of plants for under-resourced, underrepresented, and disadvantaged people.

Rue anemone
Image: Dan Shaw

1.2. Principles for the Establishment and Management of Resilient and Biodiverse Landscapes

The following information summarizes guiding principles for increasing the resiliency and biodiversity of landscapes. These principles are intended as big-picture concepts to frame ecosystem protection and management work and to express the value of this work in communicating with Minnesota residents and other partners. The guiding principles have been reviewed by the conservation community every few years since 2013 to ensure they reflect the current approaches of a wide range of professionals.

Public Engagement

1. **Engage Communities:** Landscapes have evolved through human interaction and stewardship for thousands of years. Making connections with a wide range of partners including conservation organizations, tribal nations, community groups, schools, and individual residents can strengthen the planning, resiliency and long-term stewardship of projects. The establishment and management of native vegetation and protection of wildlife species also has cultural significance and plays an important role in building relationships with the land.
2. **Engage with Individual Residents:** Individuals can make a significant different for the health of landscapes through their own planting efforts, volunteering, advocating for healthy landscapes, and supporting conservation organizations. We need the public engaged in establishing native plant diversity, supporting at-risk wildlife, and supporting landscape stewardship.

Prioritization

3. **Strategic Site Selection:** Work with project partners and local communities to identify the services or functions that are most beneficial for an individual landscape and where projects should be located to best provide those services or functions. In many cases, this involves restoring vegetation assemblages to promote animal habitat, buffering water resources (both ground and surface waters) and restoring natural processes such as nutrient cycling. Also consider linear areas between larger habitats that provide travel corridors for wildlife. Select sies that are feasible for accomplishing project goals. In some cases, areas with high nutrients such as pastures or agricultural stormwater ponds may not be favorable for restoring high diversity native plant communities.

Restored Wetland
Image: BWSR

4. **Make Landscape Connections:** Establish strong connections through landscapes. Create habitat corridors and decrease landscape fragmentation by restoring prairie, forest, savannas, and wetlands. Create a network of soil health systems by expanding conservation practice adoption across farms. Connected landscapes build resiliency and provide refugia for pollinators and other at-risk species.

Collaboration

5. **Involve a wide range of partners** such as tribal nations, federal, state and local governments, non-profits, private companies, consultants, politicians, members of the press, and residents.
6. **Work Towards Weaving Traditional Knowledge and Western Science** – Build reciprocal relationships with tribal communities that have knowledge of how their ancestors managed the land for thousands of years. Treat this knowledge as a gift and don't expect this to be given, a solid and respectful relationship must be built first. This can provide a deeper understanding and appreciation for traditional land-based practices that may be incorporated into contemporary land management. "Two-eyed seeing" is a Mi'kmaq concept of learning to see from one eye with the strengths of Indigenous knowledge and learning to see from the other eye with Western knowledge. Then learning to use both eyes together for the benefit of all.
    - **Protect and Restore Plant Species for Traditional Uses** – Climate change is affecting plants and ecosystems the Ojibwe, Dakota and other indigenous peoples have relied on and maintained relationships with for centuries. Plants were used for subsistence (e.g., wild rice, arrowhead, ostrich fern, Jerusalem artichoke, prairie turnip, and hazelnut), for ceremonial purposes and medicine (e.g., sweetgrass, prairie sage, and white cedar), and used for utility to make baskets and other practical materials (e.g., black ash and cattail). These species along with many others are at risk and need additional protection and restoration to meet spiritual, ceremonial, medicinal, subsistence, and economic needs (GLIFWC 2024).

Project Planning

7. **Apply a Systems Approach:** Plan projects to be intact systems that fit the regional climate, soils, hydrology and plant communities. Projects should be guided by local partners familiar with ecosystems and the establishment and management methods that will result in functioning systems that provide a wide range of ecosystem benefits and support a wide range of wildlife species.
8. **Match Plant Communities to the Site:** Match your targeted vegetation to the native plant community that best fits the topography, soils, hydrology, and climate conditions (including the potential future climate) of your site. Restore natural hydrologic regimes to aquatic and wetland systems as applicable. Historic plant community information can be used as a guide for decision making. When planning projects use Minnesota DNR's Native Plant Community information as a resource, as well as collaboration with natural resource staff with expertise in local conditions and management practices. Recognize that some landscapes are highly altered resulting in novel ecosystems but they still need a thorough assessment of landscape context and site conditions. Also determine the kinds of native wildlife that live in or migrate through the area and include native plants adapted to the site that will provide food and shelter for wildlife species.
9. **Design for Multiple Functions:** Be strategic in the selection of primary and secondary goals but remember that multiple functions, including wildlife habitat, plant diversity, food production, water storage, stormwater treatment, soil quality, carbon sequestration, energy production, and nutrient cycling can often be accomplished together. It is important to have project teams with diverse backgrounds and expertise to help reach project goals. See the BWSR Climate Resiliency Toolbox for strategies to address climate impacts.

Habitat Friendly Solar Project
Image: BWSR

10. **Combine Conservation Practices**: Different types of plantings and conservation projects can be combined to enhance water quality or establish a larger matrix of habitat to support wildlife. In agricultural systems, regenerative agriculture practices can be combined with native plantings in buffers, prairie STRIPS and other areas to enhance conservation benefits and improve soil health. In developed areas, rain gardens, biofiltration areas, stormwater swales, and ponds, along with urban natural areas and habitat plantings, help create a connected system of green infrastructure.
11. **Build and Maintain Biodiversity:** Ecosystems are the outcomes of millions of years of evolution and many landscapes benefit from rebuilding biological communities including microbial, fungal, floral and faunal components. The more biodiverse an area is, the better chance it has at long-term health and self-sustainability. Over the years, there will be variations in invasive species pressure, soil conditions, and climate, such as extreme drought or extreme moisture. Having a diversity of plants, wildlife, and habitats ensures that more species can adapt to these extremes and can, therefore, respond to changing environmental conditions. Diversity can be thought of at multiple scales, from microorganisms to plants to wildlife to habitat type. Diversity provides ecosystem functions that benefit people, plants, and wildlife. These same principles can be applied to agricultural systems to reduce soil erosion, maintain nutrients necessary for growing a crop, and storing water in the soil. Filling niches with native species also prevents the establishment of invasive species. Restoring natural disturbances such as prescribed fire, grazing and water fluctuations plays a key role in maintaining diversity.
12. **Provides Habitat for Pollinators and Other Insects -** Pollinators and other insects play an essential role in supporting ecosystems by pollinating as much as 70% of flowering plants and providing food sources for a wide range of wildlife species and humans. Support insect populations by minimizing pesticide use, buffering natural areas and diverse plantings from pesticide exposure, restoring habitat complexes and wide natural corridors, increasing plant diversity, managing invasive plants, providing nesting sites and shelter, and restoring clean water sources. In developed areas, replacing lawn with native plantings can provide a wide range of landscape benefits and establish a matrix of habitat to support a diversity of pollinators. See BWSR's Pollinator and Biodiversity Toolbox for additional information.
13. **Support At Risk Plants and Animals –** There is an increasing list of plant and animal species with declining populations that need support. These include a wide range of plants and animals. Methods of supporting individual species should be considered in a wide range of landscape types. The Minnesota DNR Rare Species Guide provides status, distribution, ecology, conservation, and management of our rarest plants and animals.
14. **Incorporate Effective Water Management, Treatment, and Use -** A variety of practices including buffer strips, infiltration basins, raingardens and wetland restoration help manage water resources. Incorporate these practices in urban and rural landscapes to reduce runoff, erosion and sedimentation, recharge groundwater, improve water quality, and reduce flooding. Promote the wise use of water resources and the use of catchment systems to help ensure adequate supplies into the future.
15. **Preserve and Restore Soil Health -** Soils that have good soil structure, organic content and microorganism populations translate into healthy and productive ecological and cultural landscapes and play a key role in sequestering carbon.

Restored shallow marsh
Image: BWSR

16. **Restore Natural Disturbance regimes –** Natural disturbance is critical for maintaining and renewing ecological integrity in ecosystems. Natural disturbances vary across ecosystems but can include flooding, fire, grazing, burrows, insect herbivory, and windthrow. Ecosystems that lack natural disturbancs rapidly trend towards climax communities which are desirable across landscapes but they should never domainte as they can be low in resiliency, function, and suceptable to disease.
17. **Restore Keystone Species –** Keystone species are organisms that had a significant influence on ecosystem biological, physical, and chemical processes that in turn supported biodiversity. Examples of keystone plant species in Minnesota include oaks, willow, cherry, pines and poplar. Animals such as bison, elk, wolves, and beaver can also be keystone species.
18. **Support Food Webs –** Rebuilding native food webs acknowledges top down drivers of systems (ecosystems) structuring biological assemblages in ways that increase energy flows, nutrient cycling, and provide ecosystem services. This is the primary reason plants evolved over time to become extremely edible, from mosses to strawberries and acorns. In turn, edible vegetation allowed proper nutrient cycling to prevent eutrophication.

