

PRAIRIE CONSERVATION AND RECONSTRUCTION: STUDIES IN COMMUNICATION,
APPLICATION, AND EDUCATION

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North Dakota State University's regulations and meets the accepted
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DOCTOR OF PHILOSOPHY

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ABSTRACT

Natural Resources Management is a combination of disciplines all working together to improve management practices, environmental education, and cross-discipline communication. Land managers and conservationist have become a group of people thrust into the public eye and to help the world make sense of the ecological and climatic changes that are taking place. For this reason, Natural Resources Management PhD's have become a community needed to interface with the public in order to balance environmental and societal needs. This dissertation project took a renaissance approach by examining a wide range of fields. It is said that a Renaissance man is knowledgeable and proficient in a wide range of fields or they are interdisciplinary. The world is in need of a conservation renaissance to reconnect the environment back to societal values, and it is going to need an interdisciplinary approach to do so. To do this each of the three areas: communication, education, and application were explored. Communication was addressed in two parts, first through the completion of a partnered publication with United States Fish and Wildlife Services, which used a framework from education (backward design) to communicate best practices for tallgrass prairie reconstruction in North Dakota. A second document was then completed describing how the backward design model was used to optimize communication. To further connect the importance of education to Natural Resource Management, I partnered with the Minnesota State University Moorhead Regional Science Center and their curriculum based field trips; drawing artifacts were collected and examined using the coding scheme from Human Figure Drawing and cross-racial facial recognition to determine what cues are utilized in novice plant observers. The Natural Resource Management application research was conducted on conservation lands in eastern North and South Dakota comparing the spike seeding method with more traditional seeding methods.

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I would also like to thank Anthony “Tony” Bormann for being a friend and boss for over a decade. It was with his help that I was able to gain access to the passion and opportunities to explore outdoor learning in such an in depth way. I will always remember to be “authentic” in my approach to education, and I will not forget the subtle lessons I was taught by Tony. No one could ask for a better “Boss-man,” and I will deeply miss working with you.

Last but not least, I would like to thank my friends and family who have read and edited work for me over the years and helped me produce the best writing I possible could. To name a few of these gracious people Kelly Rudolf, Lucas Wandrie, Madaline “Rosie” Russo, Megan Evans, and Lauren Fink. The world is a far better place with you in it!

DEDICATION

This dissertation is dedicated to my parents. To my dad who instilled a love of all that is nature and the outdoors and who never let me quit on my educational goals. To my mom who engrained a level of feisty into her daughter that helped her see that it was through little actions that we could change the world. Lastly, I would like to dedicate the drawing chapter to my cousin Jimmy, because without him I never would have had the idea! I would also like to dedicate this dissertation to the Standing Rock Sioux Tribe and the Bear Solider District, because it takes a village to raise a child and my village raised me to be the strong, proud, and determined. Without these traits I never would of made it this far.

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1. INTRODUCTION

Natural Resources Management (NRM) is a dynamic field that is constantly attempting to solve complex problems while communicating with various audiences. In order to answer the demands of the growing and changing field of NRM, a professional in this area needs to be able to do several things: interpret scientific literature, apply new methods of management, and communicate the validity of trying/utilizing new methods. All the while educating politicians, the public, and school aged children on the importance of maintaining and managing our natural areas and resources. It is easy to focus on just one of these three areas (i.e. application, education, and communication), but eventually all three will become required to manage natural resources successfully. For these reasons, this dissertation will address all three areas.

To begin, communication models from education, backward design, can strengthen communication in other disciplines. Chapter one is a full explanation of how and why backward design can be used in areas outside of education. To demonstrate the application potential of backward design, a joint effort with U.S. Fish and Wildlife Service led to the production of a prairie restoration guidebook for North Dakota (Appendix A). The purpose of the guidebook was to help reconstructionists better understand current methodologies and recommendations for tall grass prairie reconstruction projects. By utilizing strong models for communication, I believe we will have stronger abilities to interface with those working in the NRM field to promote the creation of diverse and sustainable native plant communities.

An understanding of what base knowledge the majority of the population has about habitat and the plants that define them is needed to better understand how to communicate why diverse plant communities are important and needed. By partnering with the Minnesota State University Moorhead Regional Science Center outreach education research was completed to

examine the roots of plant blindness, or the inability to see and value plants. Drawing artifacts were collected after the field trips and examined to determine what cues are utilized in novice plant observers. The design of this project was postured toward increasing the ability of the general public, school children, and pre-service NRM professionals to identify relevant plant cues more efficiently, leading to increased accuracy in plant identification and appreciation of diverse plant communities.

To demonstrate a strong understanding of applied NRM, a researcher needs to have a strong understanding of how landscapes are restored, managed, and maintained. To gain experience and expertise in this area, seven examined restoration sites were examined and evaluated in eastern and western North and South Dakota comparing a spike seeding method with more traditional reseeding methods seven years post seeding. The results of this study were compared to the results from years one and two post seeding. The findings of the spike seedings also informed the guidebook, and will hopefully allow land managers to design functioning plant communities similar to those found in native prairies.

In the end, all three areas are highly connected. It is time we need to start realizing the importance of educating the public about the importance of plant community, communicating how to develop and support those plant communities, and applying methodologies to restore and promote native plant communities. It is in the relationship between these areas that I believe we can truly become true stewards of nature.

2. INTERDISCIPLINARY NATURAL RESOURCES MANAGEMENT: USING BACKWARD DESIGN TO IMPROVE COMMUNICATION

2.1. Introduction

Science, in general, has become an interdisciplinary field, and the specialists of one field provide input for other fields. For this reason, science can only efficiently function with each discipline contributing something to the conversation (Franck 1999). If communications between disciplines are not done through open transparent channels, scientific productions will not reach full potential (Franck 1999). For this reason, it is time to start communicating within disciplines in ways that can be understood in other disciplines. This document will argue that the hierarchical approach of the Backward Design Model (BDM) increases the accessibility of information and increases the transparency of the intention behind the communication for all disciplines (Lauhban et al. 2012; Office of Planning and Institutional Insight 2011; Wiggins & McTighe, 2006, Childre et al. 2009).

The BDM has already been mirrored in Natural Resources Management (NRM) by Laubhan et al. (2012) in his publication, *A Conceptual Approach to Evaluating Grassland Restoration Potential on Huron Wetland Management District, South Dakota*. The methodologies described by Laubhan et al. (2012) help communicate best reconstruction practices and how to meet the associated goals, address needs, and promote ecological processes. However, Laubhan's recommendations are directed toward professionals in the field, which are people who already have high accessibility to the conversation surrounding reconstruction. Showing that a reconstruction plan has met its goal is challenging to those who are not involved in the profession unless more detailed parameters are established. For this reason, it is imperative to build framework that builds on Laubhan's model and relays more information. In this way,

people involved directly and indirectly with a project can appreciate how and why the goal was determined and how it will be met. To improve communication within and between disciplines, an interdisciplinary approach is required. Using the BDM in combination with the practices described by Lauhban et al. it is possible to begin improving communication and sharing knowledge. Therefore, the purpose of the following document is to present a theoretical explanation of why BDM is a strong approach for project management and design in multiple disciplines. To do this, the following topics will be covered:

- 1) What barriers to information access are in place and why there is a need for more transparent and formal project communication and documentation.
- 2) How BDM can be modified to demystify project planning and trajectories in NRM using an example from prairie reconstruction literature.

2.2. Communication Theory: Access and Accessibility

Scientific information that reaches today's general population changes as it moves from researchers to the general public. Many of these changes are done so mass media can make research acceptable for mass consumption. The result is an exclusion of the majority of the audience from the primary conversation (Comeau, 2009). Although most people can *access* a version of the ongoing scientific conversations, their *accessibility* to these conversations is low. Jan Van Cuilenburg (1999) explains the difference between access and accessibility to communication:

Access to Communication is the possibility for individuals, groups of individuals, organizations and institutions to share society's communications resources, that is, to participate in the market of communications infrastructure and distribution (message delivery) services, and in the market of content and communication

services. *Accessibility of communication* is the degree to which it is possible to take a share in society's communication resources (Cuilenburg, 185).

This relationship could be thought of in terms of Access/Consumption, Accessibility/Production of scientific conversations. This means that just because a person is able to access a conversation, does not mean the conversation is accessible to them. Therefore, most of the population is left to merely consume scientific conversations, and few are situated in positions that allow them to produce that conversation.

Cuilenburg (1999) further explains that the level of inclusion in elite social groups, such as scientific researchers, creates “communicative inequality,” and this inequality exists in all public debates and conversations. Older media, such as scientific journals and other publications, were not designed to be accessible for everyone, and the same restrictions applied to access. Through such sources, researchers are able to access current scientific information through their research institution because the cost of the access is often covered; in addition, they have the ability to change and contribute to the conversations because of the access and social group of which they are apart. People outside of this research social group have restricted access because of the cost and lack of accessibility to enter the conversation. In this example, cost and social group act as “gatekeepers.” Gatekeepers are people, situations, or rules that frame the conversations and restrict certain groups of people from taking part in a meaningful way.

Guarded and privileged circles are kept by the “gatekeepers” of the discipline and the further away a person is from the primary source of information, the less information they are able to access (Comeau 2009; Cuilenburg 1999). Figure 1 represents the exclusionary tendency of media. People found in the innermost circles have the most influence on the conversations and are the primary gatekeepers. The further from the primary inclusion circle, the less impact a

person has on the conversation. Hypothetically, people who purely consume the conversation have limited to no direct influence, and those who are responsible for the production of the conversation have large and direct impacts on direction and content of the conversation (Comeau 2009; Cuilenburg 1999).

The middle of the production/consumption continuum is an important area. It is the most influential point of the continuum; it is where consumption meets production and creates a point of high influence (Figure 1). People who reach the inner inclusionary level have an ability to reach a large number of people and as a result are usually well known on both the production and consumption side of the continuum, for example Bill Nye and Richard Dawkins. These people

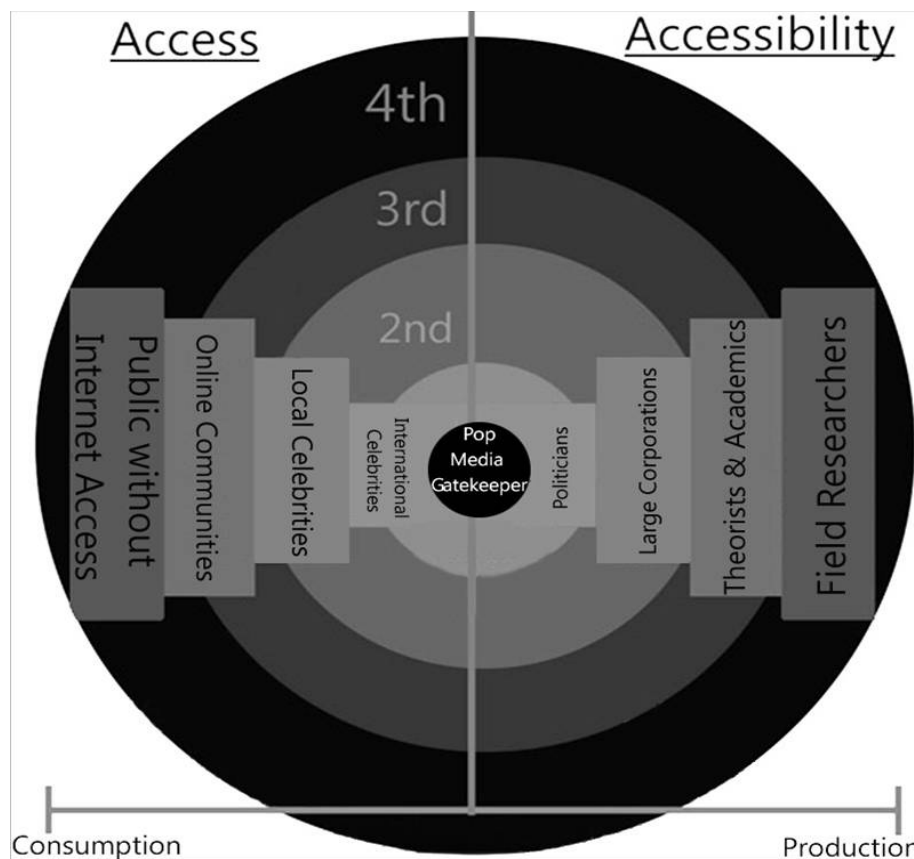


Figure 1. Production/consumption continuum (Comeau, 2009).

may not be necessarily the most respected in their fields, but are charismatic figureheads representing their views to the majority of the consuming public.

In order to develop a strong communication framework for a project the plan should attempt to communicate with both the access and accessibility side of the spectrum. If a framework is utilized that can be understood on both sides, a project becomes more transparent. The more transparent a project plan is the more available it is for public comment and involvement, resulting in less tension. In a sense, science, including Natural Resources Management (NRM), now need translators of the scientific methodology and decision-making.

NRM is a dynamic field that is constantly attempting to address the needs of various audiences, often simultaneously. However, to communicate the necessity for land to be profitable while still maintaining proper ecological function is challenging. In order to do this, a NRM professional needs to be able to do several things: interpret scientific literature, apply new methods of management, communicate the validity of trying/utilizing new methods, and educate politicians, the public, and school aged children on the benefits of maintaining and managing our natural areas and resources. Finding a balance in managing the growing needs of a resource dependent society with the needs of ecosystems now requires that more qualified translators of science step forward and address the general public.

It is imperative to create these communication lines that serve both industry and society. This becomes increasingly important as energy and civil engineering projects become larger and the public is more involved. For these reasons, organizations must balance the needs of their stakeholders, the environment, and social opinion. Likewise, NRM professionals are often monitoring and restoring multiple projects simultaneously, and they need to be able to access relevant information that is based in good research practices. The rationale behind decision-

making in professional communication needs to be more transparent and clearly disclose how the practices and application methods fulfill the project goals. With a strong framework, NRM professionals can reach more audiences and ensure that stakeholder interests in projects are known and addressed appropriately. In a sense, NRM now needs translators of scientific methodology and decision-making.

Currently, there are some frameworks that can be found in NRM literature. One of note is the multiphase approach to decision making is presented by Cain et al (2001). Cain et al. (2001) breaks down the phases in the following way:

- First phase is the “Intelligence Phase” and identifies the problem;
- Second phase is the “Design Phase” and identifies the criteria to base the decision on, the options available, and tries to predict the outcomes of the identified options
- Third phase is the “Choice Phase” which identifies the best option available (Cain et al. 2001).

However, the majority of the time this process is conducted informally and it is recognized that a more formal approach would produce more accurate and repeatable results especially when making decisions in complex systems (Cain et al, 2001; Snowden and Boone, 2007). A “complex” system is one that accepts the fact that there are more unknowns than knowns and has complicated contexts with more than one right answer (Snowden and Boone, 2007). In these systems, the relationship between cause and effect is not always discernable, but formally documenting strategies and outcomes improves future project planning.

Since there is no uniform framework, communicating management plans and civil projects can be challenging with every agency, consulting firm, and university using a slightly

different approach despite the growing importance of transparent decision making. A strong framework would allow more effort to be placed on the planning stages and potentially identify problems early. More effort placed on planning and project goals creates the strongest opportunities for success. The following section details a proposed framework to promote clear and unambiguous communication.

2.2.1. Backward Design

The Backward Design Model (BDM) from education may just be the framework that can bridge the gaps occurring when science and management practices are communicated to the general public (Wiggins & McTighe, 2006, Childre et al. 2009). It will be argued that the hierarchical approach of BDM increases the accessibility of information and increases the transparency of the intention behind the communication for all disciplines (Lauhban et al 2012; Office of Planning and institutional insight 2011; Wiggins & McTighe, 2006, Childre et al. 2009). This approach is similar to those presented in project management, business, and strategic planning (Office of Planning and institutional insight 2011; Sochi et al. 2013; MORE SOURCES).

Just as NRM has identified and worked to improve communication, teachers across grade levels have been asked to improve communication by designing curriculum for scaffold learning, or a *Backward Design* approach (Wiggins & McTighe 2006, Childre et al. 2009). The premise of backward design is that curriculum cannot be designed effectively unless the end goals are already known. BDM removes the emphasis from the instructor-delivered content and puts the *focus on* student or audience- centered learning activities (CTE-Lilly Teaching Fellows 2012). This situation has made it necessary to focus on two aspects: 1) effective instructional practices that teach state standards; and 2) the analysis of achievement data in order to improve curriculum

plans (McTighe and Thomas 2007). Backward design can serve as a guide to organize and communicate these plans. The three-stage, data driven BDM process is being used for school improvement planning. For backward design to work, desired results, or goals, need to be identified, multiple data sources needed to be considered, and appropriate action plans need to be identified (McTighe and Thomas 2007, Childre et al. 2009). It can be argued that this idea can be applied to projects in all disciplines.

With the current accountability pressures in education this emphasis on transparency is understandable, but leads improvement teams to focus on goals that are too narrow (McTighe and Thomas 2007). Wiggins and McTighe (2006) argue that BDM planning makes accomplishing broad goals more manageable by using them to design learning outcomes based on state standards and strong assessments (Childre et al 2009). Figure 2 shows an original adaptation of how curriculum can be broken down to support goals by planning specific outcomes, objectives and assessments/evaluations of learning activities based on recommendations from both education and NRM (Laubhan et al. 2012; Center for Innovative Teaching and Learning 2015).

A similar format can be used to streamline communications across disciplines. For example, when developing a plan for United States Fish and Wildlife Service (USFWS) prairie reconstructions were broken down in similar way to educational curriculum. Planning reconstructions or restorations involves creating “clear and unambiguous” goals and objectives (Laubhan et al 2012; Dixon et al. 2016), just like education curriculum. In fact, Laubhan describes framework similar to BDM (Table 1). Table 1 outlines the phases of the reconstruction process and the associated steps and goals.

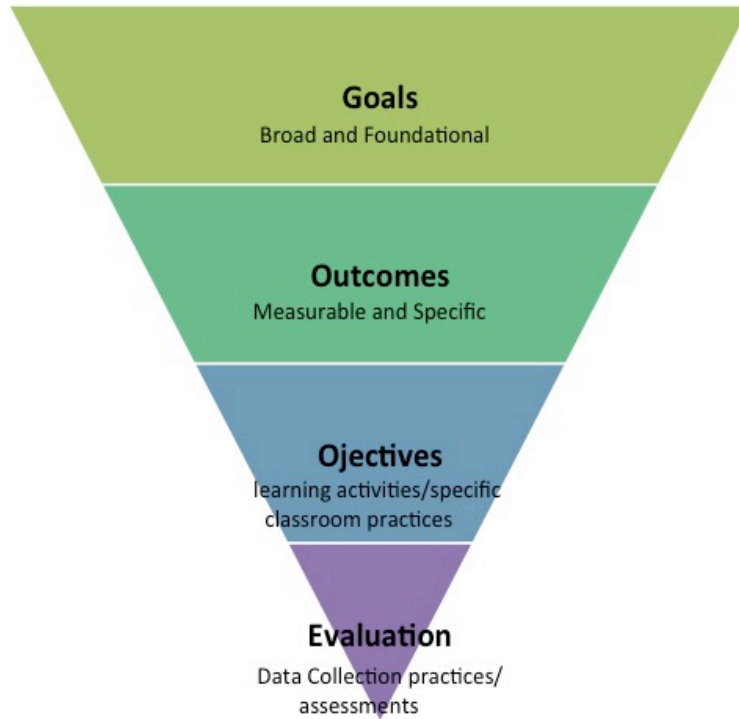


Figure 2. Backward design model (BDM).

Table 1
Phases, Steps and Goals (Dixon et al. 2016)

Phase	Steps	Phase Goals
Planning	Setting Goals & Determining Outcomes	The planning phase determines where the reconstruction will take place, timeframe and the objectives that will drive the application and implementation phase.
	Site Selection	
Application	Site Preparation	The application phase brings the reconstruction into action by directly applying predetermined methodologies for site preparation, seeding and invasive species control.
	Seeding	
	Establishment	
Implementation	Post Establishment Evaluation - Monitoring & follow-up	The implementation phase actualizes the management and evaluation protocols, providing plans for on-going monitoring.

In his 2012 article, Laubhan describes *Goals* as “general descriptions” or guidelines of optimal post-reconstruction conditions and objectives, which are actions used to achieve the outcomes, that articulate clear and measureable short-term targets used to reach the goals (Laubhan et al. 2012). This situation describes framework that relies on *objectives* to determine whether or not *goals* have been met. Wark et al. (2004) suggests that reconstruction objectives should be set based on the intended purpose, management needs, longevity of the reconstruction, and needed methodologies (Cramer 1991, Berger 1993, Jacobs and Sheley 1999). Objectives cover a lot of planning areas, for this reason, it would be beneficial in formulating and communicating project plans to insert a level between goals and objectives, named *outcomes*. Both outcomes and objectives should be determined after the overarching goals are agreed upon. The goals will then inform the outcomes and timeframe needed to successfully complete the project. In education, this can be broken down in terms of *objectives* or learning activities (lectures, homework, etc.), learning *outcomes*, final assessments or *evaluations*, and course *goals* (Figure 3) (Center for Innovative Teaching and Learning 2015).

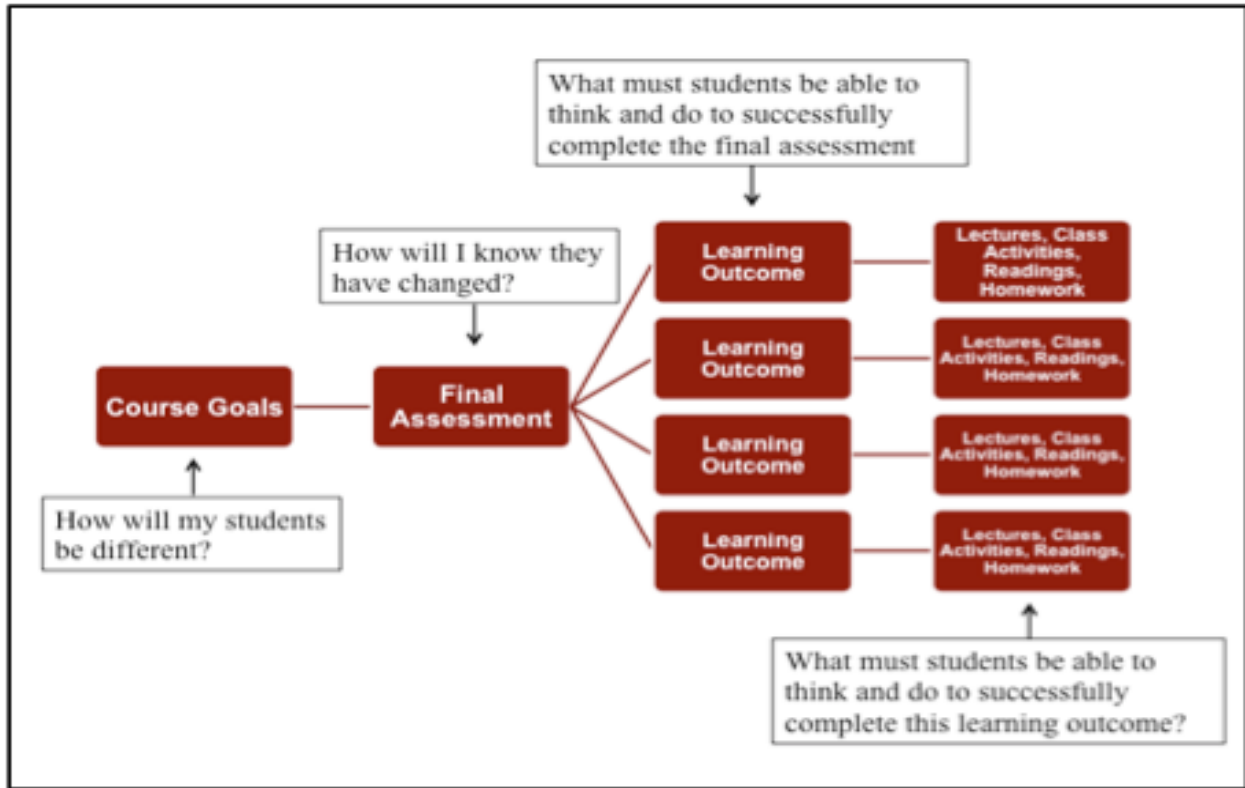


Figure 3. Backward Design Model explanation (Center for Innovative Teaching and Learning 2015).

Mirroring education in NRM, it is imperative to first identify the desired results; second, to determine how to collect acceptable evidence of desired results and; lastly, to apply appropriate management and evaluation practices. For example, Figure 3 shows how BDM can be transferred to NRM and provides example goals, outcomes, and objectives for prairie reconstruction projects. Taking a close look at how goals, objectives, and evaluations are set up can demystify the planning stages of projects. The reason that front loading much of the work to the planning phase can be effective is that it promotes discussion about all phases of a project, everything from the broad goals to the day-to-day processes that will be used to measure whether or not the goals have been met. Formulating detailed plans and that can be easily understood and

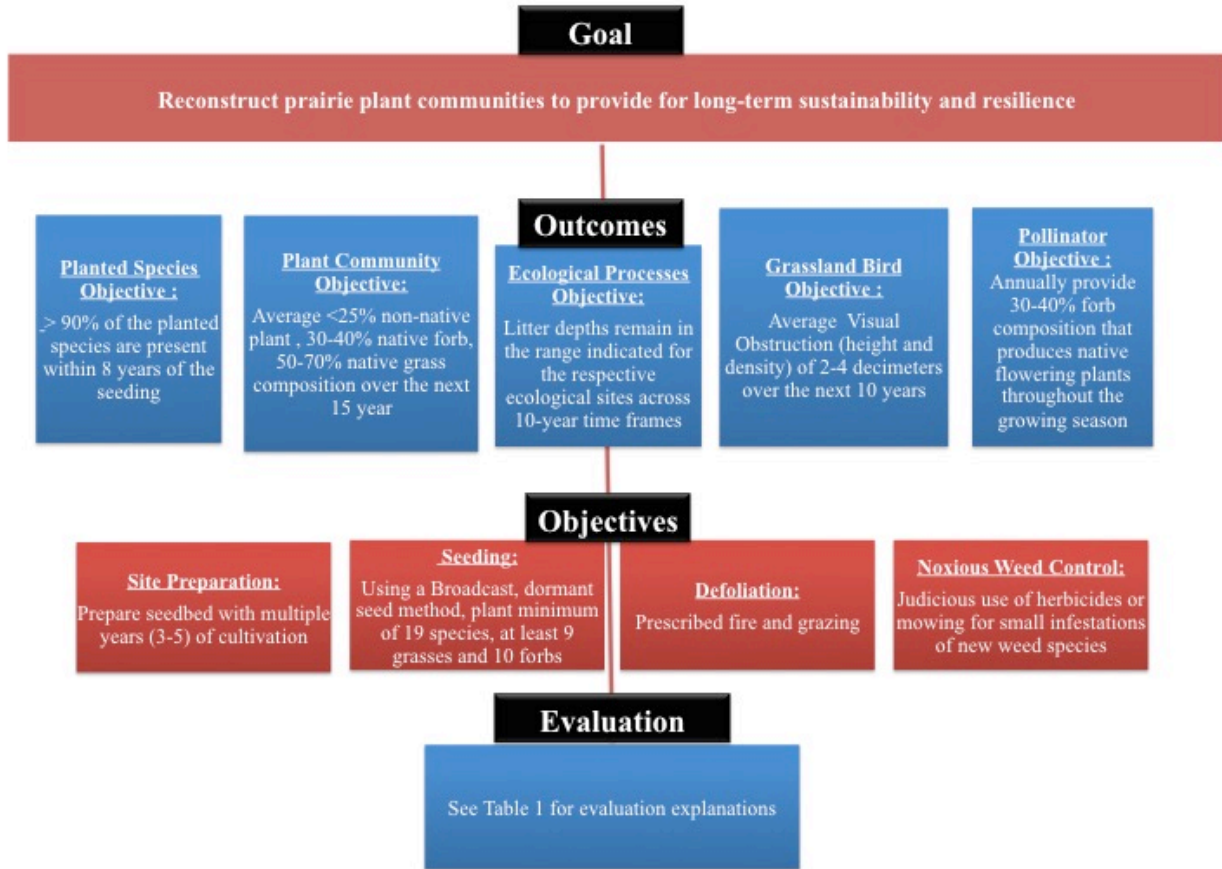


Figure 4. USFWS project plan in BDM format (see Appendix A).

communicated is imperative for project success and transparency. Figure 4 looks at how the BDM framework could be applied to NRM (see Appendix A).

Table 2 elaborates further on the evaluation plans to be utilized in the presented example and highlights the various levels of evaluation that can take place. This table also highlights the importance of identifying the level of investment the project will require. Reconstruction protocols at all levels should be developed in the planning phase, in order to understand achievement potential of goals and outcomes. To better understand how and why this framework streamline NRM communications, each level needs to be examined in depth.

Table 2

Example Evaluation Using Three Tier Approach (see Appendix A)

Outcome	Tier and Example Method
<u>Planted Species:</u> > 90% of the planted species are present within 8 years of the seeding	<u>Tier 1</u> Planted Species Checklist
<u>Plant Community:</u> Average <25% non-native plant, 30-40% native forb, 50-70% native grass composition over the next 15 year	<u>Tier 2</u> Belt-transect Method
<u>Ecological Processes:</u> Enable ecological processes on reconstructed prairie by ensuring that litter depths remain in the range indicated for the respective ecological sites across 10-year time frames.	<u>Tier 2</u> Litter Depth Measurement
<u>Grassland Bird:</u> Average Visual Obstruction (height and density) of 2-4 decimeters over the next 10 years	<u>Tier 2</u> Visual Obstruction Measurement
<u>Pollinator:</u> Annually provides 50-70% forb composition and produces native flowering plants throughout the growing season	<u>Tier 3</u> Sampling Frame Method

2.3. Section Breakdowns

2.3.1. Goals

For both communication and application methodologies to be effective, a strong plan is needed to describe project goals and objectives. Goals are general descriptive in nature and without further planning are immeasurable (Center for innovative teaching and learning 2015; Lauhban et al. 2012). When looking at the example goal, “*Reconstruct prairie plant communities to provide for long-term sustainability and resilience,*” the first noticeable thing is that the terms

are not clearly defined (see Appendix A). What is sustainable or resilience? This goal, much like company mission statements, is ambiguous and not specific.

In summary, goals should be broad targets that help guide the formation of outcomes and objectives. For this reason, they need to be developed first and before real work on a project begins. Without a strong guiding goal, strong measurable outcomes are difficult or impossible to determine.

2.3.2. Outcomes

Outcomes provide specific and measurable targets for a project to meet, and often define timelines as well. Thus, they are important considerations when planning projects and, when in place, can greatly improve the transparency of how project goals are being met. By stating the project's measurable outcomes, both professionals and non-professionals are able to glean how progress will be measured, thereby increasing the level of access to information and improving project communication. To better communicate the purpose of outcomes, Figure 5 provides examples from the USFWS's tall grass prairie restoration guidebook (see Appendix A).

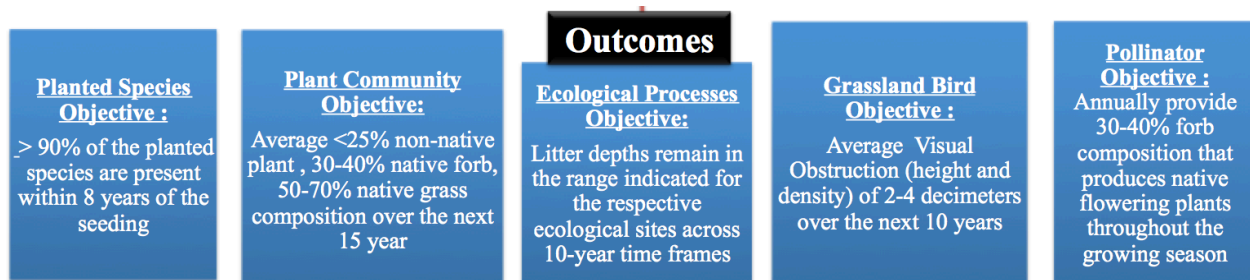


Figure 5. Tall grass prairie restoration guidebook example outcomes.

The prairie restoration guidebook bases its outcomes on a goal that emphasizes resilience and resistance, but determining how those will be measured depends a lot on how those concepts are defined. In the presented example, resilience is defined by the rate of recovery and/or the extent of recovery during a specific time frame (Gunderson 2000), and resistance refers to the ability of an ecosystem to withstand rare and unpredictable ecological impacts and disturbance (Hoover 2014). Resilience and resistance provide ways of describing a grassland's ability to remain within the environmental normal range. However, sustainability and resilience in a prairie reconstruction varies based on the current vegetative state. Therefore, metrics such as vegetation composition or production are often used as measures (Pellant et al. 2005). In the end, reconstructions are complex systems where ecological processes are difficult to measure. For this reason, it is important to develop a comprehensive plan and monitoring system for each reconstruction. See Figure 5 for detailed outcomes to be met in support of the established goal. Each outcomes provides both a component to be measured and a timeframe in which it should be met.

In summary, outcomes are strongly linked to the goal and provide a set of ideal measures that would indicate project success. Outcomes must be measureable and provide a timeframe, and for this reason are valuable for communicating whether or not the project goal has been met. In order to determine what objectives or strategies will be used to measure these decided benchmarks.

2.3.3. Objectives

The objectives should align with the spatial and temporal scales established in the outcomes and be based on the intended purpose, management needs, and longevity of the project (Lauhban 2012; Wark et al 2004) (Figure 6). Therefore, objectives are the actions that provide

the methods to achieve the intended outcomes (Figure 5). Moreover, the development of “clear and unambiguous” objectives is crucial for a successful project execution (Lauhban 2012). In terms of communication, objectives inform the audience of what actions will be completed to reach the desired outcomes and how they will be conducted.

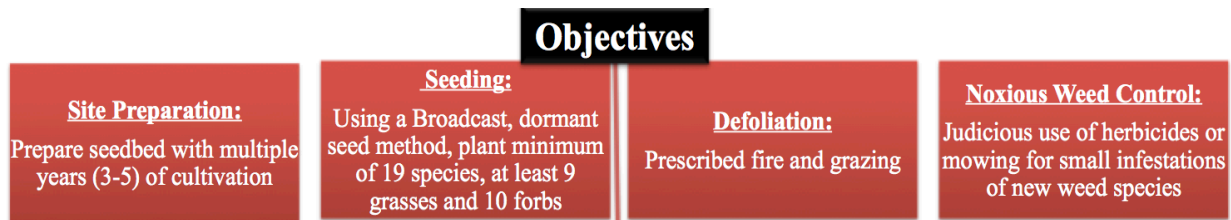


Figure 6. Example objectives (see Appendix A).

2.3.4. Evaluation

Evaluation is often dependent on the goal and varies from outcome to outcome. For this reason, it is important to consider what information will be beneficial to the specific project when developing a management and evaluation plan. Table 2 provides examples from the recommended “Three Tier” evaluation approach of the outcomes described in Table 2.

Identifying an adequate method for evaluation depends on the intended outcomes. Prior to implementing any monitoring program, discipline specific resources are useful. They allow plan developers to see what common measures are for their field and communicate their measures of success based on commonly accepted discipline standards.

The following section details a three tiered approach for monitoring projects. Each tier describes the amount of time, effort and detail needed by each approach and how it varies based on the tier and intended outcomes. The examples used were presented earlier in Table 2 and can

be found in even more detail in *A Prairie Reconstruction Guidebook for North Dakota* in Appendix A.

2.3.4.1. Tier 1 Monitoring Approach

The Tier 1 option provides minimal inputs based on the specifics needed to meet the objective. This level of project monitoring provides a “snap shot” of what is being done with the project. For example, create a checklist in a spreadsheet or database. Likely a Tier 1 evaluation will require the least amount of time and only be done at certain interval over the life of a project. It is possible that only qualitative data is collected in a Tier 1 evaluation, therefore surveys, observational data, and interviews may all be utilized. Again, certain outcomes may lend themselves more to this tier of evaluation than others and it is important to determine what information is actually needed in order to fully communicate the level of success for a desired project.

2.3.4.2. Tier 2 Monitoring Approach

Tier 2 requires more intensive effort and specific information than Tier 1 because of the need for quantitative data to meet the needs of the outcome. This method requires the evaluator gathering data and may require the consultation of a statistician to ensure that the design is appropriate for evaluating the intended outcome (see Appendix A).

Data from this method can be entered in a spreadsheet or database to quantitatively measure the specific outcome using univariate or multivariate analysis to gain insight to level of success. Grant et al. (2004) provides examples for analyzing data with this method.

2.3.4.3. Tier 3 Monitoring Approach

Tier 3 requires intensive monitoring because of the need to collect data on multiple facets of an outcome. At times, this may require the use of both quantitative and qualitative data

sources. Data are summarized using pre-established measures, again consulting a statistician in the planning phases of a project may be helpful to ensure appropriate data are collected. An associated spreadsheet or database can be developed to facilitate analysis. Because of concerns with variability, one individual should be responsible for data collection in this tier to ensure consistency. Double observer methods can also be utilized to help reduce variability, but extensive training should take place to ensure accuracy in the observations and data collection.

To see an example of how this framework was applied in a collaborative effort by USFWS site managers and district managers, North Dakota State University Extension, and NRM program, please see Appendix A. Some of the headings and verbiage were altered to better align with field specific terminology. Ultimately, the goal of using a formal framework is to improve communication across all levels access and accessibility continuum, both in and outside of the discipline.

2.4. Conclusion

While it may never be possible to provide everyone with accessibility to all information, it is possible to improve their access to it. One way to improve access is to include multiple sources of input. Managers, specialists and front line staff/technicians all have insight and experiences with various aspects of a project and including them provides insight into those aspects. It is also beneficial to consult and seek out reviews from other professionals and managers prior to beginning large projects. Through this inclusion, more people are allowed access and accessibility to the project, and with the BDM model, that information can be readily interpreted by a variety of audiences. The BDM breaks information down into distinctive categories with clear criteria:

- 1) Goals: Broad and foundational.
- 2) Outcomes: Measureable and time based.
- 3) Objectives: Actions to be completed to facilitate the achievement of the outcomes.
- 4) Evaluations: Periodic actions that will be use to collected data and determine whether the outcomes have been met.

Verbiage used to describe the parts of a project plan may vary depending on discipline (i.e. objectives may be referred to as strategies); however, the function of each level remains the same. Frameworks such as the BDM display information in a simple and easy to follow way, allowing for projects to be communicated in a transparent way for a much larger audience. In a world where companies, agencies, governments, and universities are increasingly accountable to the public and stakeholders, communicating the value of proposed projects clearly and concisely through a uniform and familiar format may in fact help to bridge communication gaps, reduce confusion and conflict, and result in more approved and completed projects.

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3. HUMAN FIGURE DRAWING AND FACIAL RECOGNITION RESEARCH REIMAGINED TO ATTEMPT TO UNDERSTAND ROOTS OF PLANT BLINDNESS

3.1. Abstract

It has been speculated that most people have plant blindness. Meaning plants go unnoticed by the majority of the population. This study sought to combine the knowledge of multiple disciplines to determine if there is evidence for this blindness, and what information people with little training in botany notice when visually examining plants. To do this, third grade students were introduced to various native prairie and wetland plants through demonstration lectures during a curriculum-based field trip to a natural area. Students were asked to draw a specific prairie plant identified by the field trip leader. Drawings were analyzed based on the plant characteristics represented in the drawings. Using a coding scheme taken from Human Figure Drawing (HFD) research, trends of oversimplification were discovered in the drawings; as well as potential evidence oversimplified mental prototypes. The features that students tend to draw were fundamental characteristics of a “plant” (stem, leaf, and flower). Some drawings included inaccurate additions, such as tulip-like flowers on plants that did not have a macro-flora structure, like Poison Ivy. These results suggest that students have a tendency to ignore subtle details of plants, and have overly simplified mental prototypes that can lead to misrepresentation. This research represents one of the first studies to investigate the roots of “plant blindness” and what may be contributing to an over-arching inclination of mental dismissal of plant communities. It is the hope that the findings from this study will help outreach professionals further science literacy across age groups.