Project Management

19. **Build Capacity to Restore and Mimic Keystone Processes –** Keystone processes such as prescribed burning and conservation grazing are critical to the ecological integrity of many plant communities. Building the capacity to conduct prescribed burns and providing infrastructure for grazing should be a consideration. To do this more training should be available to conduct prescribed burns. Initiatives that support cultural burning by tribes can built capacity around the state, this may include allowing Tribes to burn on state land or other areas that may not have the capacity to burn. Additional resources are also needed to support conservation grazing. Managing landscapes with grazing, or at least mimicking grazing is critical to maximizing biological diversity. The removal of biomass through prescribed fire and conservation grazing can be valuable to prevent the eutrophication of ecosystems. Many ecosystems that do not experience biomass harvest tend can become eutrophic and susceptible to being dominated by nitrophilic species which can often be invasive plant species.

Sheep grazing a solar project Image: BWSR

20. **Manage Invasive Species (displaced plants) Across the Land and Water-** Invasive species are ones that can become overabundant and negatively impact ecosystems by discouraging the mutual thriving of species, eliminating important food and nesting resources, causing erosion, spreading plant diseases, and more (Wakan Tipi 2024) are effective at dispersal, giving them an advantage in adapting to climate change. Learn which species to be on the lookout for and what to do if you find them by visiting the DNR invasive species page. Removing invasive species goes hand in hand with revitalizing the ecosystem and helping diversity thrive. Plan to work in partnerships, prioritize species and manage invasive plants across landscapes.
21. **Practicing Adaptive Management -** Adjust management practices based on monitoring efforts, research, and experience with successes and failures to improve the function and resiliency of plant communities. It is often beneficial to combine practices such as water level management, prescribed

burning, prescribed grazing, mowing and haying to replicate natural disturbances and promote diversity, function and resiliency.

22. **Learning from Project Experience** – Be patient! Building landscape resiliency and diversity takes time. Information about project successes, innovative practices, and traditional ecological knowledge story sharing is valuable. What practices provide the most benefits in our landscapes? What common activities are not worth the cost, or make a problem worse? BWSR's "What's Working" web page collects and shares practitioner experience about real-world outcomes.

Brown-belted bumblebee
Image: Dan Shaw

Section 2: Findings and Recommendations

The following information summarizes the advisory team's findings and recommendations on a wide range of topics related to the protection, restoration and management of native vegetation, as well as recommendations for outreach, education and future collaboration. Recommendations were developed based on a survey to a large number of conservation partners, edits from advisory team members, and input from individual discussions with partners.

2.1. General Principles for Ecosystem Protection

Northern Minnesota peatland
Image: BWSR

Protection of Existing Ecosystems in Minnesota

- Continue building and strengthening collaboration between conservation partners that work to protect native plant communities.
    - Continue coordinating and evolving state agency programs through MNDNR and BWSR to protect natural lands through partnerships with tribal nations, private landowners (conservation easements), other organizations, and by serving as public land stewards to lands and waters managed by each agency. Support local agencies and nonprofits in land conservation and permanent protection.
- Further partnerships with tribal communities and traditional knowledge holders to enhance stewardship and understanding of ecosystems.
- Focus on adaptive management as well as preservation to restore keystone processes and restore, and enhance native plant communities.
- Work to secure funding to assist in long-term management of native plant communities. Highlight the importance of funding sources such as the LSOHC and LCCMR that fund projects for protection of plant communities.
- Pursue funding to aid tribal governments, SWCDs, and other local partners in protection and restoration efforts through dedicated habitat staff.
- Further build collaboration for mapping of native plant communities and prioritization for protection of specific native plant communities and habitat corridors.
- Collaborate with DNR on efforts to protect state listed plant species. The DNR Rare Species Guide includes information about rare, endangered and special concern species and policies.

Concepts for Large Initiatives to Establish and Manage Native Vegetation

- Target restoration for multiple benefits, including clean water, wildlife, pollinators, climate adaptation and mitigation.
- Expand native plantings into multi-use landscapes such as utility corridors, campus landscapes, roadsides, solar installations, and pastures.
- Match federal funding with state programs to increase native planting opportunities.

- Increase education and outreach to the public about the role they can play in establishing and managing resilient native plant communities by planting native gardens, restoring prairies, forests, savannas, and wetlands, and supporting conservation organizations.
- Inspire new thinking among conservation professionals about effective methods of establishing and managing resilient and diverse landscapes.
- Expand tree planting in formerly forested areas for climate adaptation, mitigation and other benefits.
- Support the Minnesota Natural Shorelands Partnership and their efforts to protect and restore natural shorelines.
- Collaborate with a wide range of partners on research and new technologies for the management of diverse landscapes.
- Target watershed scale restorations, linking restoration of ecosystems with concepts of working lands to promote landscape restoration in ways that maximize biological diversity, ecosystem function, and ecosystem services while supporting social communities, employment opportunities, high quality foods and fibers, water quality, and aesthetics.

2.2. Vegetation Sourcing

General Considerations for Sourcing Minnesota Native Plants and Seeds

There is a wide range of viewpoints among conservation professionals on vegetation sourcing and assisted migration in Minnesota in response to current climate change impacts and future projections of more extreme change. Therefore, the recommendations in this report represent the current viewpoints of advisory team members, focusing on areas of consensus when possible.

White cedar swamp
Image: Dan Shaw

Agencies generally need to set limits for seed and plant source distances for funded projects, so the information in this report will help provide additional perspectives in updates of BWSR's Native Vegetation Establishment and Management Guidelines and other agency policies.

Available research suggests that some species with seed (or pollen) that is not dispersed widely by wind, water, animals or other factors could be negatively impacted if seed of that species is introduced from far distances (Keller et al. 2000, Edmonds & Timmerman 2003, Hufford & Mazer 2003, Heiser & Shaw 2006). The advisory team believes that additional research is needed on this topic as information about potential genetic impacts to species is available for a number of species used in restoration. It is also recognized that isolated populations of species can benefit from the introduction of new genetic material (such as populations with inbreeding depression). This can be a concern for small, isolated remnant plant communities. More information is also needed about which species used in restoration are most at risk from inbreeding depression. A common recommendation based on our lack of research on individual species is to use nearby, or intermediate sources for seed and plants, and a maximum source distance for projects which may vary for some species based on their characteristics. It is also becoming more common to use multiple genetic origins for the seed of plant species when possible, to help fragmented populations with low genetic diversity. Available research about seed and plant sources is listed in Appendix 3.4.

There are different definitions in use related to the movement of plants. This report uses the following three definitions from the US Forest Service (USDA)for movement of plant species.

- **Assisted Population Migration** – (also assisted genetic migration or assisted gene flow) – moving seed sources or populations to new locations within the historical species range
- **Assisted Range Expansion** – moving seed sources or populations from their current range to suitable areas just beyond the historical species range, facilitating or mimicking natural dispersal
- **Assisted Species Migration** (also species rescue, managed relocation, or assisted long distance migration) – moving seed sources or populations to a location far outside the historical species range, beyond locations accessible by natural dispersal. 2018 USDA FS CCRC Assisted Migration.pdf

Challenges for Sourcing Minnesota Native Plants and Seeds

- There is a need to identify (and obtain access to) areas for seed collection of species that are not available from existing nurseries or are in low supply.
- With an increasing focus on climate mitigation and the multiple benefits of trees and shrubs, increased seed collection and seedling production from more diverse genetic sources both within Minnesota and adjoining states is needed. There is a significant need for tree and shrub seeds and seedlings in the southern half of the state.

Needs for Plant Species Production

- Lists of herbaceous and woody species are needed identifying species where increased nursery production of MN-sourced materials would benefit conservation and restoration efforts.
    - These lists should include species from every functional group, e.g., forbs, sedges, rushes, ferns (and allies), cool-season grasses, warm-season grasses, shrubs, trees, and vines.
    - Lists will provide more clear expectations to plant nurseries and seed vendors about interest and potential demand from the conservation community.
- Increased demand for diverse seed mixes would help drive seed markets and species available in the market.
- Seek funding to support the production of plant species that can foster resilient landscapes, including native cool-season grasses that are not in production and are important for grazing as well as forb species such as wild strawberries and kitten tails, violets, and anemones.

Columbine and common violet
Image: Dan Shaw

- Identify species that do not do well from seeds and should be installed from containerized or bare-root plant materials. These include many woodland species, wild strawberries, etc. that are common in remnants but difficult to seed. More nurseries or expansion of existing nurseries are needed to help create more complete restorations.

Seed and Plant Source Considerations

- A survey of around 100 conservation professionals from a wide range of organizations in Minnesota identified 245 miles as the average maximum distance recommended for sourcing herbaceous plants, with 200 miles and 300 miles getting an equal number of votes.
- BWSR currently uses a recommended maximum distance of 175 miles.
- MnDOT and NRCS use a 200-mile maximum distance.
- For trees and shrubs, the survey of conservation professionals identified 275 miles as the average recommended source distance for trees and shrubs, with 300 miles getting the most votes.
- It may be appropriate to increase seed source distance for species that have seed dispersed widely by wind (some asters), water, or birds (wetland emergent species).
- The use of species substitutions is recommended when seed of planned species is not available within a desirable range.
- It is best practice to select seed from sites with similar site conditions ecologically and geographically, as well as areas with similar soil characteristics, plant communities and hydrology.
- Southern and western sources may be preferred origin locations for seed due to warming climate projections. This could guide distance recommendations by BWSR.
- It is a recommended practice to utilize verified-source seed from the Yellow Tag Seed Program. The Minnesota Crop Improvement Association has a directory of growers that sell yellow-tag/source-identified seed https://docs.mncia.org/public/website/WTB-Native-Seed-D24.pdf. The use of Yellow Tag discourages the growing of Minnesota origin seed in other states and being used for Minnesota plantings, which could increase the risk of weed seeds being introduced from other regions.
- Consistent bounds related to source distances for plants are needed but flexibility is also needed.
- Future demand for seed of native species could be clarified to help the seed industry meet demand. State agencies could determine their 3-year demand needs for Upland/Dry prairie, Mesic/Tallgrass prairie, wetlands, etc.
- Support is needed for efforts to increase local tree and shrub propagation such as the Nature Conservancy's Minnesota Climate-Smart Seedling Production Network from the USDA.
- Monitoring is needed to better understand the influence of source distance on plant survival, and growth, as well as wildlife value and phenology of plant bloom and insect species foraging that leads to successful pollination.
- The Minnesota Department of Natural Resources is planning to start using the new forest service Eastern Seed Zone Map for seed sourcing of trees and shrubs and this resource should be considered across agencies using woody vegetation to create consistency between conservation partners.
- Based on Advisory Team discussion BWSR is planning to adopt a 200-mile maximum recommended range for herbaceous plant species and a 300-mile maximum recommended range for trees and shrubs, with specific exceptions.

2.3. Assisted Range Extension and Species Migration

Recommendations for Assisted Range Extension and Species Migration

As with the larger conservation community, the advisory team working on this report has a variety of opinions about assisted range extension, ranging from advised caution about shifting the range of species to active promotion of assisted migration. As a result, the advisory team did not come up with specific recommendations on this topic: individual organizations are encouraged to set policies based on the input of their staff and advisors and following current science related to the topic.

- It is recommended that conservation partners work together to develop a list of species at risk from climate change that may benefit from range extensions. Existing research should be used to identify species at risk and the role of range extension for those species.
- Local technical teams should be used for decision making related to range extension, using available state and federal resources as guidance on species climate projections, range extension and species migration:
    - MNDNR Seed Sourcing for Resilient Reconstructed Prairies Seed Sourcing for Resilient Reconstructed Prairies (state.mn.us)
    - USDA Climate Change Resource Center Website AUSFS Assisted Migration| Climate Change Resource Center (usda.gov)
    - Climate Change Resource Center Report: Assisted-Migration_Climate-Change-Resource-Center.pdf (usda.gov)
    - US Forest Service Ecoregional Vulnerability Assessment Forest Service Ecoregional Vulnerability Assessments (EVAS)

Quaking aspen
Image: BWSR

- Climate Change Field Guide for Northern Minnesota Forests: https://forestadaptation.org/sites/default/files/ClimateChangeFieldGuide_NMNForests_HiRes.pdf
- Northern Institute of Applied Climate Science, Climate Projections for Individual Tree Species, Northern Minnesota
- https://forestadaptation.org/sites/default/files/Northern%20MN%20Tree%20Atlas%20Results%2010-21.pdf
- MDNR NPC Siviculture Strategies for Forest Stand Prescriptions: https://www.dnr.state.mn.us/forestry/ecs_silv/npc/index.html

2.4. Outreach Recommendations

Public Outreach regarding Native Vegetation and Biodiversity Needs

- There is a need for increased public awareness about biodiversity losses, losses of specific plant and wildlife species and how these losses affect quality and ways of life. This can be further highlighted through current and emerging programs but also with increased collaboration with schools. This outreach should be combined with positive messages about the important role that individual residents and partnerships can play.
- Greater public awareness is needed about state programs that allow residents to participate in native revegetation efforts, such as Lawns to Legumes and local conservation programs.
- Specific campaigns for public awareness and involvement may be needed to engage larger numbers of state residents.
- Further collaboration with schools is needed to combine resilient and biodiverse plantings with teaching opportunities and state science standards.

Conservation training
Image: BWSR

Outreach and Training for Natural Resource Professionals

- Conduct yearly native vegetation forum for conservation partners to discuss and update recommendations in this document and discuss case studies.
- Increase field training opportunities for tribal communities, federal, state, and local agencies, or conservation partners, while also addressing barriers to participation.
- Investigate natural resource professional certifications for native plant community assessment, mapping, monitoring, and native vegetation establishment and management.
- Highlight recommendations and resources from the state's Restoration Evaluation Program.

2.5. Recommendations for New or Updated Guidance and Standard Specifications

State Seed and Plant Sourcing Guidance and Standards

- Update BWSR Native Vegetation Establishment and Enhancement Guidelines seed source sequence and map recommendations based on advisory team recommendations in this report.
- Collaborate with MNDNR on the update of their assisted migration policy.

Project Assessment and Planning

- Update current resources such as BWSR's Pollinator and Biodiversity toolbox and What's Working Website yearly with new information including ecological planning approaches for a variety of landscape conditions.
- Additional information and emphasis is needed on site preparation, including needs for invasive species management, seed mix design, correct seeding practices, and post seeding maintenance.

- Information is needed about rewilding approaches. Rewilding is a concept more open to novel or emerging ecosystems and new species and new interactions compared to ecological restoration. This concept is more common in European countries and needs further investigation in Minnesota about its role in landscape management, particularly for highly disturbed landscapes.
- More guidance is needed to restore prairie on south facing bluff slopes in Southeast Minnesota. Afforestation is a principal driver of buckthorn, garlic mustard, and jumping worm invasion, and creates feedback with soil carbon: nitrogen ratios that also favor invasive species.
- Update state construction standards and specifications for bioengineering practices (lakeshores, streambanks, ravines), with an emphasis on alternatives to rip-rap to maximize ecological benefits.
- Update construction standards and specifications for urban development on poor soils.

Vegetation and Biodiversity Establishment

- Develop more detailed guidance on methods of establishing native vegetation on highly disturbed landscapes such as environmental contamination sites, and mine sites.
- Develop project establishment and management guidance for utility corridors and right of ways to complement BWSR's Habitat Friendly Utilities Program.
- Lake and Cook County have unique flora relative to the rest of the northeast region. Seed mixes and guidance should be developed and used that are truly native to those counties.
- With a current emphasis on restoring peatlands as part of climate mitigation and habitat restoration, additional guidance is needed in the Minnesota Wetland Restoration Guide about appropriate seed mixes, engineering design, and revegetation efforts.

Wetland restoration project
Image: Dan Shaw

Landscape Management

- Develop additional guidance about how to steward landscapes using natural practices and processes such as conservation grazing, haying, biological control, and prescribed fire.
- Additional guidance is needed on methods for managing diverse woodlands, including establishing grasses and sedges in woodland systems to help carry prescribed burns to aid invasive brush control and management methods.

Community Engagement

- Guidance is needed on methods of engaging and working effectively with volunteers as part of landscape restoration and management. Volunteers can play an important role in restoration by collecting seed of species that are not commercially available, planting and controlling invasive species.

2.6. Recommendations for Landscape Management Approaches

Vegetation and Biodiversity Establishment Considerations

Inter-seeding prairie
Image: BWSR

- Establish shoreline practices that work with nature, such as using native vegetation to stabilize shorelines. Unstable shorelands greatly increase the possibility for reverse nutrient export, and downstream flooding.
- Temporary covers established over disturbed landscapes for a season before seeding permanent native seed mixes can have multiple benefits. These covers help restore soil health, allow time for invasive species management, and allow time for chemicals to break down in agricultural systems.
- Consider multiple seedings over time for project sites, and/or incorporation of plugs for plantings. Seeding over different time periods with additional species provides several benefits including higher plant diversity.
- Seeding native grass dominated cover mixes immediately after buckthorn removal is beneficial to produce competition for buckthorn seedling growth and build fuel for prescribed burns. Cover mixes are also showing promise for suppressing herbaceous invasive species after repeated mowing.
- When practical, using a full growing season of site preparation for prairie restoration followed by dormant broadcast seeding is preferable to tillage and seed drilling. This reduces recruitment of weeds from the soil seed bank and likelihood of erosion.
- Wetlands scrapes are being used effectively to remove excess sediment from wetlands but also expose native seedbanks. When creating scrapes it is important to investigate historic elevations to release historic seedbanks to the extent possible. Additional seeding of native species is recommended following a scrape to supplement the native seedbank.
- Reducing the abundance of large warm-season grasses in favor of forb, cool-season grass, and sedge diversity can often be beneficial in seed mixes to maximize long-term plant diversity levels.
- There is a need for better understanding the role of native cool-season grasses in suppressing non-native cool-season grasses and invasive forbs. Based on field experience they play an important role.
- Increase efforts to restore beneficial microorganisms into a wide range of disturbed landscapes as part of revegetation efforts.

Landscape Management Considerations

Prescribed burning
Image: MnDOT

- To facilitate more prescribed burning, there is a need to build capacity and financial support, and address barriers for contractors who would like to do prescribed burning and for cultural burning across agencies and with partners.
- Cultural focused burning using traditional ecological knowledge (TEK) should have an increased emphasis in Minnesota. Low intensity and frequent fires support many ecosystems and help sequester carbon and immobilize excess nitrogen.