3.2. Introduction

In the 1939 film *The Wizard of Oz*, Dorothy expressed her fear of “Lions and Tigers and Bears... Oh my!” but almost had her quest foiled by a field of poises. With this same disregard, most people today are more concerned with the potential dangers found in the animal kingdom than they are with plants, and the average person shows little regard to the plants that make up the backdrop of their everyday environment. In fact, most students are twice as interested in learning about animals in their environment than they are about plants (Wandersee and Schussler, 1999; Tunnicliffe 2001). This default preference for animals over plants is creating a plethora of problems in a global society that is faced with a large number of human facilitated extinctions. For example, few people would argue against saving the panda, but how many would recognize that to save the panda we must first preserve and save the plant on which they are completely dependent (Wandersee and Schussler 1999)? With the popularity of bamboo flooring and the product being marketed as “ecofriendly” and “renewable,” it is likely that the connection between the dwindling panda populations and their food source is perhaps not at the forefront of most consumers’ minds (Wandersee and Schussler 1999; Truini 2012).

The purpose of the present study is to gather evidence as to why there is an awareness deficit concerning plants. To do so, remnant drawings from field trips were obtained from third grade students. Third grade adolescents were of interest because of the development point that falls between the ages of eight and ten. This period is critical for two reasons: 1) children begin to exaggerate less in their drawings and become more aware of relative size in relation to surroundings; and 2) they stop adding more detail to their drawing unless they are formally trained to do so (Kopptiz 1968; Cox 1993). This suggests that what a third grader sees when they look at a plant would be very similar to an average adult. The goal of this research is to

determine the cues third grade students see and represent when drawing plants and flowering structures in natural settings and to examine the physical representations presented in student drawings. Based on human figure drawing research, it is assumed that the physical representations are signals that the student perceives as important in re-identification of that plant, and that those representations may offer insight to mental models being used by students to identify plants (Kopptiz 1968; Cox 1993). Therefore, if more basic physical representations (primary epistemic cues) are prevalent in the student drawings, then the drawings will be less accurate in representing the drawn plant (Jacob and Jeannerod 2003). This research represents one of the first steps in studying mental models of plants and attempting to understand why people are less aware of the plants in their environment than the animals. Mental model research, such as this, examines the way people understand a specific area of knowledge, and while there are beneficial application purposes (i.e. better training and teaching materials), this research is fundamentally important because it provides insight as to how humans understand their world (Genter and Stevens 2014). It is believed that people have a working mental model that is used to make sense of the input information from their senses (Matsumoto 2007; Van Dijk 2008). The more experience a person has with specific knowledge, the more detailed their working model. In our increasingly urbanized society, there has been a documented decrease in the amount of time spent in natural areas and even less time being spent learning about the world's flora (Bixler et.al, 1994; Rickinson 2001).

It is hypothesized in this research that if people have simple mental models of plants, then strong sensory cues, such as strong odor, bright color, or unique morphology, act as primary cues for students and subtle cues, such as stem and leaf shape, leaf pattern, and plant texture, will be utilized less. If this can be demonstrated, it can be assumed that the majority of the population is

operating with a highly simplified plant mental model and the strong primary cues act as distractions from the more accurate secondary identification cues. To test this working hypothesis, the objectives for the presented study are as follows:

- To identify and categorize the cues third grade students incorporate when visually representing plants and flowering structures.
- To determine if there is a common plant prototype that emerges in the study population.

3.3. Plant Blindness

This study explores the tendency of humans to neither notice nor value plants in the environment. According to current literature on the subject, most people have become “plant blind” (Wandersee and Schussler 1999; Tunnicliffe 2001; Balding and Williams 2016). “Plant blindness” was a term that was first coined by James Wandersee and Elisabeth Schussler in the mid-nineties when they began a national campaign to improve science literacy with a K12 poster titled “Prevent Plant Blindness” (Wandersee and Schussler 1999).

The education and naturalist communities have presented evidence for this phenomenon since the 1970’s (Tunnicliffe 2001); however, Wandersee and Schussler (1999) were the first to coin the term and define what it meant to be “plant blind” and what “plant blindness” entails (Table 3).

Plant blindness is a problem that continues to plague botanists (Hoekstra 2000), which may be due to a preference toward animals over plants (Wandersee and Schussler 1999; Strgar 2007; Schussler and Olzak 2010). This preference may be a result of how humans interpret visual information (Wandersee and Schussler 1999; Strgar 2007; Schussler and Olzak 2010). If a

person has more experiences with animals, it would increase their ability to identify subtle differences.

Table 3
Plant Blindness vs. Plant Blind (Wandersee and Schussler 1999)

Plant Blind Characteristics	Plant Blindness Characteristics
<ul style="list-style-type: none"> • Plants are merely the background • Failing to notice the plants in daily life • Misunderstanding what plants need to live • Disregard for the importance of plants in daily life • Unable to distinguish the differing time scales of plant and animal activity. • Lacking hands-on experiences in growing, observing, and identifying plants • Failing to understand the basics of plant life cycles and plant science. • Lacking knowledge of the carbon cycle • Being insensitive to the aesthetic of plants. 	<ul style="list-style-type: none"> • The inability to see or notice the plants in local environment • The inability to recognize the importance of plants in the biosphere and in human affairs • The inability to appreciate the aesthetic and unique biological features of plants • Ranking plants inferiorly to animals

Humans receive millions of cues of visual data every second, and only fifty cues are consciously considered and fully processed leading to an in attentional blindness (Norretranders 1998; Wandersee and Schussler 1999; Mack, 2003). According to Alan Baddeley (1982), humans tend to have a decreased inability to recall specifics of objects that are encountered on a daily basis. This becomes even more evident if observers know little about the objects that they are observing (Wandersee and Schussler 1999; Tunnicliffe 2001). If people have little experience with an object or do not see value in it, they may lack the experience to create a detailed mental

model of the object (Matsumoto 2007). Without a detailed mental model, it is difficult for people to perceive subtle differences in similar objects.

However, inattention can become attention if an object is given value (Mack and Rock 1999; Wandersee and Schussler 1999). Signal value, or the level of meaning that an object carries, increases with the amount of education and experience a person has with the object (Wandersee and Schussler 1999). Due to the tendency of most life science and introductory biology instructors to give more teaching time to animals and less to plants, plants tend to have a low signal value for most people and can blend into the background (Wandersee and Schussler 1999; Hoekstra 2000; Tunnicliffe 2001; Strgar 2007). Based on this information, it is hypothesized that if plant blindness is due to common deficiencies in mental model development, then in-situ drawing will present artifacts of inefficient plant models and prototype drawings will lack specificity. If this hypothesis is accurate, we would expect to see certain characteristics or forms appear more often in the prototype drawings. If this is not the case, drawings will represent a variety of plant characteristics and forms.

3.4. Theory

3.4.1. Representation Theory of the Visual Mind and Matsumoto Model

To better understand this inattention, David Matsumoto (2007) presents a model of how people interact with their environment, and may help us better understand why some objects or organisms have higher signal value than others (Figure 7). Matsumoto's (2007) model combines "basic human nature (via universal psychological processes), culture (via social roles), and personality (via individual role identities)" and argues that an individual's behaviors are the result of interactions between the three. Therefore, culture and education play a large part in determining what information is taken in and what information is disregarded. For example, if a

child is raised on a working farm, as an adult they are more likely to notice when crops are ready to be harvested compared to a person who was raised in an urban environment. People report on the similar situations differently based on past experiences and education; therefore, everyone has their own mental representation or mental model of the situation (Van Dijk 2008, 2009; Matsumoto 2007). Mental models inform a person's perception, and a person's perception is their ability to understand the world.

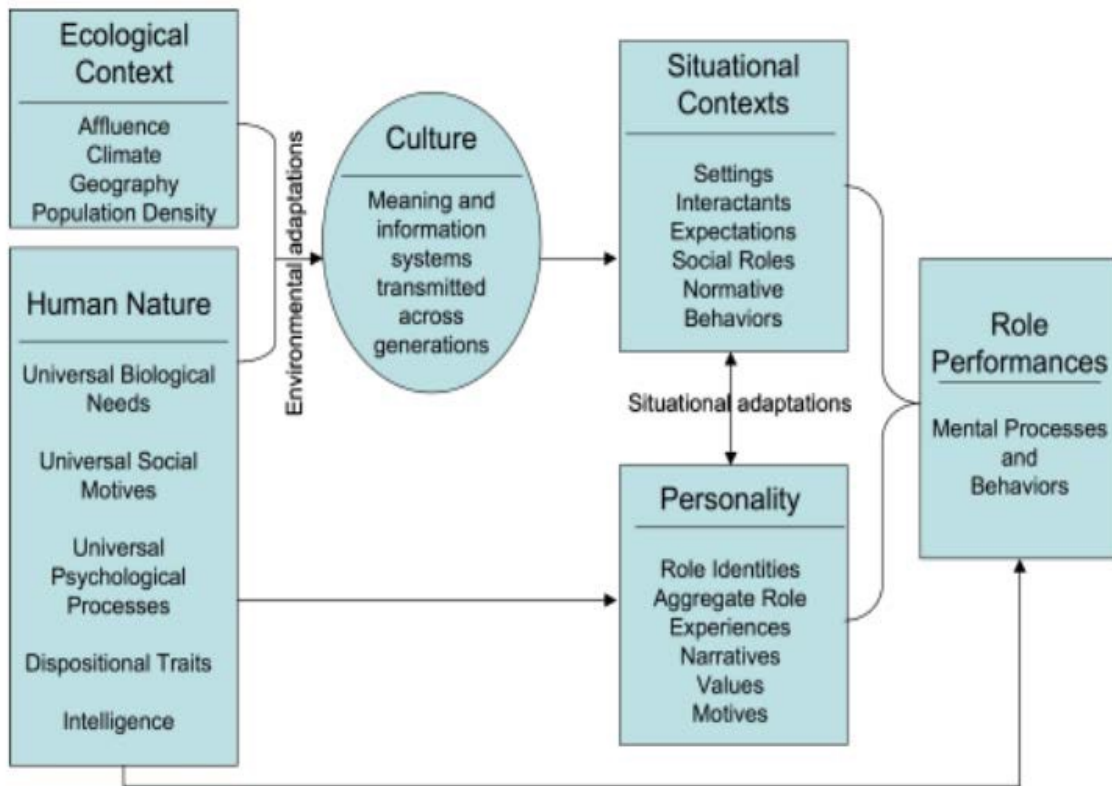


Figure 7. Matsumoto's (2007) model of human nature, culture, and personality.

When considering Matsumoto's Model of Human Nature (MMHN) in conjunction with the Representational Theory of the Visual Mind (RTVM), it is possible to begin to model how

and why a person's experiences leads to various mental representation and the possibility for misrepresentation. RTVM operates under the assumption that the mind is, at its rudimentary base, a representational device and that all mental facts are representational facts (Jacob and Jeannerod 2003). According to Jacob and Jeannerod (2003), the conscious visual experiences a person has textures the world and how they perceive it; thus, there is always an interaction between a person's experience and their reasoning, or computational thinking, about an object. The job of reasoning is to encode abstract information about an object into a representation, and the more experience a person has with an object the more detail is added to that representation (Jacob and Jeannerod 2003). A "representation" will hereby be defined as a physical structure with informational function; in other words, a physical structure that carries information for the observer. In accordance with this view, mental processes consist of the formation and the transformation of mental representation (Jacob and Jeannerod 2003), and the more experience a person has with an object the more detail can be added to the representation.

To better understand representation, we have the ideas of S, F, and G; where S represents the signal that is received, F is the property that the signal is being received from, and G is the object of which F is a part (Jacob and Jeannerod 2003; Godfrey-Smith 2006). For example: G = plant F=flower S=pink. In this situation, the object being considered is a plant, the property of that plant is the flower, and the signal is pink. As this example suggests, one signal about an object is not enough to accurately identify what exact object (plant) the viewer is looking at. In addition, the signal may provide information that is accurate or inaccurate, this is a requirement of a true or natural signal, and unless a signal can misrepresent what it indicates it cannot represent it (Jacob and Jeannerod 2003; Godfrey-Smith 2006). This means that multiple signals need to be able to be identified in order for a property and object to be epistemically

identified. Epistemic comes from the Greek work “episteme” which referred to “everyday know-how,” in the present research it will refer to the degree at which information can be accurately applied and validated (Jacob and Jeanerod 2003; Davis et al. 2008). By combining the ideas of epistemic and representation we get *epistemic representation*, which is the physical structure that carries valid information about an object. An example of an epistemic representation would be the hair-like structures on the side of sideoats grama (*Bouteloua curtipendula*) leaves. This feature of the plant is unique and a cue that allows an observer to more accurately identify that specific grass species. Similarly, *epistemic accuracy* is the ability of a viewer to correctly identify epistemic representations and interpret them. This means that in order for an observer to view something epistemically they must first have knowledge about the object.

The level at which a person can epistemically view an object or situation is directly related to the amount of knowledge a person has about that specific object or situation. A fundamental or primary epistemic view allows a person to identify the object or situation, for example, seeing the neighbor’s car in the driveway and knowing that the neighbor’s car is in the driveway (Jacob and Jeannerod 2003). At this basic level, the observer is able to accurately identify the objects or situations that they are looking at, but is unable to infer or gain any other information from what they are observing.

Secondary epistemic viewing allows a person to not only identify an object or situation but also gain information from it. This would be demonstrated by seeing the neighbor’s car in their drive way and being able to then gain the knowledge that the neighbor is now home. It could be argued that the neighbor’s car in their driveway may not always be the most reliable cue

to determine whether they are home or not, thereby making the car in the drive way a natural signal as it can accurately or inaccurately represent the situation (Jacob and Jeannerod 2003).

With these guidelines, it is possible to categorize signs relating to how epistemically appropriate they are. Table 4 below summarizes this categorization.

Table 4
Levels of Epistemic Viewing and Plant Examples

Level	Classification of Epistemic Viewing	Signal in relation to plants
Novice	Primary (Jacob and Jeannerod 2003).	Cues that vary and are dependent on external factors (Primary Cues) Examples: Color, smell, height
Intermediate	Secondary (Jacob and Jeannerod 2003).	Cues that are more in-depth, but can misrepresent or are unavailable at certain points. (Secondary Cues) Examples: seed head, flower

When exploring plant blindness under the dual lens of the MMHN and RTVM, we can begin to understand why plants may prove to be such a challenge. In fact, Matsumoto’s (2007) model may help to explain why mental representations of plants tend to lack detail, which helps to explain why plant blindness occurs and its root causes. To date, little research has been done to explore why people see plants in less detail than their animal’s counterparts. In order to provide some context for the current study, first it is necessary to explore relevant research studies in other, but related fields of cross-racial facial recognition and human figure drawing.

3.4.2. Cross-Racial Recognition

Findings in cross-racial facial recognition research has demonstrated that people's memories for faces of their own race are more accurate to their memories for other-race faces (Byatt and Rhodes 1998; Tanaka et al. 2004; Goodman 2007). The amount of experience has repeatedly been shown to be a crucial factor in cross-race recognition studies; however, it has been shown that quality, rather than the quantity, of cross-race contact that is important (Byatt and Rhodes 1998; Goodman et al. 2007). The mechanisms underlying the ability to only accurately recognize one's own race have not been well defined. In terms of primary and secondary epistemic cues (Table 4), this suggests that we are better able to identify and use the features of familiar faces to better glean meaning, or we are more equipped to identify the secondary and tertiary cues. However, with faces of people from unfamiliar races the brain is distracted by the primary cues of the face (i.e. size of nose, skin color, facial shape, hair) and is less able to see the subtler features that would allow a face to be accurately recalled (Tanaka et al. 2004; Goodman et al. 2007). Research conducted with Caucasian children and adults from the United States, Norway, and South Africa, as well as biracial (Caucasian–African American) children and adults living in the United States, were tested to determine how well they were able to distinguish differences in Asian, African, and Caucasian faces (Goodman et al. 2007). It was found that no matter the national or biracial background, 8 to 10 year-olds, 12 to 14 year-olds, and adults recognized own-race faces more accurately than faces of other races, but 5 to 7 year-olds recognized all face types equally. Biracial children and adults had similar tendencies (Goodman et al. 2007).

This may mean that during early childhood, developmental influences are plastic and, with the right conditions, may result in the ability to distinguish facial patterns of multiple races

(Goodman et al. 2007). In fact, it is suggested that individuals develop facial prototypes, or mental models through early life experiences (Mauro and Kubovy 1992; Matsumoto 2007). Most people are able to distinguish different faces through the subtle deviations from these early developed prototypes; however, faces of other races may deviate too much from the established prototype unless there have been multiple experiences with the faces of other races (Byatt and Rhodes 1998; Tanaka et al 2004; Goodman et al. 2007). Lack of experience reduces a person's ability to accurately see the subtle differences because the mind is distracted by the extreme differences in the facial pattern (Mauro and Kubovy 1992; Byatt and Rhodes 1998; Tanaka et al. 2004; Goodman et al. 2007). It could be said that similar prototypes may occur in other objects, such as plants. If a person has had little introduction to plants, it may be hard for them to decipher the subtle differences between species because their mental model for plant form is too simple.

In order to better understand how people process visual information about ecology and plants, we must first understand what cues they are consciously using when exploring in natural areas. This information can be used to better inform training and education programs. To determine what cues are needed to be taught, we first must know what cues the average human instinctually perceives. Cues, or specific characteristics of an object or person that are perceived, are prioritized by the brain based on the perceiver's life experiences. For this reason, two people can look at the same object and not focus on the same characteristics. In order to understand how cues are used and interpreted in plant identification we must first know: 1) what cues novice observers perceive consciously; and 2) what cues they may be using subconsciously. To identify the perceived cues, this research will focus on two activities: drawing and recall.

3.4.3. Human Figure Drawing

Drawing has long been used as a psychologist's tool for informing research about communication of cues or signs. Koppitz (1968) defines signs as a combination of items drawn by children that are indicative of specific developmental stages, and items are drawn objects are combined to form signs. Communication of these cues through drawing conceals many informed choices, judgments, intuitions, and assumptions about how the world works and the conversions of ideas to artifacts (Anning 1997). Moreover, drawing represents a translation or transposition of the actual world to a two dimensional form (Golomb 2004). Learning to decipher the drawer's choices is made more complicated because often the subject may not realize the choices they are making as they make them (i.e. they are made subconsciously) (Cox 1993).

Several studies have been conducted on the development of child drawing skills, and a fairly natural progression has been identified (Koppitz 1968; Cox 1993; Piaget 1999). Most of the research done to date centers on the psychological development of drawing the human body; however, this research provides a strong framework for examining other objects, such as plants (Kopptiz 1968; Cox 1993; Golomb 2003). Elizabeth Koppitz (1968) examined 1100 drawings from students ranging between pre-K to middle school aged, and was able to classify drawings based on a number of items. The following classification was used to determine what was normal for specific age ranges:

- Expected: items that occur 86%-100% in signs
- Common: items that occur 51%-85% in signs
- Not Unusual: items that occur 16% -50% in signs
- Exceptional: items that occurs >15% in signs

Koppitz (1968) did this by determining what items children were likely to include when drawing a human at specific age ranges. From this research, a language for discussing drawing emerges. Koppitz (1968) and Cox (1993) additionally demonstrated that children often indicate importance through indicators, items and/or signs that may represent student's emotional response and/or state of mind, by exaggerating/increasing or decreasing the size of the item relative to the other things present in the drawing.

Cox (1993) also interpreted Koppitz's stages in a new ways, as a set of expected drawn items combined into a sign for a specific age group. Those stages are as follows:

- Scribbling: unrecognizable marks (items), produced by unplanned and uncontrolled movements.
- Distinct forms: marks begin to show signs of purpose and begin to take on distinct and identifiable shapes
- "Tadpole": Large circle head with legs and possible arms all attached to the head.
- Transitional: Large head with longer legs and torso is indicated between the legs and arms are attached to the legs.
- Complete Representation of the human figure: Torso is present with arms and legs coming from the torso in relative appropriate places.

It is suspected that similar stages would be found in drawings of different objects, such as plants. By modifying the methodologies of Koppitz (1968) and Cox (1993), this study looks to determine whether plant drawings follow similar patterns to those identified in human figure drawings.