- Look for ways to reduce broad chemical use for site preparation and management to prevent impacting soil health and insect populations.
- Increase the use of restoration methods that are alternatives to herbicide application, specifically for wetlands but also benefitting all native plant communities. Biomass harvest can play an important role in this transition by removing nitrogen and creating conditions less favorable for invasive species.
- Canada thistle and many other displaced plants are symptoms of larger problems such as excess nutrients in soils, previous land use, lack of diverse seed mixes to fulfill niches. Until those problems are corrected it is challenging to establish and manage a native planting.
- First-year mowing of prairie has been a standard for years, but some agency staff are having good results without mowing. This topic needs more discussion as the mowing may not be needed, particularly on sites with dry conditions where there is less weed competition.
- Mowing as a long-term management practice is not comparable to burning and/or grazing and should only be used in specific situations with specific goals.
- Mowing can help facilitate fire by reducing shrub cover and improving conditions for burning. Mowing can reduce root carbohydrate reserves of invasive species, so when fire occurs it is much more damaging to target species and liberating to desirable species.
- Grazing can be an effective management method for cattail management. Many prairie pothole wetlands that lack grazing are surrounded by hybrid cattails that make them impervious to migrations of ducklings from upland nests to water, turtles nesting and herptile migrations. This grazing supports wetland renewal and maintenance of ecosystem resilience (Holling 1973, 2002).
- Broadleaf herbicide applications should be limited or used sparingly with restoration and enhancement project management. It takes significant effort to create diverse native plantings and we often eliminate weeds with herbicides that may harm native plants and biological communities.
- Long term management should consider historic maintenance processes and the role of keystone processes and keystone species such as grazers.
- Hybrid and narrow-leaf cattails which are not considered native to Minnesota are dominating many emergent zones of wetland and lakes in Minnesota, creating the need to decrease cattail establishment and use a combination of management methods to increase plant and animal diversity in aquatic systems impacted by monoculture stands.

Community Engagement

- Programming for volunteers is needed to further engage and educate them about methods of assessing and managing landscapes and assisting with invasive species removal. We need people as active participants, instead of passive observers, in ways that increase native diversity, ecosystem function, and production of multiple goods and services (UN 2005), as it has been for thousands of years. There is so much land that needs restoration, and we need many people involved in many ways to make and keep the land and water healthy.

Preventing Invasive Species Spread through Restoration

- Avoid using seed sources from longer distances (over 300 miles) due to the risk of introducing invasive species based on research (Larson et.al. 2021) and field experience, such as the introduction of Palmer Amaranth in seed mixes.

- Follow or adapt Minnesota DNR guidance for prevent the introduction of invasive species into restoration projects. Operational Order 113 Invasive Species Prevention and Management (state.mn.us).
- Use restoration strategies such as fire, grazing and biomass harvest to help decrease nutrients within plant communities that are adapted to low-nutrient conditions (such as dry prairies and savannas). Excess nitrogen gives invasive plants a competitive advantage.
- Further our understanding about how disturbance and changing nutrient levels influence the spread and persistence of invasive species within ecosystems.

2.7. Culturally Specific Considerations

Recommendations for Protecting and Restoring Plants for Traditional Uses

- Continue to build reciprocal relationships with Tribal partners, including providing resources for Tribes to perform activities that help bring back traditional land-based practices.
- Support Tribal initiatives to revitalize traditional land-based practices such as cultural burning.
- Continue discussions and collaborations with underrepresented and disadvantaged groups and people in Minnesota about their priorities for protection and restoration of plants and animals.
- Use the resources developed by the Great Lakes Indian Fish & Wildlife Commision (GLIFWC) as guidance:

    Manoomin
    Ganawenindiwag: Working with plant relatives to heal and protect Gichigami shorelines
    - Planting Moon in a Warming Climate
    - Aanii-bimaadziimagak o'ow aki: Climat Change Vulnerability Assessment Version 2
- Provide funding for collaboration with Tribal partners to develop additional resources that help others understand the importance of traditional knowledge in protecting plants and animals. This may include providing examples of how others can weave traditional and western knowledge in land stewardship for holistic outcomes.

2.8. Research, Field Study and Record Keeping Needs

Research, Field Studies, or Literature Review Needs

Plant and Microorganism Sources and Supplies

- Further research is needed to identify and document plant species that should have increased use in restoration projects for a wide range of plant communities. In particular we need to better understand the role of less commonly used cool-season grasses, sedges, rushes, forbs and ferns in restoration.
- Research is needed to further understand species that are at risk from new sources of plants being introduced (outbreeding depression), or at risk from low genetic diversity (inbreeding depression) and will benefit from the introduction of seed from additional sources. This information would help guide seed source distance planning for individual species.
- Additional information is needed about appropriate sources of mycorrhizal fungi and other microorganisms for the use increasing landscape biodiversity.

Project Planning

- Further research is needed about plant-insect interactions, and the impacts of climate change on insect populations.
- Additional information is needed about the potential for carbon sequestration in soils and biomass when restoring and managing plant communities. The projected impacts of climate change on native plant communities should be considered in planning any restoration project.

Project planning
Image: BWSR

- Partnership work is needed to better understand ways to combine traditional ecological knowledge and scientific ecological knowledge stewarding the land and water.
- Oak savanna restoration and management needs additional research and technical guidance, and seed mixes are needed to guide restoration and management.

Vegetation and Biodiversity Establishment

- Further investigation is needed about successful methods of deep marsh establishment, as it is challenging to establish vegetation due to fluctuating water levels.
- Research is needed about the success of past peatland restoration projects and the potential for new techniques for establishing sphagnum mosses and peatland vegetation.
- Case studies are needed to demonstrate plant community restoration techniques that are effective.
- More information is needed about the benefits of using diverse seed mixes and mycorrhizal inoculation for a wide range of plan communities to combat invasive species, reduce herbicide inputs, manage costs, and providing additional ecosystem functions. Native plant communities include hundreds of plant species, but most projects introduce ten to forty species.
- There is a need to develop consistency for seeds-per-ounce information used in seed mixes from agencies and conservation partners, and with seed mix calculators being used by different agencies. Every agency, program, state, etc. seems to have different numbers, creating challenges for seed vendors.
- Research is needed about ideal seeding dates for native vegetation. How can seeding dates better reflect natural processes to increase seeding effectiveness, germination rates, and more resilient plantings?

Project Monitoring

- There is a need to track ecological results and success rates of assisted migration in both rural and urban landscapes.

Landscape Management

- Research is needed about the role of conservation grazing on plant communities and biological assemblages.
- Information is needed about biomass harvest methods and landscape benefits in different types of landscapes.
- State seed mixes need to be tested for a wide range of conservation purposes and landscape settings to guide their future evolution.
- Non-herbicide methods of invasive species control need further study for reconstructed plant communities and native plant communities.

- Additional research is needed to understand effective management methods for hybrid and narrow-leaf cattail, which are not considered native to Minnesota and are dominating many aquatic systems where they impact wildlife populations.

Recommendations for Ecological Restoration Recordkeeping

- Renew discussions about developing a consistent restoration tracking system between conservation partners. The Grassland Restoration Network may serve as a model.
- Highlight and share the recordkeeping recommendations from the state's Restoration Evaluation program.

2.9 Topics Needing Ongoing Discussion Between Partners

Plant Sources and Supplies:

- There are many approaches to assisted migration, as referenced in this report. Different approaches among state and federal agencies and researchers call for more in-depth discussion.
- Is it feasible to increase production of underutilized plant species to address plant availability needs for restoration projects? Demand for many native forb and sedge species exceeds supply. If seed vendors increase production, will demand be sufficient to support their efforts?

Cream gentian
Image: Dan Shaw

Project Planning

- Further discussion is needed on topics such as "rewilding" approaches vs. "restoration" approaches, working lands programs and projects, and strategies for achieving multiple benefits in restoration projects.
- Methods of further protecting rare plant and animal species through project planning.
- Can multiple projects be combined under state grants or contract to increase efficiency?
- Opportunities to expand the implementation of lawn alternatives on large landscapes such as parks and campus landscapes.
- How projected climate change predictions should influence contingency planning for restoring ecosystems. Extreme precipitation has been particularly challenging for wetland and stream restoration.

Vegetation and Biodiversity Establishment

- Would a slower establishment process for projects increase success rates? Should the use of temporary covers be increased to help rebuild soils in restoration projects?
- What new native seed mixes are needed for restoration and conservation, including standard mixes for cities?
- What methods of mycorrhizal inoculation are resulting in improved soil health and ecosystem processes?
- Do recommended seeding rates and seeding dates need to be adjusted?
- What methods are most effective at storing carbon in peatlands and restoring healthy peatland ecosystems?
- Are there ways that we can increase the use of yellow-tag seed which has a verified source?

- What are the environmental benefits of using diverse seed mixes?
- How are land management practices benefitting the insects we are trying to save?

Landscape Management

- More discussion is needed on the long-term changes in projects and changing management needs.
- A review of noxious weeds commonly found in native prairie sites should be conducted to consider their state noxious weed status to help ensure native prairie sites do not receive unnecessary herbicide. The state noxious weed list is currently based on threats to agriculture, economy and humans and does not fully account for threats to native plant communities.
- Additional collaboration and consultation is needed to further the implementation of indigenous methods of landscape management.
- How can vegetation management practices be combined to maximize environmental benefits?
- What are emerging trends in non-herbicide methods of managing landscapes?

Section 3: Appendix

Appendix 3.1.

Definitions

Assisted Population Migration – (also assisted genetic migration or assisted gene flow) – moving seed sources or populations to new locations within the historical species range (USDA).

Assisted Range Expansion – moving seed sources or populations from their current range to suitable areas just beyond the historical species range, facilitating or mimicking natural dispersal (USDA).

Assisted Species Migration (also species rescue, managed relocation, or assisted long distance migration) – moving seed sources or populations to a location far outside the historical species range , beyond locations accessible by natural dispersal (USDA). 2018 USDA FS CCRC Assisted Migration.pdf.

Cultivar – A cultivated plant that has been selected and given a unique name because of desired characteristics and when propagated (usually vegetatively) retains those characteristics.

Eutrophication – An excessive richness of nutrients in an aquatic system, typically due to upland sources causing a dense growth of algae and other plant life and death of animal life from lack of oxygen. The terminology "soil eutrophication" is sometimes used to describe soils that are high in nutrients, particularly nitrogen.

Inbreeding Depression – Reduced biological fitness and overall health of a population due to inbreeding.

Generation 0 – Seed harvested from remnant prairie tracts that will be used to grow new plants (G1). Generation 0 seeds are considered genetically unaltered by human activity and the collection site should be in a natural state. Generation 0 seed has not been through an intentional selection process and its origin is generally definable by a geographic location from which the seed is collected.

Generation 1 – Seed harvested from fields reconstructed with source-identified Generation 0 seed.

Genetic Contamination – Loss of native plant population fitness due to the addition of non-local genes into native populations via pollen, seed or plant material.

Genetic Sensitivity – The sensitivity of an individual species to inbreeding, loss of adaptation or out-breeding depression.

Genotype – The genetic makeup of a cell or organism (the allele makeup of an organism).

Germplasm – The hereditary material that is transmitted from one generation to another.

Herbicides – Chemicals that are used to target and kill plant species.

Inbreeding – The breeding of related individuals within an isolated or a small population of plants, sometimes leading to decreased genetic diversity and fitness.

Insecticides – Chemicals that are used to target and kill insects.

Native Plant – Native plants are plant species that were growing in Minnesota's biomes when European immigrants first arrived. These plant species, along with the mammals, birds, fish, insects, and other living things, help to make each biome unique (MDNR).

Native Plant Community - a group of native plants that interact with each other and with their environment in ways not greatly altered by modern human activity or by introduced organisms**.** These groups of native plant species form recognizable units, such as oak savannas, pine forests, or marshes, that tend to repeat over space and time.

Native Plant Community Restoration or Reconstruction – Re-establishment of a native plant community, such as a prairie, wetland or forest, using seeds, seedlings, cuttings, or transplants on a site. Reconstructions are typically defined as sites with little/no actively growing remnant vegetation. Restorations augment degraded remnants by replacing missing species and/or increasing species abundance. The aim of restoration or reconstruction projects is to replicate ecologically complete historic native plant communities; re-establish wildlife and aquatic habitat by returning elements of a site's natural ecological structure and composition; and/or restore ecological components of native forest communities.

Outbreeding Depression – When offspring from crosses between individuals from two different plant populations have lower fitness than progeny from crosses between individuals from the same population.

Pesticides – Chemicals that are used to kill living organisms such as fungus, bacteria, insects, plant diseases, slugs, or weeds.

Plant Fitness – An individual's contribution of young to later generations, measured by longevity and reproductive success.

Prairie Reconstruction – The establishment of prairie species on a site that contains no actively growing remnant vegetation; such as an agricultural field or lawn.

Provenance – The geographic sources where the seeds/plant material naturally originated.

Pure Live Seed (PLS) – The measurement of the amount of seed that germinates in a standard (14 day) germination test, plus the amount found to be alive from a viability (tz) test. PLS is determined by multiplying the percent germination success by the purity of seed.

Pure Seed – Seed exclusive of inert matter and all other seeds not of the kind or variety being considered, as defined by the rules for testing seeds of the Association of Official Seed Analysts.

Remnant – Fragment of a climax plant community that remains from a former period, typically before European settlement.

Resilient Native Plant Communities – Those communities with the ability to absorb or adapt to the effects of climate change or other external forces and continue to function, although possibly in different ways or with a different suite of species than in a prior state. The resilience of a native plant community often depends on the degree of genetic variation that resides within the species which comprise that community.

Rewilding – Rewilding is a form of ecological management aimed at increasing biodiversity and restoring natural processes. It differs from ecological restoration in that while human intervention may be involved, rewilding aspires to reduce human influence on ecosystems. It also places emphasis on recovering geographically specific sets of ecological interactions and functions that would have maintained ecosystems prior to human influence. Rewilding is open to novel or emerging ecosystems which encompass new species and new interactions.

Seed Transfer Zone – The geographic range in which a given plant population will likely thrive, based on variables such as soils, topography, geology, precipitation, and temperature range.

Selected Traits – Traits that are promoted intentionally or in some cases unintentionally, such as height, flower color, form, leaf color, forage quality and leafiness.

Variety – A taxonomic subdivision of a species consisting of naturally occurring or selectively bred populations (usually propagated by seed) or individuals that differ from the remainder of the species in certain minor characteristics.

Wild Harvest – Seed that is harvested from remnant native plant communities.

Yellow Tag Seed – Source-identified seed that is comprised of the least selected germplasm for a species and are considered to be genetically diverse. The location where the material was originally collected from native stands (genetic origin) is indicated on the certification label.

Voyageurs National Park
Image: Dan Shaw

Appendix 3.2.

Inventory of Seed Source Standards and Technical Resources Used for Ecological Restoration in Minnesota

Seed and Plant Source Standards in Use

- BWSR Native Vegetation Establishment and Enhancement Guidelines
- MNDOT Seeding Manual
- Managing Forests of the Future (UMN Extension)
- NRCS Practice Standards
- Eastern Seed Zone Map (ESZ Data Viewer)
- Seed Sourcing for Resilient Reconstructed Prairies (state.mn.us)
- AUSFS Assisted Migration| Climate Change Resource Center (usda.gov)
- MDNR Division of Forestry Seed Collection Zones
- Forest Service Ecoregional Vulnerability Assessments (EVAS) Summaries -Climate Change Atlas - Northern Research Station, USDA Forest Service

Restoration Standards in Use

- Minnesota Wetland Restoration Guide
- MNDOT Seeding Manual –
- MNDOT Standard Specifications
- Minnesota Stormwater Manual
- NRCS Practice Standards
- BWSR Pollinator and Biodiversity Toolbox-Restore Your Shore
- BWSR Native Vegetation Establishment and Enhancement Guidelines
- DNR Plant Community Guides
- DNR Prairie restoration Guide for Minnesota Landowners
- DNR Natural Heritage Information System
- DNR Minnesota Conservation Explorer
- DNR Woodlands of Minnesota Landowner Handbook
- -DNR Prairies of Minnesota Landowner Handbook-
- Xerces Society Guides -
- DNR Prairie Solar Guidance
- Tallgrass Prairie Center Tech Guides
- Managing Forests of the Future (UMN Extension)
- Nature Conservancy Prairie Restoration Guides

Appendix 3.3. Inventory of State Programs for Ecological Restoration and Native Vegetation Establishment

- BWSR Habitat Enhancement Landscape Program https://bwsr.state.mn.us/HELP
- BWSR Lawns to Legumes Program Lawns to Legumes: Your Yard Can BEE the Change | MN Board of Water, Soil Resources (state.mn.us)
- BWSR Reinvest in Minnesota Program Reinvest in Minnesota Overview | MN Board of Water, Soil Resources (state.mn.us)
- BWSR Wetland Banking Program Wetland Bank Guidance and Information | MN Board of Water, Soil Resources (state.mn.us)
- BWSR Habitat Friendly Solar and Habitat Friendly Utilities Programs Minnesota Habitat Friendly Solar Program | MN Board of Water, Soil Resources (state.mn.us)
- DNR CPL Grant Conservation Partners Legacy Grant Program | Minnesota DNR (state.mn.us)
- LSOHC Grants LSOHC (mn.gov)
- LCCMR Grants LCCMR (mn.gov)
- State of Minnesota Restoration Evaluation Program Restoration Evaluation Program | Minnesota DNR (state.mn.us)
- MDA's Specialty Crop Block Grant

Appendix 3.4 References

Altrichter, E. A., Thompson, J. R., & Mabry, C. M. (2017). Stakeholders ’ Perceptions of Native Plants and Local Ecotypes in Ecological Restoration. *Ecological Restoration*, *35*(3), 218–228.

Baer, S. G., Gibson, D. J., Gustafson, D. J., Benscoter, A. M., Reed, L. K., Campbell, R. E., Klopf, R. P., Willand, J. E., & Wodika, B. R. (2014). No effect of seed source on multiple aspects of ecosystem functioning during ecological restoration: Cultivars compared to local ecotypes of dominant grasses. *Evolutionary Applications*, *7*(2), 323–335. https://doi.org/10.1111/eva.12124

Basey, A. C., Fant, J. B., & Kramer, A. T. (2015). Producing native plant materials for restoration: 10 rules to collect and maintain genetic diversity. *Native Plants Journal*, *16*(1), 37–53. https://doi.org/10.3368/npj.16.1.37

Batavia Illinois, pp. [20]-30 in Warwick, Charles, Editor Proceedings Fifteenth North American Prairie Conference Bend, Oregon.