3.5. Methods

3.5.1. Preliminary Efforts

Data was collected during an established, curriculum-based field trip with all third grade classes from an at-risk Minnesota school district with over 300 students. The programming consisted of two field trips, one in the fall and one in the spring of the academic year. In an attempt to gain insight to cues students may be using to re-identify plants, a recall activity was done in fall 2012. During this activity students assembled into groups of three to five, went back into the prairie, and found one plant from the morning hike that they were able to confidently identify. Once students found an example of a plant they felt comfortable identifying, they collected a portion of that plant, and indicated the plant's name on a piece of card stock provided. Both the plant and the indication card were placed in a Ziploc bag. Plant samples and identification cards were analyzed by determining whether students chose to draw a grass or forb and on correctness. In addition, when identification was incorrect, the similarities between the plant collected and the plant indicated was considered in order to determine what cues the student was using to make their identification and how those cues may have lead them astray.

3.5.2. Plant Drawing

Based on the recall activity results, drawings were completed as part of the field trip forest and woods hike in 2012 and part of the fall and spring hikes in 2013. The students were asked to draw grasses in fall 2013 as part of an in situ plant measuring activity. In the spring, again students were asked to draw a plant in situ, this time the activity was utilized as part of the hike. In both cases, students were within a meter from the plant they were drawing and had ten to fifteen minutes to draw. A specific plant was pre-determined by the researcher for the student drawing activity. Plants were selected based on the following criteria: 1) it was emerged and in

bloom (if applicable); and 2) there was enough of the plant in a given area for 25 third graders to each find their own plant. The plants were either found in the forest or on the prairie, preference was given to prairie plants. Students were given a brief introduction to the plant, clipboard with a blank sheet of paper, and a black sharpie pen. After the introduction, students were given the following prompt:

After you leave today, I am going to come back and use your drawings to find the same plant that you looked at today. Can you draw a picture for me that would help me find the same plant that you are looking at again?

They were also instructed that they could use words in their drawings if they wanted. Drawings were collected at the end of the timeframe and any identifying marks were removed.

3.5.3. Prototype Drawings

During spring 2014, students were brought into an auditorium prior to any outdoor exploration and asked to complete “prototype” drawings. Prior to exposure to the natural flora, students were given a drawing notebook and asked to turn to a blank page and section it into quarters. In the upper left hand section, students were asked to “draw the first thing that comes into your mind when I say the word ‘plant.’” In the upper right, students were asked, “please draw the first thing that comes into your mind when I say the word ‘flower.’” In the lower left section students were asked to “draw the first thing that comes to your mind when I say ‘grass.’” The lower right corner students were asked to “draw the first thing that comes to your mind when I say ‘tree.’” Students were told that it was appropriate to have similar looking drawings for “plant” if they thought and drew the same thing for “plant” as they did for “flower”/ “grass”/ “tree.”

3.5.4. Drawing Analysis

The Koppitz (1968) Framework is a psychological tool that utilizes the Human Figure Drawing test (HFD). The HFD can be administered as a group test or as an individual test, however individual is preferred since it enables the researcher to observe the child while they work and permits the child to ask clarification questions about the figure if it is needed (Koppitz, 1968). When administering the HFD Test according to protocol, the researcher should seat the child comfortably at an uncluttered space and provide them with a blank sheet of paper sized 8 ½ “ X 11” and a pencil with an eraser (Koppitz, 1968). The researcher then asks, “on this piece of paper I would like you to draw a WHOLE person. It can be any kind of person and not a stick figure or a cartoon figure (Koppitz, 1968).” In interpretation of the HFD, a variety of HFD signs are believed to be related to the child’s age and level of maturity. These signs are called developmental items (Koppitz, 1968). Some examples of developmental items presented by Koppitz are: head, neck, body, fingers, correct number of fingers, feet, feet two-dimensional, and good proportion (Koppitz, 1968). The HFD was given to 1,856 elementary school students aging from 5-12, and a baseline of normal or of what can be “expected” at each age was determined (Koppitz, 1968).

During the current project, the Koppitz (1968) framework was adapted to code the plant drawings. First the drawings were assessed based on what students chose to represent when free drawing a plant. Lists of all features that appear in the collected drawings were produced; for example, students may choose to draw stems, a leaf or leaves, and flowers. All of this information will be used to help identify what features could be expected in a plant drawing done by a third grader. The drawn features were classified into categories based on how likely it was that a child was to include that item in their drawing. The categories used were: Expected (86-

100%), Common (51-85%), Not Unusual (16-50%), and Exceptional (15% or less) based on Koppitz (1968). Natural breaks appeared in the number of signs students communicated through drawings (tables 5, 6, 7 in Results and Discussion sections). From there, a baseline of items that research can confidently expect the student to represent in plant drawing at ages 8-10 (third grade level) was determined. All drawings were coded and categorized based on the number of items that the drawer chose to represent. The items were compiled and used to establish rubrics will be used for consistency in coding and the testing of inter-rater reliability in follow up research studies (Appendix B). Drawing totals for each plant is included with the respective table (tables 5, 6, 7 in Results and Discussion sections). Basic Statistics were used to create the drawing totals, and sign percentages were determined by dividing the number of drawings a particular sign occurred in by the number of total drawings.

3.6. Results and Discussion

3.6.1. In Situ Drawings

Psychological evidence suggests that, unless an adult is trained to pay attention to more details, third grade observational data would be representative of novice observational data from older age groups as well (Kopptiz 1969). Students were asked to draw plants while directly observing them in a nature area. Each classroom was only asked to draw one specific plant. Through the course of the field trip season, three plants in total were used for the drawing activity, poison ivy (*Toxicodendron radicans*), wild leek (*Allium tricoccum*), and bloodroot (*Sanguinaria canadensis*). Each plant was selected for specific reasons: poison ivy due to the dangerous potential, wild leek due to simplicity and edibility, and bloodroot for the daisy like flower and unique root structure. Poison ivy drawings (n= 186) had a total of fourteen signs that were represented. Wild leek (n=189) had a total thirteen signs represented. Bloodroot (n=168)

had a total of seventeen signs represented (Tables 5, 6 and 7). Of these represented signs, only two items could be *expected* in student drawings of bloodroot and poison ivy, stem and leaves. In wild leeks stem and leaves were the only expected signs to be drawn, but in addition leaves could also be expected to be drawn symmetrically (Table 6). Thus it can be expected that most people would notice a plant's most prominent features, stem and leaves, but potentially ignore the patterning of the plant's structure

This phenomena mirrors cross-racial facial recognition, and the observers focus on primary cues rather than more subtle ones (Tanaka 2004). Potential evidence for blindness of plant structure emerged from several drawings that included unanticipated and inaccurate additions to the plant. In bloodroot drawings, 21.5% of students added inaccurate extra leaves. Similarly, in drawings of wild leek and poison ivy about 3% added inaccurate features (i.e. flowers and thorns) (Table 5 and 6; Figure 8). The addition of features, despite their absence in the actual observed plant structure, suggests that something may be impeding student's ability to see plants accurately and could be evidence for an inaccurate and simplified mental model of plant structure.

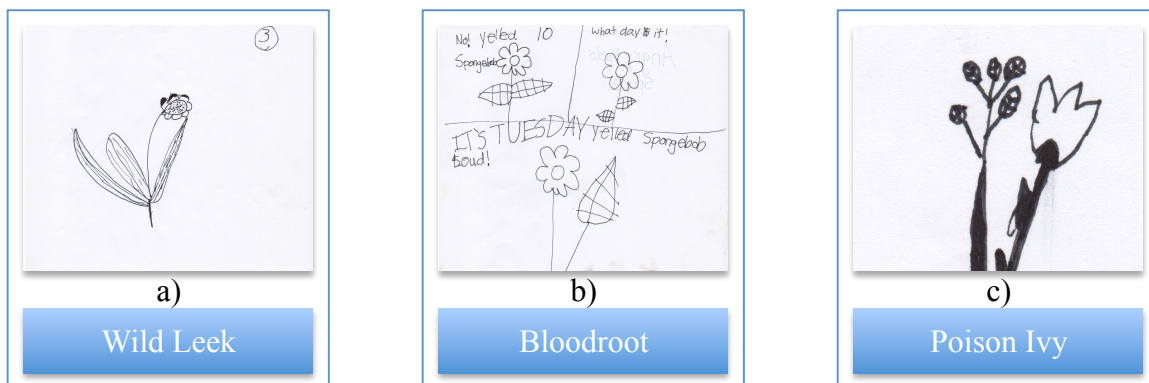


Figure 8. Inaccurate representations of wild leek (a), bloodroot (b), and poison ivy (c).

Table 5
Poison Ivy Data Breakdown (n=186)

Classification	Sign	# of Occurrences	Occurrence
Exceptional (0-15%)	Leaf Scars	9	4.86%
	Asymmetry	9	4.86%
	Accurate Venation	25	13.51%
Not Unusual (16-50%)	Woody Stem	39	21.08%
	Accurate Branching	42	22.07%
Common (51-85%)	Branching	107	57.84%
	Venation	110	59.46%
	Accurate Leaf	121	65.41%
	Clustered Leaves	144	77.42%
Expected (86-100%)	Stem	184	98.92%
	Leaves	184	98.92%
Inaccurate	Thorns	2	1.08%
	Flowers	6	3.23%
Unseen	Roots	14	7.53%

Table 6
Leak Data Breakdown (n=189)

Classification	Sign	# of Occurrences	Occurrence
Exceptional (0-15%)	Accurate root structure	0	0%
	Roots		
	Accurate Venation	15	8.11%
	Color Variation	16	8.65%
Not Unusual (16-50%)		19	10.27%
	Venation	53	28.65%
Common (51-85%)	Stem	93	50.27%
	Dagger Shape	93	50.27%
	Branching (clear)	123	66.49%
Expected (86-100%)	Leaf symmetry	161	87.03%
	Accurate Leaf #	167	90.27%
	Leaves	185	100%
Inaccurate	Leaf Serrations	4	2.17%
	Flower	7	3.78%

Table 7
Bloodroot Data Breakdown (n=168)

Classification	Sign	# of Occurrences	Occurrence
Exceptional (0-15%)	Accurate Venation	13	8.23%
	Color Variation	17	10.76%
	Accurate root structure	19	12.03%
Not Unusual (16-50%)	Branching	27	17.09%
	Accurate stem #	34	21.52%
	Venation	36	22.78%
	Root	47	29.75%
	Accurate leaf shape	74	46.84%
Common (51-85%)	Accurate flower shape	88	55.70%
	Leaf symmetry	89	56.33%
	Large leaf	101	63.92%
	Accurate leaf #	105	66.46%
	Flower	131	82.91%
	Accurate flower #	131	82.91%
Expected (86-100%)	Leaf	146	92.41%
	Stem	155	98.10%
Inaccurate	Extra Leaves	34	21.52%

3.6.2. Prototype Drawings

In order to explore potential reasons for addition of inaccurate features, drawings of plants that were completed in a classroom setting without any introduction or lecture were used to determine what mental models may look like and to determine if there was any prevalent form that arose in the study population. Students were asked to draw their interpretations of plants, flowers, grasses, and trees (Figure 9); 62 random drawings were selected for coding.

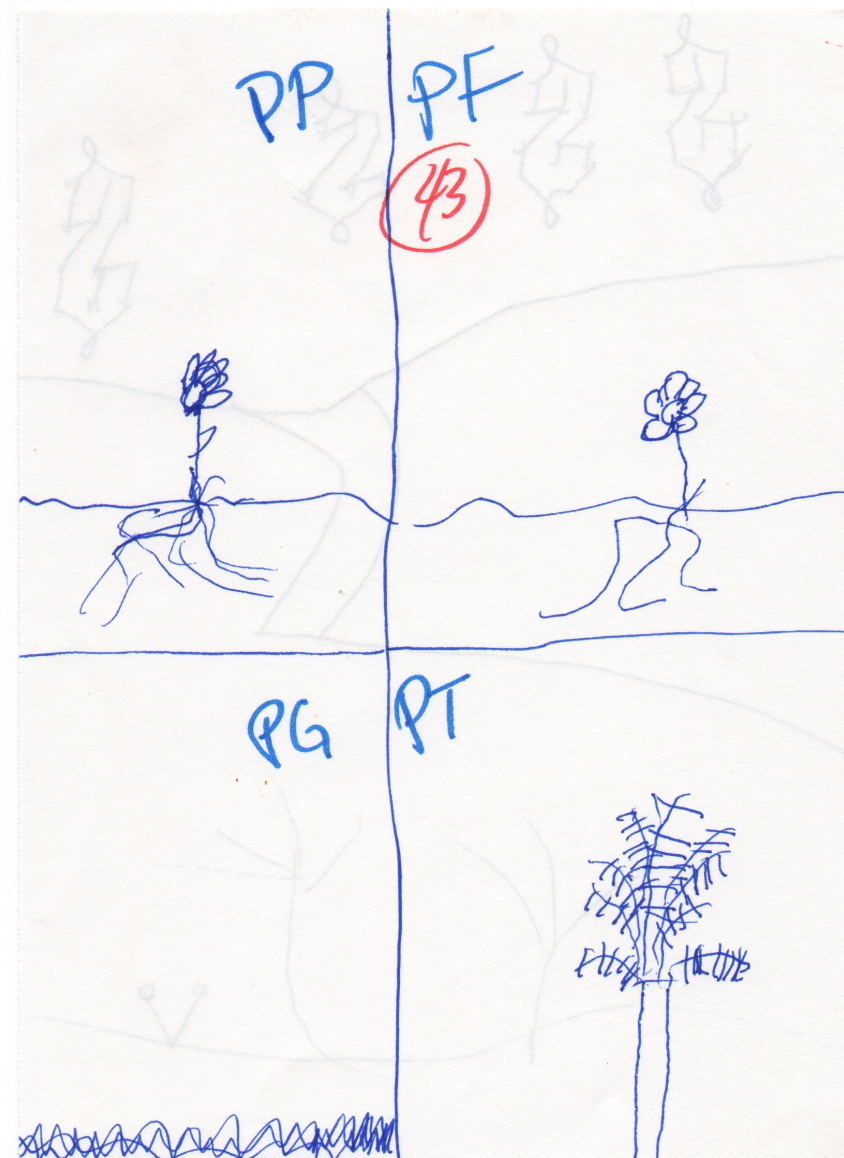


Figure 9. Example of prototype drawings. PP= Plant, PF= Flower, PG= Grass, PT= Tree

Sixty-eight percent of students chose to draw a flower when asked to draw their idea of a “plant” (Table 8). Of the student that chose to draw flowers when asked to draw a “plant,” 77% chose to draw the flower-form of a daisy. Intriguingly, in poison ivy and wild leek the most commonly added inaccurate feature was the presence of a flower, either a tulip or daisy form (Figure 9).

Table 8

What is a Plant Drawing Responses

Type of Plant Drawn	% of Drawings
Flower	68%
Grass	15%
Tree	11%
Other	6%

Table 9

What is a Flower Drawing Responses

Flower Form	% of Drawings
Tulip	17%
Daisy	43%
Rose	5%

When students were asked to draw their idea of “flower,” again an overwhelming percentage chose to draw a daisy form (43%) (Table 9). However, for both “plant” and “flower” drawings, there was not a statistically significant difference ($p > 0.05$) in whether student chose to draw a flower or not a flower or daisy versus not a daisy based on a t-test analysis.

Tree drawings had the most variety in their added features, but overwhelmingly deciduous trees were represented (99%); however, a majority of the deciduous trees drawn consisted of a trunk or stem with a large cloud or shaped crown (82.2%). This representation was determined in the study to represent a mass generalization of leaves and branches clustered at the top of tree (Table 10). Within the limited conifer representations, the branches and needles were generalized into a triangle shape on top of a rectangular shaped stem. While more studies are needed to draw any substantial meaning, it would appear that the third graders in this study had a common mental model of “tree,” and it is highly deficient in detail. The multitude of features chosen to be included with tree drawings may be a result of the many anthropogenic uses of

trees, and may demonstrate a conscious or unconscious attempt by the students to indicate uses they are familiar with or experiences they have had with trees. Often if animals or houses were included in the drawings they had more detail included than the tree itself (Figure 10).

Table 10
What is a Tree Responses

Type of Tree Represented	% of Drawings
Deciduous	98.4%
Coniferous	1.6%

Features Included	% of Drawings
Stem	98.4%
Leaves/Leaf	9.6%
Flower	1.6%
Roots	6.4%
Large cloud shaped crown	82.2%
Fruit	24.1%
Seeds	1.6%
Animal hole	13%
House/bird house	3.2%
Branches	41.9%



Figure 10. Tree representation with an animal addition.

If this is true, it might suggest that trees are seen in terms of the benefit that their structure and by-products provide to humans and animals rather than being seen as a living thing themselves. If amount detail is indicative of relative importance in the eye of the drawer, the simplification of the tree in comparison to the animal and anthropometric features included could be supporting evidence for Wandersee and Schussler's (1999) claim that plant blindness people see plants as background and less important than animal or human uses.

Grasses were drawn with the least amount of detail, and of the 62 drawings, 87% only drew one sign and the remaining 13% only drew two signs. Again, stem and leaves were prevalent, but rarely included together in drawings of grass (Table 11). In other words, students represented grass as either a "stem," indicated as a single drawn line or series of lines, or a leaf, indicated a by a triangular shape or series of triangular shape.

Table 11
What is a Grass Responses

Features Included	% of Drawings
Stem	61.2%
Leaf	40.3%
Flower	1.6%
Seed	8.1%

The lack of detail in the grasses was particularly interesting because the student drawings used in this study were completed as part of a two-phase field trip series (described earlier), and the drawings analyzed for the presence of mental models were completed in the spring of the academic year. The fall field trip took the students on a mile-long hike through the tall grass with the specific purpose of introducing students to grassland ecosystems. As a part of this field trip students were asked to identify seed dispersal methods on a variety of plants (both grasses and forbs), they collected grass seeds for planting, and were asked to draw and measure 6-10 different species of grass. Despite this intimate interaction with grass and grasslands students still did not include seed heads or reproductive parts of grasses in their drawings, and these drawings had the lowest number of signs collectively represented.

In fact, none of the drawings included all of the features deemed important in identification by common field guides (Stevens 1963; Shirley 1994; Williams 2010). Most drawings focused heavily on the primary cues (leaves and stems). These findings are similar to the studies done in cross-racial facial recognition. Similarly to recognizing the patterns of faces of different races, seeing the differences in other objects such as plants may prove difficult because the experience with those types of patterns are not familiar (Matsumoto 2007; Tanaka 2004). Despite having some experiences with a variety of plants it may take multiple

experiences, preferably at an early age (prior to age seven), to have enough of an impact to engrain the ability to differentiate of plant species.

The interpretations of the third grade drawings supports the claims of the Matsumoto (2007) model, the more experiences with an object or concept the more detailed and useable the mental model. In addition, when considering the situational context was novel for the majority of the students, the ability to focus on a specific plant may have been reduced due to the lack of experience in nonurban areas. Outreach and fieldtrip research has shown that the more familiar a child is with an area, the better they are able to learn in that environment (Orion and Hofstein 1994). Orion and Hofstein (1994) go so far as to recommend that multiple experiences in the same space be used to increase student focus and learning. This suggests that one intimate experience in a natural area may not be enough to add detail to their mental models, because students are still at a point of exploration and less able to focus on the more subtle details. In addition, the similarity in many of the student prototype drawings may be linked to the urban school systems used in the study. The Matsumoto model suggests basic human nature, culture, and personality would account for differences in student performance behaviors, but new situations may evoke a more similar response from all students, with similar experience levels, regardless of personality or culture (Matsumoto 2007). Since all the students used in this research originated from one school district, it is likely that the majority of the students had similar experience levels in natural areas.

The potential overarching implications of this inability to see plants in detail, even after instruction designed to teach this skill, is potentially a reduced ability to see the value of individual ecosystems and decreased environmental literacy. If people are unable to see how one grass is different from another then they are less likely to notice that the grasses growing on the

sandy cliff are different from the ones growing in the valley. Without this knowledge it is unlikely that they will understand that different grasses fulfill different roles in the environment, thus decreasing their environmental literacy and their ability to see the diversity of plant life in an ecosystem. If diversity cannot be seen, then the difference between monocultures (large areas occupied by a single plant) and heterogeneous mixes (areas with a mix of a variety of plants) is lost, and the importance of diverse plant communities, which are needed for ecosystem resilience, is also lost (Biggs et al. 2012). Therefore, a better understanding of what environmental mental models are in play in the population are needed to better inform education and outreach efforts. Results of this study need to be verified with further studies in other areas outside of the Midwest/Red River Valley. In addition, it needs to be expanded to target additional ethnic groups that may have closer ties to the environment, such as tribal communities, to see if the hypothesized mental models and simplification is wide spread or unique to the study's region.

3.7. Conclusions

It is hypothesized that humans use different cues when asked to draw versus collect plants (e.g. view versus touch), which is a suggested future direction for plant blindness research that may begin to unlock doors for improving environmental literacy. Based on the preliminary study, it is suspected that drawings will present a different set of signals/signs than if participants were asked to recall plants with in a community. The findings in this study suggest that there may be a common and over simplified mental model for plants, and this simplified mental model reduces people's ability to see and distinguish between plant species. Likely, due to a lack of experience with plants that would have facilitated the building of detailed mental models, people are unable to discern differences between plant species. This inability was consistent through all

third grade students surveyed and teachers. An inability to see plants may lead to a reduction in appreciation of varying plant communities and ecosystems.

This demonstrates that most students are not able to utilize more than a primary epistemic viewing level, but most experts go beyond a secondary epistemic viewing level. Therefore, it is argued that there is a third or expert level, tertiary epistemic viewing. At this level multiple cues are considered and dismissed or accepted in the information processing to understand the object or situation. This type of epistemic viewing would be characterized by an ability to consider multiple cues simultaneously and glean accurate information from them. For example, the neighbor’s car is in the driveway with the trunk open, bags of groceries in the trunk, and the front door is open; therefore the neighbor has recently returned home and has been shopping.

Table 12
Level, Classification and Signal with Addition of Expert/Tertiary Level

Level	Classification of Epistemic Viewing	Signal in Relation to Plants
Novice	Primary (Jacob and Jeannerod 2003).	Cues that vary and are dependent on external factors (Primary Cues) Examples: Color, smell, height
Intermediate	Secondary (Jacob and Jeannerod 2003).	Cues that are more in-depth, but can misrepresent or are unavailable at certain points. (Secondary Cues) Examples: seed head, flower
Expert	Tertiary	Cues that are available at most times during life cycle and tend to be relatively unique. (Tertiary Cues) Example: venation, leaf shape, hairs and hair density.

What the tertiary level provides is a way of approximating how far professionals working with plants and creating field guides are from the average population. This means the inherent value that an expert in plant ecology or botany sees in the world's multitude of ecosystems can not be fully understood or shared with the majority of the population.

If plant communities are not valued for their individual importance, then they may be seen as interchangeable or worse changeable, and the majority of the population may not value the biodiversity and provided ecosystem services. The origins of this phenomenon are yet to be identified, but the prevalence of cartoon daisy-like flowers and highly simplified trees in early childhood literature and textbooks may be partially to blame and may prove to be the source of the origin of plant models. More studies are needed to verify these findings.

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4. HOW USING A HIGH DENSITY OF NATIVE FORB SEEDS INFLUENCES PRAIRIE RECONSTRUCTIONS: LONGER TERM EFFECTS OF SPIKE SEEDINGS

4.1. Abstract

The North American prairies were diverse and charismatic ecosystems that have been greatly reduced over the course of the development of agriculture and urban activities. Past studies have shown that reductions in grassland plant richness leaves the ecosystem vulnerable to invasions by non-native plant species, and the loss of basal species may greatly impede the integrity and functioning of grassland ecosystems. These concerns move to the forefront of ecological concerns as the world faces new threats and disturbances, linked to climate change and other stressors. For these reasons, there has been a call for new approaches to establish and promote native plant communities. This study investigated the long-term impacts of using the spike seeding method for prairie restoration. It was found that in 2015 and 2016, five and six years post seeding, that the spike seedings had reduced Canada thistle (*Cirsium arvense*) cover compared to the non-spike, but both sites were below the action threshold. This study of the spike seeding method demonstrated the following results: 1) reduced Canada thistle establishment initially and longer term, 2) increased cover of the planted native forbs initially but this did not result in a spike species later dominating the plant community, 3) increased planted richness and diversity which is reflected in differences in the plant community. While the study did pick up some residual effects from the spike seeding six years post seeding, they were still positively correlated with the aforementioned results.

4.2. Introduction

Historically, the North American prairies were a diverse and charismatic ecosystem that has been greatly reduced over the course of the development of agriculture and urban activities.

Today, the prairies support everything from birds to butterflies and meadowlarks to mallards, and while invasive plant species can provide cover for a short period, native prairies are required to sustain these species in healthy populations for the long term (USFWS 2016). Studies have shown that reductions in grassland plant richness leaves the ecosystem vulnerable to invasions by non-native plant species, and the loss of basal species may greatly impede the integrity and functioning of grassland ecosystems (Knops et al. 1999). These concerns move to the forefront of ecological concerns as the world faces new threats and disturbances, linked to climate change and other stressors. Now more than ever, it is imperative to have the diversity provided by native prairies to sustain common and rare species for the foreseeable future.

The Northern Tallgrass Prairie has several pockets of intact native grassland, and a regional effort is in effect to connect those pockets with high quality prairie reconstructions to increase potential pollinator habitats and improve ecological services (Davis et al. 2008; USFWS 2016). High quality restorations are those that contain plant communities similar to those of native prairie remnants and provide important ecological services for both crop and native plants in many ecosystems and their conservation is essential to sustaining prairie remnants (Davis et al. 2008). By considering how space and time influence restoration, ecologists can begin to make predictions and develop strong methodologies that promote biodiversity in conservation projects (Brudvig 2011). In doing this, restoration goals are developed and met more reliably.

The ultimate goal of a restoration is to reliably restore ecosystems to areas that are resilient and resistant to disturbances and other stresses. However, traditionally, restoration methodologies have lacked documentation and resulted in unpredictable outcomes (Brudvig 2011). For this reason, researchers and managers have examined methodologies that would help make restoration outcomes more predictable. A common factor that may indicate restoration

success or failure often can be linked to the amount of planted and native species that emerge from the plantings, but also the amount of undesired species (Norland et al. 2015; Andrews 1990). Boiondini et al (2011) concluded that the invasion of non-seeded species into research plots decreased as planted species and functional form richness increased. This suggests that native seed mixes that have several native forbs at a high seed density added or “spike mixes” (Norland et al. 2013) would have the potential to promote native forb establishment at the expense of non-seeded species and reduce the potential for the planted community to be invaded as the restorations aged.

The reduction of a well-known exotic invasive species like Canada thistle (*Cirsium arvense*) in prairie reconstructions will require well-designed protocols to reduce thistle seedlings during the restoration establishment phase (Rowe 2010). In 2010 and 2011 the use of the “spike” seeding method was investigated as a means to reduce recruitment of Canada thistle from the existing seed banks (Norland et al. 2013). The spike seeding method utilizes a high density, 4-10 times the recommended seeding density (300 seeds/m²), of 3-5 native forbs that are in the same functional group as Canada thistle (Norland et al 2013). The functionally similar spike species were determined based on Biondini’s (2007) research, which measured nine quantitative functional traits for 55 grassland plants. These spike species are then added (spiked) to a native seed mix adapted to the site.

Norland et al. (2013) found that canopy cover of Canada thistle for small plot and large plot experiments with spike seedings had significantly lower thistle cover in the spike plots compared to plots seeded with the same native seed mix without the spike species (non-spike) for the first two years after seeding (Figure 11).

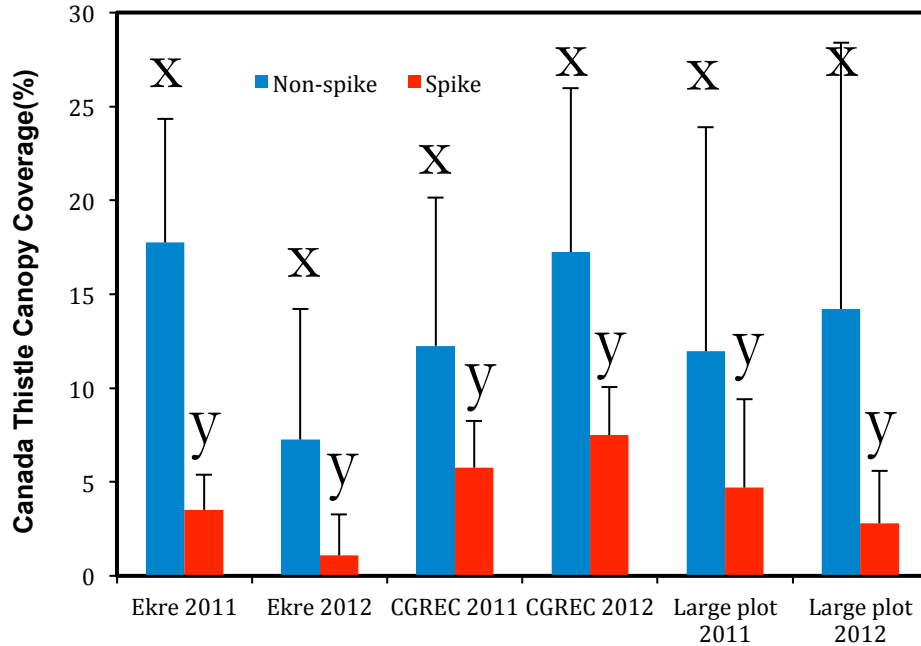


Figure 11. Percent canopy coverage (\pm 1SD) of Canada thistle. The small and large plots spike and non-spike treatments for the first two growing seasons after planting (GREC is Central Grassland Research and Extension Center) (different letters denote significant difference $p < 0.05$) (Norland et al 2013).

In the first two years, the study demonstrated how spiking a typical seed mix reduced Canada thistle establishment (Norland et al. 2013). It is suspected that both symmetrical and asymmetrical competition mechanisms led to the success of the spike seedings. The proposed mechanisms are:

- Symmetrical competition: Interspecies competition from the spiked species rooting and uptake systems had similar characteristics to Canada thistle.
- Asymmetrical competition: the fast establishment allows for an unequal division of resources between individuals and species (Freckleton and Watkinson 2001).

The high seed density and the two forms of competition then likely produced a competitive environment that restricted the establishment of Canada thistle (Norland et al. 2013).

Besides the reduction in Canada thistle cover, the planted native forb cover was significantly higher in the spiked plot (50%) compared to the non-spike plots (8%) the second growing season (unpublished data). This result was not surprising given the high seed density of the spike species. Norland et al. were uncertain as to how the high density of spike species would affect the eventual reconstructed plant community, since it created a high cover of native forbs. It was speculated that spiked native forbs would reduce in dominance with normal successional forces resulting in a diverse native plant community similar to high diversity prairie reconstructions (Norland et al. 2013). Those original experimental sites used by Norland et al along with three additional sites seeded the same way a year later were sampled during years five to seven after planting to determine:

- 1) Whether the spike species had impacts on the establishment of other native species;
- 2) Whether spike species either dominate or have reduced cover over time; and
- 3) Whether there were any residual effects from the spike seeding.

4.3. Methods

Seven different sites were used in the study. Four sites were part of the original study (Norland et al. 2013) and an additional three were brought into the study. All the sites were on US Fish and Wildlife (USFWS) lands. Five sites were on Waterfowl Production Areas located in the Madison Waterfowl Management District: Alquire, Clear Lake, Halverson, Ramsey North and Ramsey South (Minnehaha County and Kingsbury County, SD), one site was on the Tewaukon National Wildlife Refuge (Sargent County, ND) and one site on a Waterfowl Production Area in the Valley City Waterfowl Management District, Fullers (Steele County, ND). Each site had a spike seeded area and non-spike seeded area and was treated as paired plot

design. The size of the paired plots were not equal but the area of the spike seeding was not less than 1.5 hectares, with the average area of the spike plantings being 2.8 hectares and the non-spike 3.2 hectares.

The native species selected for the spike mix were identified to have similar functional traits as Canada thistle (Biondini 2007) though other species were used for the spike seeding given availability (Table 14). The spike mix densities ranged from 900 to 3000 seeds per m² (90 to 300 seeds per square foot). The non-spike seeding averaged around 300-600 seeds per m² (30-60 seeds per square foot). The number of native species and the species used in the non-spike seeding varied and was under the control of the USFWS managers. The non-spike seed mix for the different sites ranged from 23 to 39 total species with grass species making up 8-11 species (see Table C1 for a list of species used in the non-spike seed mixes).

The canopy cover of each species was estimated in late July and early August of 2015 and 2016. Canopy cover was measured using ocular estimation to the nearest percent in m² frames. Sample frames were arranged in a transect with four frames being 10 m apart. Transects were placed within the plots in a restricted randomization method. This method divides the plot into equal units and within those units the transect was randomly placed. At least two units were delineated in each plot with the larger plots having three units. To ensure consistency the same observer was used to estimate cover in both years.

Table 13

List of Sites with Latitude and Longitude Coordinates, along with the Native Species Used as the Spike Species

Spike Sites	Lat, Long. Coordinates	Spike Species
Clear lake, seeded 2010	43.765299° -97.005405°	<i>Dalea purpurea</i> , <i>Verbena stricta</i> , <i>Achillea millefolium</i>
North Ramsey, seeded 2011	44.190965° -96.964345°	<i>Rudbeckia hirta</i> , <i>Achillea millefolium</i> , <i>Coreopsis tinctoria</i>
South Ramsey, seeded 2011	44.188203° -96.967476°	<i>Rudbeckia hirta</i> , <i>Achillea millefolium</i> , <i>Coreopsis tinctoria</i>
Alquire, seeded 2011	44.188444° -96.977165°	<i>Rudbeckia hirta</i> , <i>Achillea millefolium</i> , <i>Coreopsis tinctoria</i>
Halverson, seeded 2010	44.403952° -97.524779°	<i>Dalea purpurea</i> , <i>Verbena stricta</i> , <i>Achillea millefolium</i>
Tewaukon, seeded 2010	46.006056° -97.351056°	<i>Rudbeckia hirta</i> , <i>Dalea purpurea</i> , <i>Coreopsis tinctoria</i> , <i>Ratibida columnifera</i>
Fullers, seeded 2010	47.301605° -97.582735°	<i>Helianthus maximiliani</i> , <i>Dalea purpurea</i> , <i>Rudbeckia hirta</i>

4.4. Analysis

The canopy cover was averaged over the transects within the plots for analysis. A paired t-test was used to test if spike and non-spike plots at the same sites were different for vegetative categories, richness and Shannon diversity. The plant community analysis used PERMANOVA as implemented in PC-ORD (McCune and Mefford 2011) to test the differences between the spike and non-spiked plantings (Anderson 2001). A randomized block design was used in the analysis. The Nonmetric Multidimensional Scaling (NMS) analysis was used to produce a graphical representation of the data. The analysis followed the setup used in PC-ORD. Only two axes were chosen based on a significant randomization test and where axes had to reduce the final stress by more than 5 based on a 0-100 scale. A successional vector was used to connect paired plots at each of seven sites. The relative Sorensen index was used in the NMS and

PERMANOVA analysis. The percent canopy coverage was arc-sine square root transformed before analysis.

4.5. Results

4.5.1. 2015 Analysis

Four and five years after planting, Canada thistle cover was lower in the spike plots compared to the non-spike ($p=0.01$), but the absolute cover thistle level in both treatments was low and below the level needed for action (non-spike 8.5% vs. spike 3.6%) (Table 14). The USFWS determines that a cover of 10% or more is needed to trigger control measures for a noxious weed (Norland et al. 2013). The values for the relative cover of the spike species (Table 15) had Halverson and Tewaukon with the highest cover level for spike species. However, only in Halverson did the spike species contribute more than half to the total planted forb cover. There was no significant difference between spike and non-spike plots in terms of planted forb cover ($p=0.08$) (Table 16). The planted relative cover (combined grasses and forbs) is different with the spike having higher levels ($p=0.03$) (Table 17).

Table 14
Percent Canada Thistle Cover in 2015 by Site

Site	Spike	Non-spike
Alquire	5.3	9.8
Clear lake	2.0	3.5
Fullers	1.4	0.6
Halverson	5.5	15.5
Ramsey North	3.5	14
Ramsey South	2.7	7.7
Tewaukon	5	8.9
Mean cover	3.6	8.6

Table 15

Relative Percent Spiked Forb Cover in the Spike Plots for Each Site in 2015

Site	Percent spike cover
Alquire	1.1
Clear lake	7.1
Fullers	8.4
Halverson	15.0
Ramsey North	2.2
Ramsey South	1.1
Tewaukon	15.4

Table 16

Relative Percent Planted Forb Cover in 2015 for Each Site

Site	Spike	Non-spike
Alquire	8.0	6.3
Clear lake	33.6	29.4
Fullers	28.9	21.5
Halverson	18.3	1.9
Ramsey North	9.8	9.1
Ramsey South	12.4	10.0
Tewaukon	34.5	35.3
Mean cover	20.8	16.2

Table 17

Relative Percent Planted Cover in 2015 for Each Site

Site	Spike	Non-spike
Alquire	31.9	33.1
Clear Lake	80.0	80.8
Fullers	69.0	48.8
Halverson	54.2	41.4
Ramsey North	63.1	47.2
Ramsey South	69.3	58.8
Tewaukon	77.2	75.2
Mean cover	63.5	55.0

The PERMANOVA analysis found that the plant community was not significantly different between the spike and non-spike though the p value was 0.058 (Figure 12).

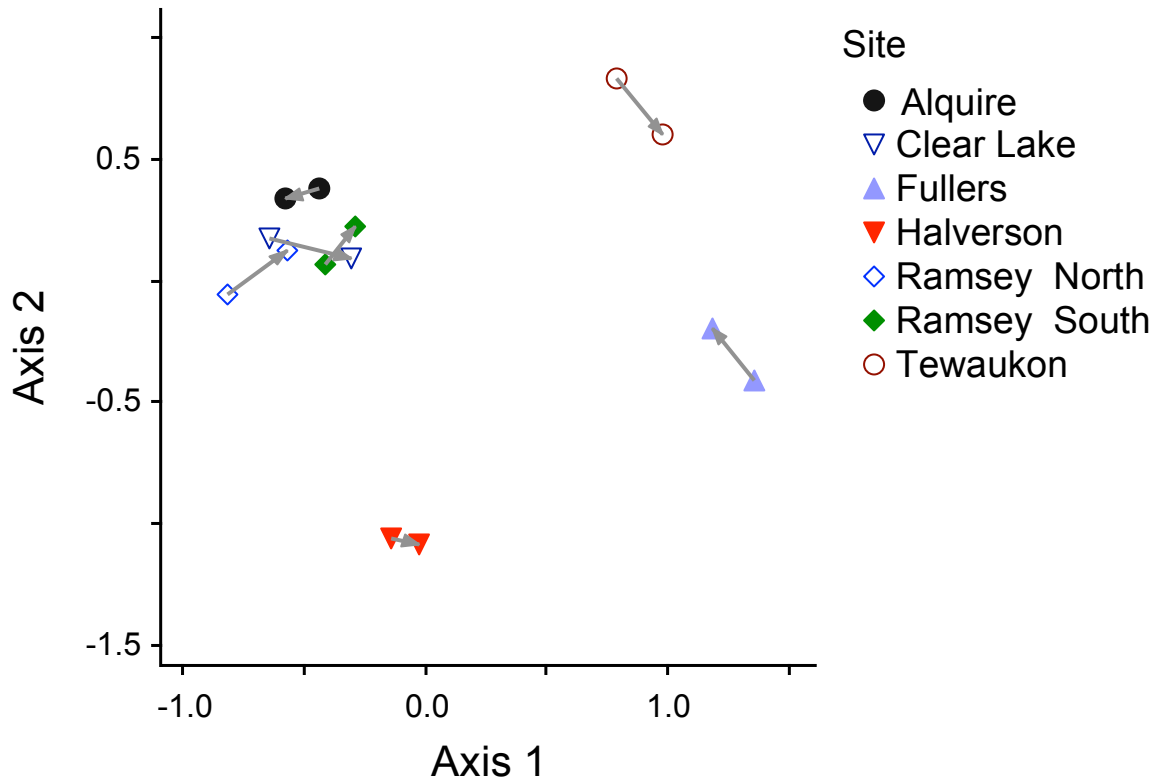


Figure 12. Graph of the NMS analysis for the 2015 non-spike and spike plant community data showing the 7 sites. Directional arrows connect spike and non-spike treatments in a site. Axis 1 explains 55.6% of the variability and Axis 2 explained 20.6%. Cumulatively, 76.1% of variation is explained by the model.