Betz, R. F., Lootens, R. J., Becker, M. K. (1997). Two decades of prairie restoration at Fermilab,

Biological Survey, and Natural Heritage and Nongame Research Program, MNDNR.Naeem, S.; Knops, J. M. H.; Tilman, D.; Howe, K. M.; Kennedy, T.; Gale, S. (2000). Plant diversity increases resistance to invasion in the absence of covarying extrinsic factors. Oikos 91:97-108.

Bohnen, J. L. and S. M. Galatowitsch. (2005). Spring Peeper Meadow: Revegetation Practices in a Seasonal Wetland Restoration in Minnesota. Ecological Restoration 23: 172-181.

Bower, A., St. Clair, J. B., & Erickson, V. (2014). Generalized provisional seed zones for native plants. *Ecological Applications*, *24*(5), 913–919.

Biondini, M. (2007). Plant Diversity, Production, Stability, and Susceptibility to Invasion in Restored Northern Tall Grass Prairies (United States). Restoration Ecology 15: 77-87.

Breed, M. F., Harrison, P. A., Bischoff, A., Durruty, P., Gellie, N. J. C., Gonzales, E. K., Havens, K., Karmann, M., Kilkenny, F. F., Krauss, S. L., Lowe, A. J., Marques, P., Nevill, P. G., Vitt, P. L., & Bucharova, A. (2018). Priority actions to improve provenance decision-making. *BioScience*, *68*(7), 510–516. https://doi.org/10.1093/biosci/biy050

Breed, M. F., Stead, M. G., Ottewell, K. M., Gardner, M. G., & Lowe, A. J. (2013). Which provenance and where? Seed sourcing strategies for revegetation in a changing environment. *Conservation Genetics*, *14*(1), 1–10. https://doi.org/10.1007/s10592-012-0425-z

Broadhurst, L. M., Lowe, A. J., Coates, D. J., Cunningham, S. A., McDonald, M., Vesk, P. A., & Yates, C. (2008). Seed supply for broadscale restoration: Maximizing evolutionary potential. *Evolutionary Applications*, *1*(4), 587–597. https://doi.org/10.1111/j.1752-4571.2008.00045.x

Bucharova, A., Bossdorf, O., Hölzel, N., Kollmann, J., Prasse, R., & Durka, W. (2018). Mix and match: regional admixture provenancing strikes a balance among different seed-sourcing strategies for ecological restoration. *Conservation Genetics*, 1–11. https://doi.org/10.1007/s10592-018-1067-6

Bucharova, A., Michalski, S., Hermann, J. M., Heveling, K., Durka, W., Hölzel, N., Kollmann, J., & Bossdorf, O. (2017). Genetic differentiation and regional adaptation among seed origins used for grassland restoration: Lessons from a multispecies transplant experiment. *Journal of Applied Ecology*, *54*, 127–136. https://doi.org/10.1111/1365-2664.12645

Burton, P.J.; Burton, C.M. (2002). Promoting Genetic Diversity in the Production of Large Quantities of Native Plant Seed. Ecological Restoration, Vol. 20, No. 2:117-123.

Carter, D. L., & Blair, J. M. (2013). Seed source has variable effects on species, communities, and ecosystem properties in grassland restorations. *Ecosphere*, *4*(8), 1–16. https://doi.org/10.1890/ES13-00090.1

Casler, M. D., Stendal, C. A., Kapich, L., & Vogel, K. P. (2007). Genetic diversity, plant adaptation regions, and gene pools for switchgrass. *Crop Science*, *47*(6), 2261–2273. https://doi.org/10.2135/cropsci2006.12.0797

Durka, W., Michalski, S. G., Berendzen, K. W., Bossdorf, O., Bucharova, A., Hermann, J. M., Hölzel, N., & Kollmann, J. (2016). Genetic differentiation within multiple common grassland plants supports seed transfer zones for ecological restoration. *Journal of Applied Ecology*, *54*(1), 116–126. https://doi.org/10.1111/1365-2664.12636

Edmands, S., & Timmerman, C. C. (2003). Modeling factors affecting the severity of outbreeding depression. *Conservation Biology*, *17*(3), 883–892.

Erickson, B.; Navarrette-Tindall, N.E. (2004). Missouri Native Ecotype Program: Increasing Local-Source Native Seed. Natural Areas Journal. 24, 1: 15-22.

Espeland, E. K., Emery, N. C., Mercer, K. L., Woolbright, S. A., Kettenring, K. M., Gepts, P., & Etterson, J. R. (2017). Evolution of plant materials for ecological restoration: insights from the applied and basic literature. *Journal of Applied Ecology*, *54*(1), 102–115. https://doi.org/10.1111/1365-2664.12739

Falk, D.A.; Knapp, E.E.; Guerrant, E.O. (2001). An introduction to restoration genetics. Society for Ecological Restoration.

Fargione, J.; Brown, C. S.; Tilman, D. (2003). Community assembly and invasion: An experimental test of neutral versus niche processes. Proceedings of the National Academy of Sciences 100:8916-8920.

Fargione, J. Tilman, D. (2005a). Diversity decreases invasion via both sampling and complementarity effects. Ecology Letters 8:604-611.

Fargione, J., Tilman, D. (2005b). Niche differences in phenology and rooting depth promote coexistence with a dominant C4 bunchgrass. Oecologia 143:598-606.

Frankham, R., Ballou, J. D., Eldridge, M. D. B., Lacy, R. C., Ralls, K., Dudash, M. R., & Fenster, C. B. (2011). Predicting the probability of outbreeding depression. *Conservation Biology*, *25*(3), 465–475. https://doi.org/10.1111/j.

Fraser, LH and EB Madson. (2008). The interacting effects of herbivore exclosures and seed addition in a wet meadow. Oikos 117: 1057—1063.

Gallagher, M. K., & Wagenius, S. (2016). Seed source impacts germination and early establishment of dominant grasses in prairie restorations. *Journal of Applied Ecology*, *53*(1), 251–263. https://doi.org/10.1111/1365-2664.12564

Galatowitsch, S.M. (2008). Seedling establishment in restored ecosystems. Chapter 15: Seedling Ecology and Evolution. M. Leck and T. Parker (Ed.). Cambridge Press.

Galatowitsch, S., L. Frelich, and L. Phillips-Mao. (2009). Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America. Biological Conservation 142: 2011-2022

Gray, M. M., St. Amand, P., Bello, N. M., Galliart, M. B., Knapp, M., Garrett, K. A., Morgan, T. J., Baer, S. G., Maricle, B. R., Akhunov, E. D., & Johnson, L. C. (2014). Ecotypes of an ecologically dominant prairie grass (Andropogon gerardii) exhibit genetic divergence across the U.S. Midwest grasslands' environmental gradient. *Molecular Ecology*, *23*(24), 6011–6028. https://doi.org/10.1111/mec.12993

Grime, J. P., Hodgson, J. G., & Hunt, R. (2014). Comparative plant ecology: a functional approach to common British species. Springer.

Gustafson, D. J., Gibson, D. J., & Nickrent, D. L. (1999). Random amplified polymorphic DNA variation among remnant big bluestem (Andropogon gerardii Vitman) populations from Arkansas' Grand Prairie. *Molecular Ecology*, *8*(10), 1693–1701. https://doi.org/10.1046/j.1365-294X.1999.00756.x

Gustafson, D. J., Gibson, D. J., & Nickrent, D. L. (2004). Conservation genetics of two co-dominant grass species in an endangered grassland ecosystem. *Journal of Applied Ecology*, *41*(2), 389–397. https://doi.org/10.1111/j.0021-8901.2004.00904.x

Gustafson, D. J., Gibson, D. J., & Nickrent, D. L. (2004). Competitive relationships of Andropogon gerardii (Big Bluestem) from remnant and restored native populations and select cultivated varieties. *Functional Ecology*, *18*(3), 451–457. https://doi.org/10.1111/j.0269-8463.2004.00850.x

Gustafson, D. J., Gibson, D. J., & Nickrent, D. L. (2002). Genetic diversity and competitive abilities of Dalea purpurea (Fabaceae) from remnant and restored grasslands. *International Journal of Plant Sciences*, *163*(6), 979–990.

Gustafson, D. J., Gibson, D. J., & Nickrent, D. L. (2005). Using local seeds in prairie restoration--data support the paradigm. *Native Plants Journal*, *6*(1), 25–28. https://doi.org/10.1353/npj.2005.0022

Grace, J.B., TM Anderson, MD Smith, E Seabloom, SJ Andelman, G. Meche, E Weiher, LK Allain, H. Jutila, M Sankaran, J. Knopps, M Ritchie, and MR Willig. (2007). Does species diversity limit productivity in natural grassland communities? Ecology Letters 10: 680-689.