4.5.2. 2016 Data Analysis

All 2016 canopy cover data were relativized except Canada thistle cover because of the high amount of cover due to the grasses at most of the sites growing as high as 1.5 m tall. Six and seven years post seeding, canopy cover of Canada thistle was significantly different between the spike and non-spiked plots ($p = 0.001$) (Table 18). The Canada thistle cover in the non-spike

plots was at 10% or more for four of the seven sites in 2016 which is at the action level for a noxious weed. Only one spike plot was at 10% in 2016. Five of the seven sites had low levels of spike species cover (Table 19). The Fullers site joined with the and Halverson site with higher spike cover, different from 2015; but just like 2015, only Halverson had spike species contribute more than half to the total planted forb cover. As in 2015, relative forb cover was not different between spike and non-spike plots ($p=0.50$) (Table 20). Likewise, the relative planted cover was not different between spike and non-spike ($p=0.11$) (Table 21) which was different from 2015 when spike was higher than non-spike. In both years the relative planted cover averaged well over 50%. This level of planted cover meant that both spike and non-spike plots had established a dominant level of native planted cover.

Table 18
Percent Canada Thistle Cover in 2016 by Site

Site	Spike	Non-spike
Alquire	5.8	12.0
Clear lake	3.5	7.6
Fullers	0.7	3.3
Halverson	3.8	10.1
Ramsey North	10.8	19.5
Ramsey South	6.6	12.4
Tewaukon	3.8	5.2
Mean cover	5.0	10.0

Table 19

Relative Percent Spiked Forb Cover in the Spike Plots for Each Site in 2016

Site	Percent Spike Cover
Alquire	2.3
Clear lake	5.0
Fullers	11.7
Halverson	16.3
Ramsey North	2.0
Ramsey South	1.7
Tewaukon	7.3

Table 20

Relative Percent Planted Forb Cover in 2016 for Each Site

Site	Spike	Non-spike
Alquire	17.7	19.1
Clear lake	39.4	37.4
Fullers	38.3	35.5
Halverson	20.1	7.2
Ramsey North	32.9	17.5
Ramsey South	16.3	26.7
Tewaukon	31.9	36.1
Mean cover	28.0	25.6

Table 21

Relative Percent Planted Cover in 2016 for Each Site

Site	Spike	Non-spike
Alquire	73.7	59.5
Clear Lake	77.3	73.0
Fullers	71.3	66.8
Halverson	58.6	56.5
Ramsey North	70.4	51.7
Ramsey South	70.7	69.2
Tewaukon	71.2	76.4
Mean cover	70.4	64.7

The PERMANOVA analysis found that the plant community was significantly different between the spike and non-spike ($p=0.033$) with the Halverson site having the largest difference between the spike and non-spike (Figure 13). This result is different from 2015, though a combined p value for both years would be $p=0.01$ using the Fisher combined p value method (Gotelli and Ellison 2004).

Spike plot planted species richness was significantly higher for both 2015 and 2016 (2015, $p=0.008$; 2016, $p=0.008$) compared to non-spike (2015 spike 23 vs. non-spike 21; 2016 spike 19 vs. non-spike 16). Spike plot planted diversity was not significantly different in 2015 ($p=0.1$) (spike 2.3 vs. non-spike 2.0) while in 2016 diversity was significantly higher ($p=0.016$) (spike 2.4 vs. non-spike 2.2). The spike plots did not reduce planted species richness and diversity but instead promoted planted species richness and diversity.

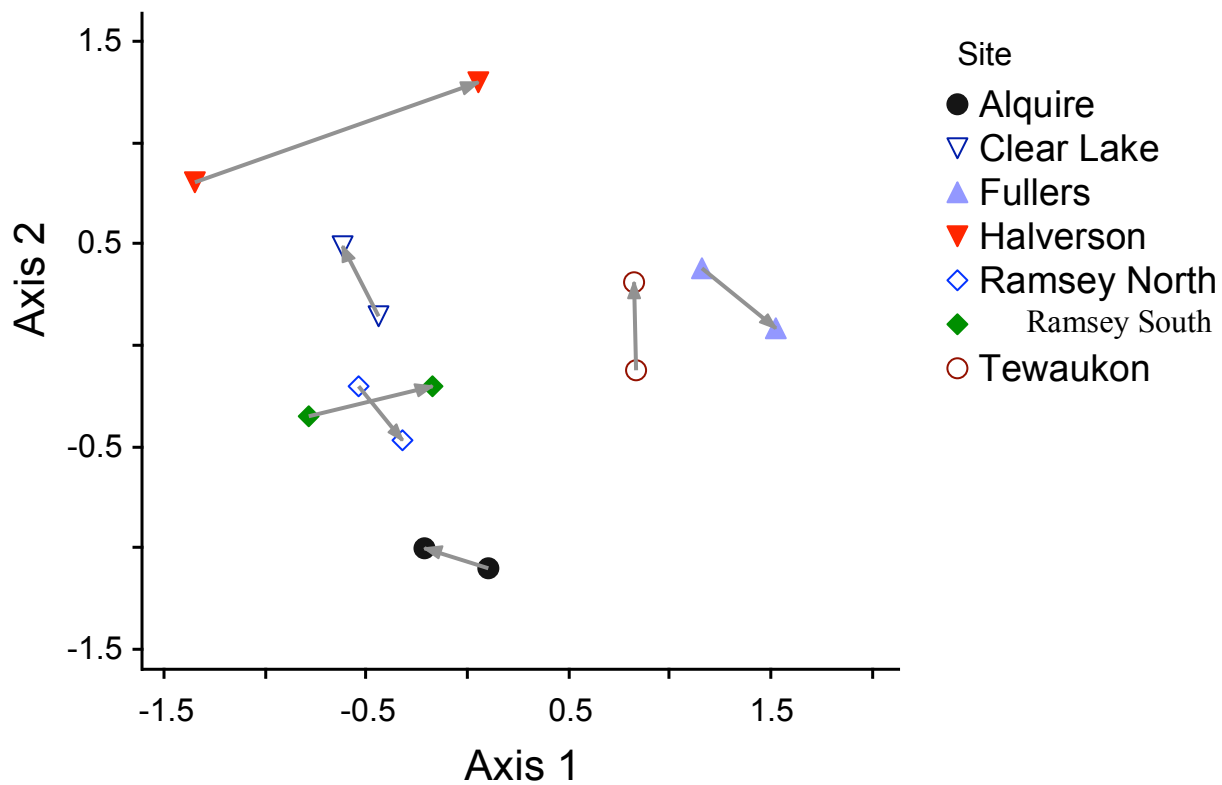


Figure 13. 2016 graph of the NMS analysis. Directional arrows connect spike and non-spike treatments for each site. Axis 1 explains 52.8% of variability, axis 2 explains 31.8%, and cumulatively 84.6% is explained.

4.6. Discussion

Ecological theory predicts that loss of biodiversity at the base of an ecosystem will impact the entire system (Knops et al. 1999; Funk et al. 2008). Therefore, well thought out conservation of our autotrophs and active efforts to restore our foundational native plants to areas where their populations have been reduced is imperative. A successful invasion of exotic plants is thought to work primarily due to a lack of natural enemies, and not because of novel interactions with their new neighbors (Callaway and Aschehoug 2000). It has also been shown

that exotic species increase the mineralization more rapidly than the native species can recalcitrant the litter in undisturbed areas, and once this process is initiated, the exotic annual litter may completely turn over organic matter and nitrogen, thus preparing the soil to the advantage of the exotic species (Zink et al. 1995). This suggests that once exotic and invasive species take hold, it can be challenging to restore native plant communities to a site. This can lead to dominance of invasive species such as brome and Kentucky bluegrass if an area is left idle for too long (DeKeyser et al. 2015, USFWS 2016). For areas that have been idle, reconstructionists need to constantly be on the lookout for new tools and tactics that may improve reconstruction and restoration success.

The findings of the present study suggest that a spike seeding is a potential powerful new tool for the reconstructionist tool kit. It was found that after five to seven growing seasons, the cover and establishment of planted native species was high in both the spike and non-spike plots. The level of planted native cover and establishment was greater than 50% on all plots which would be considered to meet the objective of creating an area dominated by native plants (Norland et al. 2015). The native forbs utilized in the spike seeding mixes that dominated the first two to three years, were no longer dominating the planted cover and were not even dominating the planted forb cover. The native species used in the spike had reduced to be another component within the planted cover, not the dominant planted cover. However, there are still some statistically detectable differences in plant community composition and planted species richness in both years between the spike and non-spike, suggesting that the spike has some lasting effects. Despite these residuals, the spike actually increases the chances of planted cover and richness being higher and there is little support that the spike species dominate the plantings;

therefore, the spike plantings do not inhibit the planting from meeting goals for a native prairie reconstruction.

The reduction in Canada thistle seen in the first years of the spike compared to the non-spike was still present five to seven years after. What has happened is that the non-spike cover of Canada thistle has been reduced so that in 2015 the plots were below the 10% cover level which is below the action level for the control of a noxious weed by the USFWS at those sites (Norland et al. 2013). In 2016 the Canada thistle did increase to where some non-spike plots were now above the 10% level of cover where action to control noxious weeds would occur. Such year to year variability in Canada thistle cover is not unusual and reasons for a one year increase are not well known (personal communication Cami Dixon, Dakota Zone Biologist, USFWS) (Larson et al. 2011). Therefore, even though there is an overall decrease of Canada thistle in the non-spike the continued effect of the spike on Canada thistle will reduce the need to consider control action on Canada thistle in most all years.

The reasons for the reduction in the spike species is more than likely linked to reintroducing the basal autotroph community back into the ecosystem. As the foundational plant communities return to landscape, species native to the region are better able to carry out their life functions. This would be supported by the findings of Danne et al. (2010), who found that indigenous cover crops had the potential to promote an increase in natural enemies providing fortuitous control of pest species and other ecosystem services. It is becoming clear that the services an ecosystem can provide are intimately link to the interaction the species within a community and if functional groups are not filled by native species, than invasive will move into the niche (Biodini et al. 2007; Funk et al. et al. 2008; McGill et al. 2006).

Besides increasing diversity and filling functional niches, the spike seeding utilized species that were annuals and short-lived perennials like *Coreopsis tinctoria* or *Rudbeckia hirta*. These species tend to naturally reduce their numbers over time as more high seral species in the seeding become established. Other more long-lived forb species like *Achillea millefolium* or *Helianthus maximiliani* can be reduced by pathogens (Mills and Bever 1998) or competition with native tall grasses like *Andropogon gerardii* (Funk et al. 2008, Dickson and Busby 2009). Other plantings have been shown to progress to plant communities dominated by high seral species, but what species become established is adjusted by filters and plant assembly processes (Grman et al. 2015). Since it was found that the species used in the spike method did not dominate the resulting plant community but reduced to more native-like distributions in the community is evidence those filters are present and do adjust the plant assembly.

Even though the spike species did not dominate the reconstructed plant community as originally speculated, there are lasting effects. These lasting effects are positively correlated with an increase in established native species. Spike seedings were positively associated with increased planted richness, diversity and cover all of which provide additional benefits to the reconstruction. These positive associations maybe linked to increased nitrogen fixation and in the soil and other soil conditioning from the forbs and grass that support decomposition processes, which conditions the soil for native species. The increased native species establishment translates into the spike method providing critical habitat development for pollinators and wildlife (USFWS 2016). Butterflies and other pollinators rely on many native prairie plants for food and reproduction, such as the Powershiek Skipperling (*Oarisma poweshiek*), which requires native prairie plants like the little bluestem and purple coneflower as nutrient or nectar sources (USFWS 2016). And for these reasons, the spike seeding is a strong tool for future restorations.

This study of the spike method lead to these beneficial results: 1) reduced Canada thistle establishment initially and longer term, 2) increased cover of the planted native forbs initially but this did not result in a spike species later dominating the plant community, and 3) increased planted richness and diversity which is reflected in differences in the plant community. Along with this long list of benefits, the spike also has the added benefit of providing forb patches for use by pollinator communities, which could provide a method to connect areas of native prairie to improve and increase pollinator habitat. In fact, the species utilized in the spike mix overlap with advertised pollinator seed mixes (Prairie Restoration Inc. 2016; USFWS 2016). In addition to adding habitat and cover for wildlife, the natural controls for invasive species has the potential to reduce herbicide cost, which leads to less staff time for wildlife managers spent on weed control.

4.7. References

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5. FUTURE RESEARCH

Moving forward in NRM communication, the use of backward design needs to be tested in other fields. Determining if backward design is usable in other fields would be a way to show the transdisciplinary nature of NRM and backward design. I would like to see backward design implemented in areas of engineering and business because the transferability of the communication model into these areas would show its applicability as generalizable communication model.

In outreach and education, I believe it is imperative to better understand the limitations that simplified mental models play in the way a person understands nature. To do this I think that the research done with third graders needs to be done with pre-K and early elementary school children, targeting ages three to seven years of age. It is important to do a categorical inventory of signs that signal environmental literacy in order to determine where the number of signs stabilize, and with this information we can better determine what age groups are appropriate to target in environmental education programming. In addition, work needs to be done on how to appropriately code drawings done of nature and the environment. To do this, I propose combining efforts with plant experts and elementary school teachers to develop rubrics that could be used for evaluating environmental education programming used in both classroom and outreach settings.

Lastly, to better understand the applied studies and how and why the spike seedings have higher diversity, studies on the changes in soil chemistry and microenvironment need to take place. The documented symbiotic relationships with forb roots and species of mycorrhizae are where I think future studies should begin. With an increase in forb root masses in the

reconstruction sites, it can be assumed that the mycorrhizae population likely increases as well, which may result in soil conditions that favor native species, both planted and in the seed bed.

APPENDIX A. A PRAIRIE RESTORATION GUIDEBOOK FOR NORTH DAKOTA

This guidebook will focus on *prairie reconstruction*, which is defined as the planting of a native herbaceous seed mixture composed of multiple prairie species (graminoids, forbs, and small shrubs) in an area where the land has been heavily cultivated or anthropogenically disturbed. This definition differs from *prairie restoration*, which focuses on utilizing treatments, like prescribed burning and grazing, to increase the biodiversity of native plant populations within *native prairie*, or land areas with no cultivation history. Reconstructing prairies on former cultivated areas provides opportunities to create sustainable and resilient grassland cover that reduces soil erosion and invasive species along with creating habitat for a variety of native wildlife. In addition, with proper planning, a reconstruction can begin the reestablishment of site ecological processes. Grassland ecological process include:

- the water cycle (capture, storage, and redistribution of precipitation),
- energy flow (conversion of sunlight to plant and animal matter), and
- the nutrient cycle (cycling of nutrients such as nitrogen and phosphorous through the physical and biotic components of the environment) (Pellant et al. 2005).

When ecological processes function within a normal range, they support grassland integrity. They are considered ecosystem drivers and provide a variety of feedback mechanisms to shift vegetative state (Pellant et al. 2005). Thus they are important considerations when planning prairie reconstructions and, when in place, can greatly improve an ecosystem's resistance and resilience.

Both resistance and resilience measures can provide insight to the overall health before and after reconstructions. Resistance is the ability of ecological processes to function with minimal change following a disturbance. Resilience is defined by the rate of recovery and/or the

extent of recovery during a specific time frame. Resistance and resilience provide a way of describing a grassland's ability to remain within the environmental normal range. However, resistance and resilience in a prairie reconstruction varies based on the current vegetative state. Therefore, metrics such as vegetation composition or production are often used as substitutes (Pellant et al. 2005). In the end, reconstructions are complex systems where ecological processes are difficult to measure. For this reason, it is important to develop a comprehensive plan and monitoring system for each reconstruction.

The purpose of this document is to provide land managers in North and South Dakota with a comprehensive overview of native prairie reconstruction practices needed to reach reconstruction goals and outcomes. We will place those practices into the conceptual framework presented by Laubhan et al.'s (2012) technical publication for the U.S. Fish & Wildlife Service, *A Conceptual Approach to Evaluating Grassland Restoration Potential on Huron Wetland Management District, South Dakota*. We describe methodologies for properly selecting and implementing best reconstruction practices to meet goals and address needs and promote ecological processes.

A.1. Preparing for Prairie Reconstruction

Preparing for a prairie reconstruction is a multi-phase process, which is dictated by the land history and goals determined by the land manager. Table A1 outlines the phases of the reconstruction process and the associated steps and goals. Careful consideration of each step, in terms of the reconstruction goal, creates the strongest opportunities for success.

Table A1
Planning Phases

Phase	Steps	Phase Goals
Planning	Setting Goals & Determining Outcomes Site Selection	The planning phase determines where the reconstruction will take place, timeframe and the objectives that will drive the application and implementation phase.
Application	Site Preparation Seeding Establishment	The application phase brings the reconstruction into action by directly applying predetermined methodologies for site preparation, seeding and invasive species control.
Implementation	Post Establishment Evaluation - Monitoring & follow-up	The Implementation phase actualizes the management and evaluation protocols, providing plans for on-going monitoring.

A.2. Planning Phase

The project goals and objectives should align with the spatial and temporal scales, along with abiotic and biotic factors. Reconstruction protocols should be developed in the planning phase, in order to understand achievement potential of goals and outcomes.

A.2.1. Step 1 - Setting Goals and Determining Objectives

Developing plans for prairie reconstruction involves creating “clear and unambiguous” goals and objectives (Laubhan et al 2012). *Goals* are defined, by Laubhan et al. (2012), as “general descriptions” or guidelines of optimal post-reconstruction conditions. In order to determine whether or not goals have been met, the project relies on *objectives* and *strategies*. Objectives articulate clear and measureable short-term targets to be reached by a specific time (Laubhan et al. 2012). Strategies are the actions, tools, or techniques used to achieve the

objectives. Wark et al. (undated) suggests that reconstruction objectives should be set based on the intended purpose, management needs, longevity of the reconstruction, and as a method of weed control (Cramer 1991; Berger 1993; Jacobs and Sheley 1999). Therefore, the objectives should be determined after the overarching goals are agreed upon. The goals will then inform the objectives and timeframe needed to successfully complete the project. Simply stated, as a reconstruction project plan is created, it is imperative to identify the desired results; second, to determine how to collect acceptable evidence of desired results and; lastly, to apply appropriate management and evaluation practices. Figure A1 defines goals, objectives, and strategies while Figure A2 provides example goals, objectives, and strategies highlighting timeframes and measures. Considering the vast changes that prairie landscapes have incurred since European settlement, prairie reconstruction goals, objectives, and strategies should focus on the desired results for a specific site, rather than restoring it to historic integrity.

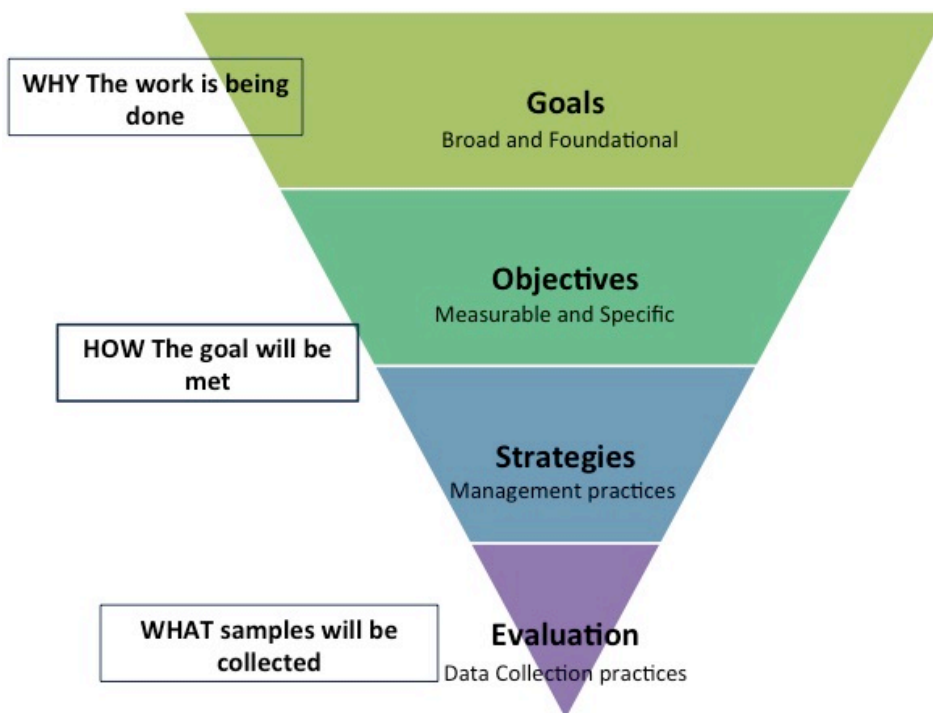


Figure A1. Planning framework.