Hamilton, J., Flint, S., Lindstrom, J., Volk, K., Shaw, R. G., & Ahlering, M. A. (2020). Evolutionary approaches to seed sourcing for grassland restorations. *New Phytologist*, *225*, 2246–2248. https://doi.org/10.1111/nph.16427

Havens, K., Vitt, P. L., Still, S., Kramer, A. T., Fant, J. B., & Schatz, K. (2015). Seed sourcing for restoration in an era of climate change. *Natural Areas Journal*, *35*(1), 122–133. https://doi.org/10.3375/043.035.0116

Heiser, D. A., & Shaw, R. G. (2006). The fitness effects of outcrossing in Calylophus serrulatus , a permanent translocation heterozygote. *Evolution*, *60*(1), 64–76.

Herman, B., Packard, S., Pollack, C., Houseal, G., O'Leary, C., Fant, J., Derby Lewis, A., Wagenius, S., Gustafson, D., Hufford, K. M., Allison, B., Shaw, K., Haines, S., & Daniels, C. (2014). Decisions...decisions...how to source plant material for native plant restoration projects. *Ecological Restoration*, *32*(3), 236–239.

Hille Ris Lambers, J.; Harpole, W. S.; Tilman, D.; Knops, J.; Reich, P. (2004). Mechanisms responsible for the positive diversity-productivity relationship in Minnesota grasslands. Ecology Letters 7:661-668

Hooper, D. U., F.S. Chapin, III, J.J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J.H. Lawton, D.M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A. J. Symstad, J. Vandermeer, and D. A. Wardle. (2005). Effects of biodiversity on ecosystem processes: implications for ecosystem management [ESA Public Affairs Office, Position Paper]. Ecological Society of America. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/habitat/econsens/index.htm (Version 24AUG2006).

Hopwood, J., Vaughan M., Shepherd M., Biddinger D., Mader E., Black S.H., and Mazzacano C., (2012). A Review of Research into the Effects of Neonicotinoid Insecticides on Bees, with Recommendations for Action. The latest information on how these compounds affect insects with an ornamental focus included. Discusses impacts worldwide and in U.S. The Xerces Society for Invertebrate Conservation.

Houseal, G., & Smith, D. D. (2000). Source-identified seed : The Iowa roadside experience. *Ecological Restoration*, *18*(3), 173–183. https://doi.org/Genetic Considerations in Ecological Restoration

Howell, E. A. and W.R. Jordan III. (1989). Tallgrass prairie restoration in the north American Midwest. Pp. 395-414 in Spellerberg, I.F., F.B. Goldsmith, and M.G. Morris (eds)/ The scientific management of temperate communities for conservation. The 31st Symposium of the British Ecological Society Southampton 1989.

Huff, D.R., A.J. Palazzo, M. van der Grinten. (2006). Relationships Between Geographic Distance and Genetic Differentiation: Or, Why Don't You Write Home More Often? P. 161 in M.A. Sanderson et al (eds). Proceedings of the Fifth Eastern Native Grass Symposium, Harrisburg, PA, October 10-13, 2006.

Hufford, K. M., Krauss, S. L., & Veneklaas, E. J. (2012). Inbreeding and outbreeding depression in Stylidium hispidum: Implications for mixing seed sources for ecological restoration. *Ecology and Evolution*, *2*(9), 2262–2273. https://doi.org/10.1002/ece3.302

Hufford, K. M., & Mazer, S. J. (2003). Plant ecotypes: Genetic differentiation in the age of ecological restoration. *Trends in Ecology and Evolution*, *18*(3), 147–155. https://doi.org/10.1016/S0169-5347(03)00002-8

Hunter, M.L., (2007) Climate change and moving species: furthering the debate on assisted colonization. Conservation Biology 5, 1356-1358

Johnson, G.R.; Sorensen, F.C.; St Clair, J.B.; Croon, R.C. (2004). Pacific Northwest Forest Tree Seed Zones: A Template for Native Plants? Native Plants Journal. 5, 2: 131-140.

Johnson, L. C., Olsen, J. T., Tetreault, H., Delacruz, A., Bryant, J., Morgan, T. J., Knapp, M., Bello, N. M., Baer, S. G., & Maricle, B. R. (2015). Intraspecific variation of a dominant grass and local adaptation in reciprocal garden communities along a US Great Plains' precipitation gradient: Implications for grassland restoration with climate change. *Evolutionary Applications*, *8*(7), 705–723. https://doi.org/10.1111/eva.12281

Jones, T. (2005). Genetic Principles and the Use of Native Seeds – Just the FAQs, please, just the FAQs. Native Plants, Spring 2005: 14-24.

Jurgenson, J.; Devries, R. (2004). Analysis of Genetic Diversity of Iowa's Native Plant Species using the Beckman CEQ 8000 Genetic Analyzer. Iowa DOT project 90-00-LRTF-409.

Kay, J.J., (2000). Ecosystems as Self Organizing Holarchic Open Systems: Narratives and the Second Law. Handbook of Ecosystem Theories and Management. CRC Press – Lewis Publishers.

Keller, M., J. Kollmann, and P.J. Edwards (2000). Genetic introgression from distant provenances reduces fitness in local weed populations. Journal of Applied Ecology 37:647-659.

Kittelson, P. M., & Handler, S. D. (2006). Genetic diversity in isolated patches of the tallgrass prairie forb, Lithospermum canescens (Boraginaceae). *The Journal of the Torrey Botanical Society*, *133*(4), 513–518. https://doi.org/10.3159/1095-5674(2006)133[513:GDIIPO]2.0.CO;2

Kline, V. M. (1997). Orchards of Oaks and a Sea of Grass, pp. 3-21 in Packard, Stephen and Cornelia F. Mutel (eds)/ The Tallgrass Restoration Handbook, For Prairies, Savannas, and Woodlands. Island Press, Covelo, CA.

Klopf, R. P., & Baer, S. G. (2011). Root Dynamics of Cultivar and Non-Cultivar Population Sources of Two Dominant Grasses during Initial Establishment of Tallgrass Prairie. *Restoration Ecology*, *19*(1), 112–117. https://doi.org/10.1111/j.1526-100X.2009.00539.x

Knops, J. M. H.; Tilman, D.; Haddad, N. M.; Naeem, S.; Mitchell, C. E.; Haarstad, J.; Ritchie, M. E.; Howe, K. M.; Reich, P. B.; Siemann, E.; Groth, J. (1999). Effects of plant species richness on invasion dynamics, disease outbreaks, insect abundances and diversity. Ecological Letters 2:286-293.

Kramer, A. T., Wood, T. E., Frischie, S., & Havens, K. (2017). Considering ploidy when producing and using mixed-source native plant materials for restoration. *Restoration Ecology*, *26*(1), 13–19. https://doi.org/10.1111/rec.12636

Krauss, S. L., & Koch, J. M. (2004). Rapid genetic delineation of provenance for plant community restoration. *Journal of Applied Ecology*, *41*(6), 1162–1173. https://doi.org/10.1111/j.0021-8901.2004.00961.x

Lambert, A. M., Baer, S. G., & Gibson, D. J. (2011). Intraspecific variation in ecophysiology of three dominant prairie grasses used in restoration: Cultivar versus non-cultivar population sources. *Restoration Ecology*, *19*(SPEC.ISSUE), 43–52. https://doi.org/10.1111/j.1526-100X.2010.00673.x

Lesica, P., and F.W. Allendorf. (1999). Ecological genetics and the restoration of plant communities: Mix or match? Restoration Ecology 7:42-50.

Martin, L.M., K.A. Moloney, and B. Wilsey. (2005). Journal of Applied Ecology. An assessment of grassland restoration success using species diversity components. Journal of Applied Ecology 42: 327-336.

Martinez-Reyna, JM and KP Vogel. (2008). Heterosis in switchgrass: spaced plants. Crop Science 48: 1312-1320.McCully, W.G. 2000. Utilizing The Ecotype Concept: An Insight into Native Plant Establishment, in Harper-Lore

Martin, L.M. and B.J. Wilsey. (2006). Assessing grassland restoration success: relative roles of seed additions and native ungulate activities. Journal of Applied Ecology.

McKay, J. K., Christian, C. E., Harrison, S., & Rice, K. J. (2005). “How local is local?”A review of practical and conceptual issues in the genetics of restoration. *Restoration Ecology*, *13*(3), 432–440. https://doi.org/10.1111/j.1526-100X.2005.00058.x

Meissen, J. C., Galatowitsch, S. M., & Cornett, M. W. (2015). Risks of overharvesting seed from native tallgrass prairies. *Restoration Ecology*, *23*(6), 882–891. https://doi.org/10.1111/rec.12295

Millar, C.I.; Libby, W.J. (1989). Disneyland or Native Ecosystem: Genetics and the Restorationist. Restoration & Management Notes 7:1, 18-24.