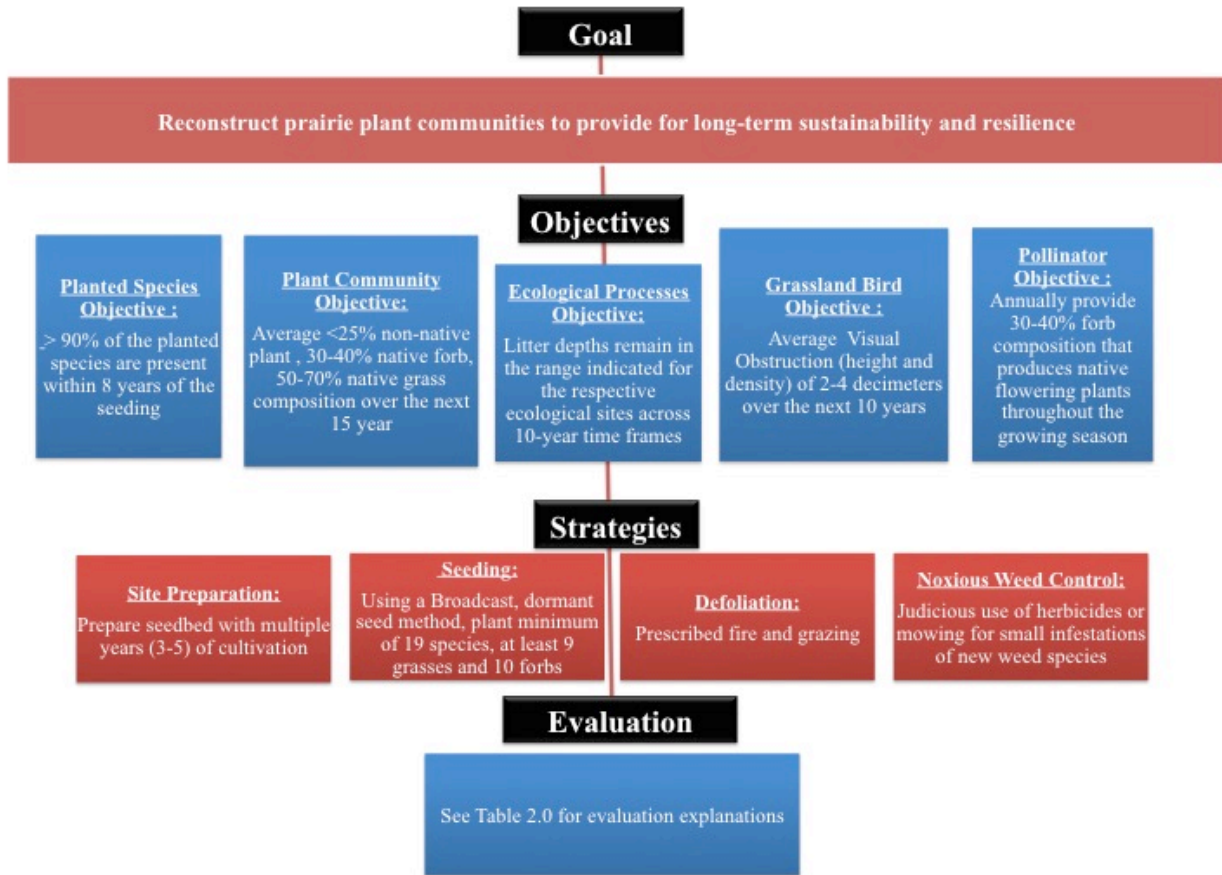


Figure A2. Example USFWS planning flow chart.

Evaluation can often vary from outcome to outcome depending on the goal of a restoration. For this reason, it is important to consider what information will be beneficial to the specific restoration when developing a management and evaluation plan. Table A2 provides examples from the recommended Three Tier evaluation approach of the outcomes in Figure A2.

Table A2
Tiered Evaluation Approach

Outcome	Tier and Example Method
<u>Planted Species:</u> > 90% of the planted species are present within 8 years of the seeding	<u>Tier 1</u> Planted Species Checklist
<u>Plant Community:</u> Average <25% non-native plant, 30-40% native forb, 50-70% native grass composition over the next 15 year	<u>Tier 2</u> Belt-transect Method
<u>Ecological Processes:</u> Enable ecological processes on reconstructed prairie by ensuring that litter depths remain in the range indicated for the respective ecological sites across 10-year time frames.	<u>Tier 2</u> Litter Depth Measurement
<u>Grassland Bird:</u> Average Visual Obstruction (height and density) of 2-4 decimeters over the next 10 years	<u>Tier 2</u> Visual Obstruction Measurement
<u>Pollinator:</u> Annually provides 50-70% forb composition and produces native flowering plants throughout the growing season	<u>Tier 3</u> Sampling Frame Method

(Further explanations are provided in section A.5.2: Step 6 – Evaluation.)

A.2.2. Step 2 - Site Selection

Understanding the limitations or the reconstruction potential of a particular site can facilitate reasonable goal development and appropriate outcomes and objectives. An optimal reconstruction target site contains an area of land with specific physical characteristics that enable it to produce a specific native plant community (Sedivec and Printz 2012, Wark et al. undated). Links for the 2016 ecological site description and morphological summary tables can be found in the reference list at the end of this document. These tables can be used to identify potential climax plant communities for any given site based on hydrogeomorphic factors.

Sedivec and Printz (2012) provide guidelines for determining stable, transitional, degraded, and

climax plant communities for many soil types that are found in mixed and tallgrass prairies sites in the Dakotas.

Optimality of a site can also be determined using numerous tools to direct prioritization. Species distribution and spatial models are two often used. Species distribution models can be developed to determine the suitability of a site for certain weeds (e.g., yellow toadflax, leafy spurge; Crall et al. 2013; Uden et al. 2015). For example, if an area planned for reconstruction is identified as highly vulnerable to leafy spurge invasion, land managers may want to reconsider or adjust the seed mix to provide more competition. Spatial models for wildlife may be useful in determining and prioritizing sites for reconstruction. Descriptions of model development and associated examples for waterbirds are presented in Niemuth et al. (2008) and Reynolds et al. (2006). Johnson et al. (2010) describe the background behind the Grassland Bird Conservation Areas, providing associated figures to help identify sites that may be priority for reconstruction across the Prairie Pothole Region based on predicted bird occurrences.

A.3. Application Phase

A.3.1. Step 3 - Site Preparation

A.3.1.1. Seedbed Preparation

The goal of site preparation is to increase the likelihood of native seed establishment. This process involves litter removal in order to improve seed-to-soil contact and reduces weeds by promoting native species' growth (Smith et al. 2010). Management activities should be planned in advance and consistently followed throughout the reconstruction. Shortcuts can lead to establishment failures (Schramm 1990, Wark et al. undated). Potential methods for site preparation are listed and described in the following paragraphs, and presumes that the site possesses a history of cultivation:

A.3.1.1.1. The Clean-Till Method

The *clean-till method* is best suited for disturbed areas primarily composed of perennial invasive plants (e.g., smooth brome and Kentucky bluegrass) that possess a history of cultivation. In the fall, herbicide should be applied to the existing vegetation site followed by plowing or tilling, which allows the winter frost to kill any invasive perennial grass or forb roots (Schramm 1990). This method is considered the preferred option for seedbed preparation in the Dakotas. Soil erosion, and short-term impacts to soil structure and organic matter are the major drawbacks of this method. Soil attributes can be rebuilt when the native perennial cover is established on the site.

The use of cropping can serve as a pre-seeding weed control, through repetitive herbicide and tillage applications. If the site has a high density of perennial invasive plants, land managers often complete a 3-5 year cropping rotation (i.e., *clean-till method*) to prepare the seedbed. Herbicides can also be used to manage invasive species, but the land manager will need to consider herbicide residual effects, which can inhibit the growth of native grasses and forbs for up to four years following application (Smith et al 2010). For example, an Aminopyralid, such as Milestone, can have residual effects for 3-4 years.

A.3.1.1.2. No -Till Method

The *no-till method* allows for seeding, without tillage, into the standing stubble of a previous crop. This method occurs under a conservation tillage or no-tillage cropping system. Excess straw or chaff needs to be removed prior to seeding. To prevent excess chaff problems, it is recommended to use harvest equipment that spreads straw along a minimum of 80 percent of the header width. If invasive species are present or previous crop excessively reseeds, herbicides may be needed (USDA 2015; Schramm 1990). In studies conducted by Bakker et al. (2003), the

establishment success between a prepared seedbed and the no-till method demonstrated no significant difference.

A.3.1.1.3. Tillage and Herbicide Summerfallow (Chem-Fallow) Method

The *tillage and herbicide summerfallow method* is labor intensive, but may provide a proper seedbed for native prairie reconstructions. For sites with persistent perennial weeds, Wark et al. (undated) recommends herbicide treatments combined with tillage. Tillage equipment used should have minimum surface erosion potential. The bare soil conditions created by this preparation method can be used for broadcast or drill seeding. Again, the land manager will need to consider herbicide residual effects.

An example treatment sequence schedule:

- Year 1 – Disk the site 2-3 times
- Year 2 – Treat with glyphosate (spring) and disk 2-3 more times
- Year 3 -- Treat with glyphosate (spring) and disk 2-3 more times
- Year 4 – Treat with glyphosate (spring) and plant native mix

A.3.1.1.4. Stand Enhancement (Interseeding)

Seed additions into an established stand of vegetation without disrupting the soil through cultivation or disking is called ‘stand enhancement’ or ‘interseeding’. Established stands may range from monotypes of warm-season native grasses to cool-season invasive grasses. Enhancement commonly involves increasing heterogeneity through native forb and native grass inclusion without totally removing the established stand (Smith et al. 2010). Site preparation includes multiple years of consecutive burning, mowing, grazing, and possible herbicide treatments to increase opportunities for seed-to-soil contact and reduced competition (Packard and Mutel 1997; Smith et al. 2010).

Stand enhancement as a seeding method results in mixed successes (Foster et al. 2007, Martin and Wilsey 2006, Martin and Wilsey 2014). Non-native cool-grasses such as smooth brome and Kentucky bluegrass may increase with site preparation activities (Packard and Mutel 1997), creating a more competitive environment for newly seeded species. If the current cover of the site includes smooth brome, it is likely that the soil has been modified to facilitate the growth of this plant and may be less compatible for native plant growth (Jordan et al. 2007). The thatch layer associated with Kentucky bluegrass invasion may limit possibilities for seed-to-soil contact despite prior burning and herbicide treatment. The challenges associated with stand enhancement limit the opportunities for success when utilizing this site preparation method. If increasing forb diversity is desired, Grygiel et al. (2009) provide a method for creating small disturbances within established stands utilizing a technique that requires cultivating and seeding small patches.

A.3.1.1.5. Cover Crop Method

The *cover crop method* involves planting a high residue producing crop, such as oats, barley, flax, grain sorghum, millet, or sudangrass. This is done during the growing season before or during seeding of the reconstruction plants. It is most often used if existing cover is insufficient to control erosion. Other objectives such as weed suppression and increased fuels for fire do not appear to occur with cover crop use (Helzer et al. 2010). Research is still lacking in the area of tuber (radishes, turnips, etc.) cover crops. Current literature should be reviewed and discussions with experienced reconstructionists should occur prior to utilizing cover crops

Table A3
Summary of Seedbed Preparation Methods

Method	Site Conditions	Limitation	Time Commitment	Action(s) Required
<i>Clean-Till</i>	Areas with previous cropping history or other formerly cropped sites in current cover of perennial invasive plants (e.g., smooth brome, Kentucky bluegrass)	May require 3-5 years of cropping for seedbed preparation	3-5 years or possibly less if site has been in cropping rotation prior to reconstruction decision.	Tilling, herbicide, crop production
<i>No-Till</i>	Areas with previous cropping history that have been in a conservation tillage system.	Extra straw or chaff needs to be removed prior to seeding. Concerns with seed to soil contact.	3-5 years or possibly less if site has been in cropping rotation prior to reconstruction decision.	Straw of chaff removal with harvest equipment, herbicide, and crop production
<i>Tillage and Herbicide Summerfallow</i>	Areas with previous cropping history or other disturbed sites in current cover of perennial invasive plants (e.g., smooth brome, Kentucky bluegrass)	Process is labor and time intensive	4 years	Tilling, herbicide
<i>Stand Enhancement</i>	Areas with established grass stands	Competition from current stand of grasses may limit opportunities for success	1-3	Possible actions: burning, mowing, grazing, herbicide
<i>Cover Crop</i>	Areas with previous cropping history or other disturbed sites in current cover of perennial invasive plants (e.g., smooth brome, Kentucky bluegrass)	More research needed. Benefits and limitations not clearly understood	1 year	Tilling, herbicide, planting

A.3.1.2. Nutrients

Prior to European settlement, the prairie was a nitrogen limited system, but anthropogenic activities have changed nutrient processes (Funk and Vitousek 2007). Over-nutrition of soils is often a concern that needs to be addressed in the site preparation process. Soil nutrient levels can increase due to fertilization of soils and the varying nutrient cycles of non-native plants.

Several studies have shown correlation between increased nutrients and invasion of exotic plants; therefore, controlling nitrogen (N) and phosphorus (P) availability on cultivated lands prior to implementing a reconstruction can reduce the likelihood of invasion (Funk and Vitousek 2007, Rowe 2008). For example, shoot production of established Canada thistle is positively correlated with N availability in soils (Hamdoun 1970). There is an increased likelihood of finding high nutrient levels in cultivated areas that have been continuously treated with fertilizer (McLauchlan 2006). Vasquez et al. (2008) developed a conceptual model that predicts the outcome of community dynamics based on N availability and demonstrates the relationship between invasion by non-native plants and soil nutrients. This model predicts that, at some increased level of N, early-seral species and invasive annual grasses are able to grow and reproduce more successfully than native mid- and late-seral species (Vasquez et al. 2008). In the same way at some point an increase in phosphorus will promote early seral and invasive species rather than native late seral species (Grygiel et al. 2010)

Certain native plants uptake nutrients better than others (e.g. sunflower), and could be included in the seed mixture for sites with nutrient levels that are a concern (Levang-Brilz and Biondini 2002). Annual crops that utilize high nutrients (e.g. corn and sunflowers) are another way to remediate high nutrient levels in soils, for more details on selecting species to seed. See ‘Seeding’ section. In order to best understand the site preparation needs, practitioners should

collect soil samples to submit for testing. There are companies that can provide analysis of phosphorous, nitrogen, and other soil constituents of soil samples. This kind of documentation will help direct the planning process for seeding. For example, if phosphorus levels are high enough to support a corn crop, the site is likely too nutrient rich to promote native plants over weedy plants.

A.3.1.3. Herbicide Residue

Inadequate weed control, especially of cool-season invasive grasses, causes more grass seeding failures than any other factor (Duebbert et al. 1981, Jordan 1988, Roundy and Call 1988, Wilson and Gerry 1995). These species readily re-sprout from persistent seedbanks, or remnant root or vegetative fragments. In general, controlling invasive species should be conducted in the years preceding seeding as well as shortly before seed is installed (Wark et al. undated).

Herbicide application can occur between six days (Schramm 1990) and three weeks prior to seeding (Wark et al. undated). The exact timing and application depends largely upon the target weeds being controlled and site conditions. For example, to control Canada thistle and quackgrass, Wark et al. (undated) recommends application of glyphosate from mid-August to early September to ensure the plants are green and actively growing.

Herbicide application history is an important factor to consider in site preparation, because residue can inhibit establishment of native grasses and forbs for up to four years after application (Smith et al. 2010). For this reason, the previous four years' herbicide history should be identified prior to seeding. Residues from certain herbicides, such as Milestone and Odyssey, may prevent the establishment of some native plants, specifically forbs. If herbicide use is suspected on a site, delaying seeding eliminates potential carryover of residual herbicide.

A.3.1.4. Firm Seedbed

The final step in preparing the site is creating a firm seedbed, which ensures the seed is placed at the appropriate depth. The soil should be firm enough so that adult footprints are hardly visible when walking across the packed soil (UDSA 2015, Packard and Mutel 1997). Often seedbed preparation activities produce a firm seedbed; however if this does not occur, a standard agricultural cultipacker can be used to pack the soil.

A.3.2. Step 4 - Seeding

A.3.2.1. Methods

Planting seeds at the proper depth and facilitating good seed-to-soil contact are key factors in successful prairie reconstruction. Optimum depth for native grasses, forbs, and small shrubs are $\frac{1}{4}$ to $\frac{3}{4}$ inches (UDSA 2015, Smith et al. 2010). Seeds planted too deep in the soil will not germinate due to the inability of light to penetrate. There are two main seeding methods used in reconstructions, grass drill and broadcast seeding.

A *grass drill* is well-suited for seeding into an existing stand or a firmly-packed bare seedbed (Smith et al. 2010). Seed must be properly cleaned, prepared, mixed, calibrated, and the drill operated correctly for successful seeding. It is important to monitor seeding during application to ensure that depth is continually shallow ($\frac{1}{4}$ to $\frac{3}{4}$ inches) since seed planted too deep will not emerge. Forb seed, in particular, must be seeded to a very shallow depth to promote emergence.

Grass drills can usually handle three types of seed with the differing seed boxes. The types of seed include:

- clean, smooth seeds (e.g. western wheatgrass);
- chaffy/trashy seeds (e.g. little bluestem, porcupine grass); and

- fine, smooth seed (e.g. switch grass and purple prairie clover).

For details on which boxes individual specials should be placed, see Smith et al. (2010) Table 5.2, pages 66-68. In addition, USDA (2015) provides documentation on drill calibration; however, it is also recommended that land managers new to grass drilling seek assistance from professionals experienced in calibrating and operating a drill.

Broadcast seeding requires a smooth, firmly packed seedbed with minimal residual cover. The seed must be properly mixed and seeding rate carefully calculated. It is recommended that a drag harrow, cultipacker, roller packer, or similar equipment be pulled behind the broadcaster to press the seed into the soil surface to maximize seed-to-soil contact. If you are using seeding rate calculations from USDA (2015), note that you will need to increase this rate by 1.5 times. Smith, et al. (2010) indicates that for snow/frost broadcast seeding the rate should be increased by 25% from regular seeding rates. Increasing seeding rates compensates for losses from wind erosion and predation (Smith, et al. 2010).

In addition, reconstructionists often prefer to broadcast seed into soybean stubble rather than corn because corn residue leaves furrows that may impede broadcasted seed from making seed to soil contact (Helzer et al. 2010, Rowe 2008). In comparison, soybeans create a light layer of residue that can help bind seeds (Rowe 2008). However, several successful seedings have occurred in corn stubble when stocks are lying down and the soil is packed appropriately. In addition to the present crop residue, there may be other factors to consider, such as herbicide carry over and soil nutrients (see previous documentation in Step 3). Some sources indicate that the optimal method and time to seed is a dormant season broadcast seeding onto Roundup Ready soybean stubble (Helzer 2010, Rowe 2008, Larson, et al. 2011), because:

- 1) the seeds do not need to be cleaned to pass through the drill;
- 2) results are more natural looking because you cannot see rows;
- 3) reduced equipment costs;
- 4) some forb seeds germinate better if placed on the surface (Rowe 2010).