Miller, B. P., Sinclair, E. A., Menz, M. H. M., Elliott, C. P., Bunn, E., Commander, L. E., Dalziell, E., David, E., Davis, B., Erickson, T. E., Golos, P. J., Krauss, S. L., Lewandrowski, W., Mayence, C. E., Merino-Martín, L., Merritt, D. J., Nevill, P. G., Phillips, R. D., Ritchie, A. L., … Stevens, J. C. (2017). A framework for the practical science necessary to restore sustainable, resilient, and biodiverse ecosystems. *Restoration Ecology*, *25*(4), 605–617. https://doi.org/10.1111/rec.12475

Miller, S. A., Bartow, A., Gisler, M., Ward, K., Young, A. S., & Kaye, T. N. (2011). Can an Ecoregion Serve as a Seed Transfer Zone? Evidence from a Common Garden Study with Five Native Species. *Restoration Ecology*, *19*(201), 268–276. https://doi.org/10.1111/j.1526-100X.2010.00702.x

Minnesota Department of Natural Resources. (2005). Field Guide to the Native Plant Communities of Minnesota: The Eastern Broadleaf Province. St. Paul MN: Ecological Land Classification Program, Minnesota County

Minnesota's List of Endangered, Threatened, and Special Concern Species." Minnesota Department of Natural Resources, December 3, 2024. https://files.dnr.state.mn.us/natural_resources/ets/endlist.pdf.

"Minnesota's Wildlife Action Plan 2015-2025." Natural Resource Planning. Minnesota Department of Natural Resources, (2024). https://www.dnr.state.mn.us/mnwap/index.html.

Moncada, K. M., Ehlke, N. J., Muehlbauer, G. J., Sheaffer, C. C., Wyse, D. L., & DeHaan, L. R. (2007). Genetic variation in three native plant species across the State of Minnesota. *Crop Science*, *47*(6), 2379–2389. https://doi.org/10.2135/cropsci2007.02.0082

Mutegi, E., Stottlemyer, A. L., Snow, A. A., & Sweeney, P. M. (2014). Genetic structure of remnant populations and cultivars of switchgrass (Panicum virgatum) in the context of prairie conservation and restoration. *Restoration Ecology*, *22*(2), 223–231. https://doi.org/10.1111/rec.12070

North American Prairie Conference : seeds for the future, roots of the past : held 16-20, July, (2000), North Iowa Area Community College, Mason City, Iowa.

Odum, E.P. (1969). The strategy of ecosystem development. Science 164:262-270.

Odum, E. P. (1975). Diversity as a function of energy flow. In Unifying concepts in ecology (pp. 11-14). Springer, Dordrecht.

Odum, E. P. (1985). Trends expected in stressed ecosystems. Bioscience, 35(7), 419-422.

Odum, H.T. (1988). Self organization, Transformity, and Information. Science 242.

Odum H.T. (2007). Environment, Power, and Society for the Twenty First Century. 2nd addition, the original being published in 1971 Columbia University Press.

Packard, S. (1994). Successional restoration: thinking like a prairie. Restoration & Management Notes 12(l):32-39.

Perry, L. G., S. M. Galatowitsch, C. J. Rosen. (2004). Competitive control of invasive vegetation: a native wetland sedge suppresses Phalaris arundinacea in carbon-enriched soil. Journal of Applied Ecology 41: 151-162.

Piper, J.K. (1996). Composition of prairie plant communities on productive versus unproductive sites in wet and dry years. Can. J. Bot. 73: 1635-1644.

Piper, J. K., E. S. Schmidt, A.J. Janzen. (2007). Effects of Species Richness on Resident and Target Species Components in a Prairie Restoration. Restoration Ecology 15: 189-198.

Piper, J. K., Pimm, S.L. (2002). The creation of diverse prairie-like communities. Community Ecology 3: 205-216. Schramm, Peter. 1978. The "do's and don'ts" of prairie restoration, pp. 139-150 in Glenn-Lewin, David C.;

Ploegstra, J. T., Ruyter, B. D. E., & Jelsma, T. (2015). Population genetic structure of Asclepias tuberosa in Northwest Iowa: A comparison within and between remnant prairies and commercially available seed. *Journal of the Iowa Academy of Science*, *122*(1–4), 1–6.

Rogers, D., Montalvo, A. (2004). Genetically Appropriate Choices for Plant Materials to Maintain Biological Diversity, USDA Forest Service.

Sambatti, J.B.M.; Rice, K.J. (2006). Local Adaptation, Patterns of Selection, and Gene Flow in the Californian Serpentine Sunflower (Helianthus exilis). Evolution, 60(4): 696-710.

Selbo, S. M., & Snow, A. A. (2005). Flowering phenology and genetic similarity among local and recently introduced populations of Andropogon gerardii in Ohio. *Restoration Ecology*, *13*(3), 441–447. https://doi.org/10.1111/j.1526-100X.2005.00055.x

Smith, S.E.; Halbrook, K. (2004). A Plant Genetics Primer, Basic Terminology. Native Plants, Fall 2004: 105-111.

Smith, MD, JC Wilcox, T. Kelly, and AK Knapp. (2004). Dominance not richness determines invasibility of tallgrass prairie. Oikos 106: 253-262.

St. Clair, B., R. Johnson. (2004). Structure of Genetic Variation and Implications for the Management of Seed and Planting Stock. USDA Forest Service Proceedings RMRS-P-33. 2004.

Symstad, A. (2000). A test of the effects of functional group richness and composition on grassland invasibility.Ecology 81:99-109.

Symstad, A. J.; Tilman, D.; Willson, J.; Knops, J. M. H. (1998). Species loss and ecosystem functioning: effects of species identity and community composition. Oikos 81:389-397.

Tallmon, D, Luikart, G., Waples, R. (2004). The Alluring Simplicity and Complex Reality of Genetic Rescue, Trends in Ecology and Evolution, Vol. 19.

Tilman, D. (2001). Functional diversity. Pages 109-120, in, S. A. Levin, Editor-in-Chief, Encyclopedia of Biodiversity, Vol. 3. Academic Press, San Diego, CA.

Tilman, D. (2000). Causes, consequences and ethics of biodiversity. Nature 405:208-211.

Tilman, D. (1999). The ecological consequences of changes in biodiversity: a search for general principles. The Robert H. MacArthur Award Lecture. Ecology 80:1455-1474.

Tilman, D. (1997). Community invasibility, recruitment limitation, and grassland biodiversity. Ecology 78:81-92. Tilman, D. 1996. Biodiversity: Population versus ecosystem stability. Ecology 77(3):350-363.

Tilman D., P.B. Reich, J. M. H. Knops. (2006). Biodiversity and ecosystem stability in a decade-long grassland experiment. Nature: 441: 629-632.

Tilman, D., J. Knops, D. Wedin, P. Reich, M. Ritchie, E. Siemann. (1997). The influence of functional diversity and composition on ecosystem processes. Science 277:1300-1302.

Tilman, D., J.A. Downing. (1994). Biodiversity and stability in grasslands. Nature 367:363-365.

Tober, D.; Duckwitz, W.; Jensen, N.; Knudson, M. (2008). Five Reasons to Choose Native Grass Releases. USDA Natural Resources Conservation Service, Plant Materials Center, Bismarck, North Dakota.

Ulanowicz, R.E. (1979). Complexity, stability and self-organization in natural communities. *Oecologia (Berlin)* 43:295-298

Ulanowicz, R. E. (2012). Growth and development: ecosystems phenomenology. Springer Science & Business Media.

Vander Mijnsbrugge, K., Bischoff, A., & Smith, B. (2010). A question of origin: Where and how to collect seed for ecological restoration. *Basic and Applied Ecology*, *11*(4), 300–311. https://doi.org/10.1016/j.baae.2009.09.002

Wagenius, S., Hangelbroek, H. H., Ridley, C. E., & Shaw, R. G. (2010). Biparental inbreeding and interremnant mating in a perennial prairie plant: Fitness consequences for progeny in their first eight years. *Evolution*, *64*(3), 761–771. https://doi.org/10.1111/j.1558-5646.2009.00860.x

Wedin, D. A., D. Tilman. (1996). Influence of nitrogen loading and species composition on the carbon balance of grasslands. Science 274:1720-1723.

Wedin, D. A., D. Tilman. (1992). Nitrogen cycling, plant competition and the stability of tallgrass prairie. Pages 5-8 in D. D. Smith and C. A. Jacobs, Eds., Proceedings of the Twelfth North American Prairie Conference. University of Northern Iowa Press, Cedar Falls, IA.

White, A., Fant, J. B., Havens, K., Skinner, M., & Kramer, A. T. (2018). *Restoring species diversity : assessing capacity in the U . S . native plant industry*. 1–7. https://doi.org/10.1111/rec.12705

Williams, D. W., Houseal, G., & Smith, D. D. (2004). Growth and reproduction of local ecotypes and cultivated varieties of Panicum virgatum and Coreopsis palmata grown in common gardens. *Proceedings of the 19th North American Prairie Conference*, 55–60.

Williams, M. I., & Dumroese, R. K. (2014). *Planning the Future's Forests with Assisted Migration*. *Langlet 1971*, 133–144. https://doi.org/10.5876/9781607324591.c008

Wilsey, B. J. (2010). Productivity and subordinate species response to dominant grass species and seed source during restoration. *Restoration Ecology*, *18*(5), 628–637. https://doi.org/10.1111/j.1526-100X.2008.00471.x

Wilsey, B.J. and H.W. Polley. (2004). Realistically low species evenness does not alter grassland species-richness productivity relationships. Ecology 85: 2693-2700.

Wilson, L. R., Gibson, D. J., Baer, S. G., & Johnson, L. C. (2016). Plant community response to regional sources of dominant grasses in grasslands restored across a longitudinal gradient. *Ecosphere*, *7*(4), 1–16. https://doi.org/10.1002/ecs2.1329