However, it appears that establishment is similar between the two methods (Bakker et al. 2003, Rowe 2008). In addition Newman and Redente (2001) found that, after 20 years, plant community composition and productivity were the same.

Despite similarities in production and composition, the two methods do have their own advantages and disadvantages. Drilled seeds tend to be more buffered from drying than those broadcast onto the soil surface. In Saskatchewan, germination was significantly higher for grass seeds buried 1 cm deep than for those scattered on the soil surface (Ambrose and Wilson 2003). The opposite result occurred at another site nearly 80 miles away, and broadcasting was more effective (Bakker et al. 1997). Broadcasting has been successful for reconstructions in Kansas (Kindscher and Tieszen 1998) and Wisconsin (Howe 1999). Larson (2011) identified that planting a seed mix with high grass diversity and moderate forb diversity in conjunction with broadcast seeding produced the most successful results. Drilling promotes grass germination, but tends to have an inverse effect with increased forb diversity (Wilson 2002). The variability of these findings emphasize how necessary it is to base a reconstruction on site conditions (soils and weather), timing, history, and existing vegetative cover. No matter which approach is used, the seedbed should be prepared so that it is free of competing vegetation, firmly packed, not subject to excessive erosion, and in a location unaffected by herbicide residues or excessive nutrients.

Table A4
Overview of Seeding Methods

Method	Soil Requirements	Tools Required	Pros	Cons
<i>Grass Drill</i>	A firmly-packed bare seedbed or established stand	Grass Drill	Increases grass germination Increased seed buffering from drying	Seeds may be drilled at inappropriate depths Seed drills may not distribute fluffy seeds efficiently if not prepared properly May decrease forb diversity Calibration can be challenging
<i>Broadcast</i>	Smooth, firmly packed seedbed with minimal residual cover	Broadcaster or hand dispersal Drag harrow, cultipacker, roller packer	Increased success for reconstructions Increased forb diversity	Increased seed dry out Increased seed percentages recommended to account for exposure to weather conditions and predation

A.3.2.2. Timing

The time of year that a planting occurs is another critical factor to consider in the seeding step. The following options exist for the time of year a planting may occur in the Dakotas:

dormant, spring, summer, and snow or frost.

A.3.2.2.1. Dormant

Dormant planting can be done when soil temperatures are below 40 degrees Fahrenheit and have been for a minimum of 5 days (usually after November 1). This timing ensures that the seeds will not germinate until the following spring. Two methods can be used to determine if soil temperatures are appropriate: 1) the Agriculture Weather Network; or 2) field measurements at a depth of 2 inches (USDA 2010). Seeding in this window mimics the natural progression of seed

ripening and autumn/winter dispersal of prairie plants and due to this synchrony with the natural cycle reconstructionists prefer dormant season planting (Rowe 2010). Many forb species respond well to dormant planting because the cold winter months provide the stratification that facilitates germination. Smith, et al. (2010) indicates that if a seed mixture contains 50:50 forb (or more) to grass seed ratio, a dormant planting is a viable option. Likewise, Larson, et al. (2011) documented that perennial forbs responded more favorably to the dormant broadcast seeding, but warm-season grasses responded more favorably to drill seedings during the growing season.

Dormant planting may not be the best option for seed mixtures with higher grass to forb seed ratios, with the exceptions of switchgrass and Canada wildrye, as seed mortality may increase (Mayer and Gaynor 2002). If dormant seeding is selected for high grass seed ratio mixtures, Henderson and Kern (1999) suggest increasing grass seed by 25% to compensate for seed loss. Additionally, the seed should be planted into the soil ($\frac{1}{8}$ to $\frac{1}{4}$ "") and packed. Managers should avoid seeding onto ice or frozen ground, as this will increase opportunities for predation and wind dispersal (Smith, et al. 2010).

A.3.2.2.2. Spring

A spring planting usually takes place in the Dakotas from late April to mid-June (see recommendations specific to your Major Land Resource Area in UDSA 2015). An early spring seeding may favor species such as cool-season grasses, sedges and certain forbs. This contrasts a later spring seeding that favors warm-season grasses and certain forbs. Since some forbs require *stratification*, and may not germinate until the required environmental conditions are reached (Smith, et al. 2010).

A.3.2.2.3. Summer

A summer planting takes place in mid to late summer. It is usually not recommended because of the potential for drought and onset of cold temperatures, because both weather related situations can harm newly emerged plants (Smith, et al. 2010). Data from Larson (2011) indicate that summer plantings (6/8-9/1) had the lowest success rates in western Minnesota and eastern North Dakota. In wet areas, where this season may be the only option, selection of specific species that germinate and mature quickly may survive the onset of winter.

A.3.2.2.4. Snow or Frost

Snow or frost seeding is a dormant planting that occurs late in the winter when temperatures are above freezing during the day and drop below freezing at night. The freezing and thawing action allows for seed to soil contact. Individuals in North Dakota and eastern Minnesota that utilize this technique are attempting to seed on top of the snow using a Viacon Broadcast seeder. As the freezing and thawing occurs, the seed is getting embedded into the saturated soils. Broadcast seeding is usually the only option for a snow seeding unless there is no snow on the ground, in this case a drill can be used. Germination rates for snow seeding compared to other seeding times is unknown at this time. Proponents of snow seeding note that one of the prominent benefits is that the seed is in the soil less time, so, in comparison to a fall dormant seeding, predators and pathogens have fewer opportunities to affect seed (Smith, et al. 2010). Data from Larson (2011) indicate that winter planting (10/21-4/14) had the highest probability for success in western Minnesota and eastern North Dakota.

Table A5
Overview of Timings

Timing	Temperature/time requirements	Advantages	Disadvantages
<i>Dormant</i>	Soil must be 40 F for minimum of 5 days	Mimics natural cycle Forbs respond well	Seed mixes with higher grass ratios may not respond as well
<i>Spring</i>	April-June depending on year	Favors cool season species	Forbs requiring stratification may not germinate
<i>Summer</i>	Mid-late Summer	Not recommended Species that germinate quickly may thrive	Does not provide enough time between germination and winter Increased likelihood for drought related damage
<i>Snow or Frost</i>	Late winter where temperatures are above freezing in the day and below at night	Freezing and thawing provides seed to soil contact Fewer opportunities for predators and pathogens to effect seeding	Unknown germination rates Narrow window of opportunity to seed.

A.3.2.3. Selecting Species to Seed

Establishing a diverse, native plant community is key to producing a reconstruction capable of regenerating and long-term plant succession (Smith et al. 2010). Diverse seed mixes increase likelihood of long-term resilience (Biondini 2007) and allow for successful establishment of the target community (Piper and Pimm 2002). It is well documented that a high diversity planting provides for ecological resilience, reduced weed invasion, and season-long resources for herbivores, pollinators and other wildlife (Blumentahl 2003, Sheley & Carpinelli 2005, Helzer et al. 2010, Pokorny 2002, Pokorny et al. 2004, Pokorny et al. 2005, Sheley and Half 2006, Tilman 1996). It should be noted that having a seed *efficiency* goal (germination rates similar to seeding rates) for planting a high diversity seed mix is not preferred. Rather,

reconstructionists strive for plant community *effectiveness*, or a functioning prairie ecosystem comprised of a mix of forbs and grass similar to native conditions.

Diverse seedings are needed to create these structural and functional prairie communities. Piper and Pimm (2002) recommend that seed mixes should be composed predominantly of representatives from four major plant functional groups:

- perennial C4 grasses,
- C3 graminoids (grasses and sedges),
- N-fixing species (primarily Fabaceae and Mimosaceae), and
- late summer flowering, drought-hardy composites (Asteraceae) (Kindscher and Wells 1995).

It is functionally and structurally important to include forbs within seedings.

Functionally, the inclusion of forbs in these mixtures appears to be necessary in attempts to restore variables such as nutrient cycling and energy flow (Pokorny et al. 2005). Likewise, a diverse mix plays an important role in the belowground community by providing a well-developed root system to sustain the plants through climate variations, fire, and herbivory (Guo et al. 2006). Structurally, Sheley and Half (2006) indicate that in areas of high competition seeding a wide range of forbs increases the likelihood that forbs will inhabit more niches and experience increased survival. Piper and Primm (2002) also show that as diversity increases in a seed mixture, dominant species stand a better opportunity to out-compete subdominants, therefore excessively high diversity mixes and inclusion of numerous rare species at low densities may not be worth the cost and effort (Larson 2011).

In addition, seed mixes with high forb densities have been found to reduce densities of invasive species. Norland et al. (2013) identified that Canada thistle can be reduced through

inclusion of forbs that are functionally similar and seeded at high rates (identified as ‘spiked’ mixtures). The spiked native forbs were seeded at a rate of approximate 100-300 seeds/square foot, and resulted a statistically significant reduction in Canada thistle in the first three growing seasons and tapering into a plant community similar to native prairie compositions by the fifth and sixth growing season. The native forbs chosen for the spike mix have natural occurring pathogens and predators and eventually reduce their dominance in the planting (Norland et al. 2013). In the end, the use of multiple forbs may help to overcome several obstacles, because it is likely that some of the species species will germinate despite competition and dynamic weather conditions of the Dakotas (Tilman and Downing 1994, Sheley and Half 2006).

Further supporting increased seed diversity, Larson (2011) found that a minimum of 19 species in a mixture, with at least 9 grass species and 10 forbs, provided the highest probability of success. This information was based on his assessment of reconstructed sites in eastern North Dakota and Western Minnesota. Larson also advocated for inclusion of a diverse forb component. Similarly, Guo et al (2006) identified that at least 16 species were necessary, and not more than 32 species promoted long-term productivity. Other opportunities such as Precision Prairie Reconstruction (Grygiel et al. 2009) may provide better opportunities for inclusion of rare species if desired. Considering species selection, Larson (2011) suggests avoidance of 5 or less grasses, and excessively low (<10) and excessively high (>30) forb species. Rowe (2010) documents that most practioners have reduced the seeding rates of grasses relative to forbs, which has improved forb establishment resulting in a more diverse reconstruction. Smith et al. (2010) suggest 6 grasses, 3 sedges, and 25 forbs for seedings in the tallgrass prairie, with a planting ratio of 50:50 grass to forb seed.

Selecting the right seed mix for a site needs to be based on multiple factors such as site history, location, and reconstruction needs. Seed mix selection should be specific to the site and consider the following factors:

- slope and aspect, purpose of the seeding,
- management regimes, seed availability,
- seed costs,
- longevity,
- ease of establishment, and
- the functional groups of available plant species (Wright 1994).

Functional groups for specific climax communities can be identified by reviewing the particular Ecological Site Description (ESD) presented by Sedivec and Printz (2012).

Community specific information provided on plant community composition, general functional groups (grasses, forbs, shrubs, etc.), and community pathways provide valuable information for developing site-specific seed mixes and management strategies. For each ESDs, climactic data, growth curves, soil data, and water features are documented. These factors may help determine the timing and methods for seeding the site, as well as develop a plan for post-seeding management. It is common for there to be multiple ESDs within a single reconstruction site. Despite this, some reconstructions may utilize one seed mix and apply it uniformly across a single unit; however a preferable approach may be to develop various seed mixes based on a unit's multiple ecological sites. This is known as a *sculptured seeding*. The longevity and diversity of reconstructed sites can be enhanced by sculpturing the seeding (Jacobson et al. 1994).

A.3.2.3.1. Seed Sources

Local ecotype seed sources should be used in prairie reconstructions (Helzer et al. 2010, Packard and Mutel 1997, Shirley 1994, Smith et al. 2010). Various authors have a number of criteria to determine what can be considered “local.” Schramm (1978) suggested a 200 mile radius, but to also consider the east-west rainfall regimes as better guide for regional variability. Similarly, Thornburg (1982) suggested that native seed should not be moved more than 300 miles north or 200 miles south of its point of origin. These precautionary ranges are intended to prevent problems with genetic drift, winter hardiness, longevity and disease. Seed vendors should know the origin of seeding they are selling, and it is important for land managers to know what seed varieties are appropriate for their site. Special caution should be used when seeding tallgrass prairie species in an area of mixed prairie to ensure that non-local species are not accidentally introduced

Sometimes native harvested seed can be purchased from vendors, but more than likely this is a task that needs to be completed individually using mechanical or hand harvest methods. Native prairie is typically harvested in the fall (e.g. September) using a combine, seed stripper, flail vacuum, or by hand. While fall is an optimal season for harvest of warm season species, it may not be the best time to harvest earlier blooming species (e.g. pasque flowers, native cool-season grasses). These species may require hand harvesting earlier in the season to create a more diverse mixture. If the decision is made to implement a native harvesting program, several resources are available (e.g. Smith et al. 2010, Houseal 2007) and collaboration with individuals already involved in this effort are encouraged.

Cultivars are cultivated varieties of native grasses and forb species that have been developed by the USDA Plant Materials Center. Cultivar grass varieties are developed through

collecting and propagating seeds from individual plants from multiple locations to select for certain traits. For example, there are two developed ecotypes for Little Bluestem, Badlands and Itasca. The Badlands ecotype was developed for early maturing, good plant vigor, seed production, disease resistance, etc. Origins include a composite of sixty-eight vegetative collections from various native sites across North and South Dakota. In comparison, the Itasca composites of 72 vegetative collections are from eastern North Dakota, north central South Dakota, and center and northwest Minnesota.

Cultivars provide a straight-forward method to ensure that purchased seed that will grow for the specific area of the reconstruction. The NRCS Plant Materials Center provides numerous publications on their website to assist with identifying cultivars that are specific to your area. Cultivars do not exist for all species that may be desired in a seed mixture and caution should be used when purchasing species if the origin or variety is not listed. Working with seed vendors to find local ecotype seed or harvesting the targeted species are options for inclusion of specific species. Most native seed suppliers can custom blend, bag and import (if necessary) to meet needs.

When a bag of seed is obtained, the entire bag is known as the 'bulk' seed. Seeding rates are based on pure live seed (PLS), which factors in the *purity* and *germination* rate of the seed. *Purity* measures weeds and inert matter mixed with the actual seed. *Germination* accounts for the percentage of dead or dormant seed and is an indicator the percentage of seed that will sprout and grow. It is important to determine the PLS of the bulk seed. PLS is determined by multiplying the percent of pure seed by the percent germination and dividing by 100 (UDSA 2015). To identify the pounds of bulk seeding rate per acre, take the pounds of PLS recommended rate per acre (see UDSA 2015) and divide by the percent PLS. For calculating

seeds per square foot, take the number of seeds of the individual species per pound (USDA 2015) x the total PLS pounds divided by acres to seed x 43,560 feet² per acre. These and more calculations are included in the 'Formulas' section of this document.

To order seed from a vendor, the following information will be needed:

- Species name (e.g. Big bluestem)
- Full seeding rate (this is provided in USDA [2011]; for big bluestem = 7.9 PLS)
- Percent of the individual species you want in the mix (you can only have 100% for all species in the mix, so you will likely have anywhere from 7% of a species in a mix to 1%, dependent on diversity)
- Seeded PLS pounds per acre (this is the full seeding rate x the percent of the species in the mix)
- Number of acres you plan to seed
- Total PLS pounds (This is the number you will provide the vendor); this is the seeded PLS pounds per acre x the number of acres

Calculations can be made in the native seeding planning sheets that are provided by several agencies. These are located on the resources links page.

Optimum seeding rates have not yet been determined for native species as they have been for many introduced species (Pyke and Archer 1991). Excessively high seeding rates may waste seed, however they may result in faster establishment and the control of unwanted species (Wilson 2002). Seeding rates for species like big bluestem, Indiangrass, and switchgrass have been decreased over the years because of the tendency of these species to dominate. In areas dominated by cool-season grass, the same can occur especially when using cultivars of greenneedle grass, slender wheatgrass, and Canada wildrye.

Seeding rates tend to increase with soil productivity, annual rainfall, and perennial weed pressure. For example, there are major moisture regime changes from the Red River Valley to more drought-prone western parts of North and South Dakota. According to the USDA (2015), seeding rates in western Minnesota and eastern North Dakota average 25-40 seeds per ft² for a diverse mixture of grasses, forbs and small shrubs. Smith et al. (2010) recommends a minimum of 40 seeds/foot², and for slopes of 3:1 or greater, a minimum of 60-80 seeds/ft² are recommended because of erosion concerns. Smith et al. (2010) recommends that 20 of those seeds should be forbs and 20 grasses or sedges in a distribution of 40 seeds/ft². Sedivec et al. (2014) estimate that a reconstruction should include approximately 10-12 PLS pounds per acre. The USDA (2015) has a listing that identifies seeds per pound, seeds per foot², PLS pounds per acre for numerous species. If a species is not on this list, several books exist regarding the tallgrass prairie including:

- Smith, Daryl, Dave Williams, Greg Houseal, and Kirk Henderson. 2010. The Tallgrass Prairie Center Guide to Prairie Restoration in the Upper Midwest. The University of Iowa Press, Iowa City, IA.
- Shirley, Shirley. 1994. Restoring the Tallgrass Prairie. The University of Iowa Press, Iowa City, IA.
- Houseal, Greg A. 2007. Tallgrass Prairie Center Native Seed Production Manual. The Tallgrass Prairie Center, Cedar Falls, IA.

A.3.2.4. Seedbed Establishment

There is an establishment period for prairie reconstructions that can last from 3-5 years depending on several variables (e.g. moisture regimes) (Smith et al. 2010, Packard and Mutel 1997). The first year of a seeding often produces a dominant cover of annual weeds. Mowing

may be necessary in wetter areas of the tallgrass prairie where annual weeds are tall and more robust. Reconstructionists in Minnesota and Iowa frequently utilize mowing in the first year and possibly the second because low light levels in a closed canopy may reduce emergence and growth of the native plants (Williams et al. 2007). However, in the drier parts of the tallgrass and mixed grass prairie, mowing is not as common. Considerations related to mowing are likely a site-by-site decision, depending on the thickness of the annual weed cover and the possible impacts to native seedlings (e.g. the litter created post-mowing). If mowing is utilized, set the mower to a height of 8-10" (UDSA 2015) and implement in late June when root reserves are lowest (Jacobs et al. 2006).

Successful establishment of native seedlings will be able to compete with perennial weeds, although the first few years may produce annual weeds in reconstructions (Norland 2015). In years 2-4 more of the planted species become prominent and there tends to be less annual weeds. However, Canada thistle and other perennial weeds may become problematic. Opening up the canopy through mowing may improve opportunities for Canada thistle growth because it thrives in open canopy areas and dies in low light (Bakker 1960, Bostock and Benton 1983, van Leeuwen 1987). Mowing the main shoot of Canada thistle stimulates sprouting from other root buds and more vegetative stems are produced, which creates opportunities for spread (Larson et al. 2013).

After year two, Funk et al. (2008) found that native plants with similar resource-use traits (functional traits) reduce problematic exotic species in reconstructions. Specific to North and South Dakota, Norland et al. (2013) identified that Canada thistle can be reduced through inclusion of forbs that are functionally similar and seeded at high rates (identified as 'spiked' mixtures). Results from the first two growing seasons showed significant decrease of Canada

thistle cover in the spike treatment compared to non-spike control. The spiked native forbs were seeded at a rate of approximate 100-300 seeds/ft² and resulted in six times less Canada thistle than the non-spiked plots (Norland 2013). The native forbs chosen for the spike mix have natural occurring pathogens and predators and eventually reduce their dominance in the planting (Norland 2013).

Year three usually provides enough litter fuel to carry a fire and a prescribed burn is usually implemented during the third or fourth year (Rowe 2010). Early spring burns encourage cool season species, and late spring burns encourage warm season species and suppress cool season species (Wark et al. undated). Fall burns tend to have a neutral effect on species shift. In fields where managers are content with species density and distribution, a fall burn to remove accumulated litter is recommended.

Grazing is also not recommended until the third or fourth year. Prior to that time frame, seedlings do not have well-developed root systems with adventitious roots above the sown seed (UDSA 2015). Often reconstructionists in North and South Dakota will burn in year 3, then do the initial graze in years 4 or 5. Once the seeding is established, defoliation techniques (i.e. burning and grazing) occur regularly throughout the life of the stand.

A.4. Implementation

A.4.1. Step 5 – Invasive Species

Appropriate site preparation (Smith et al. 2010) and seed selection (Norland et al. 2013) will provide the foundation for reducing invasive plants problems beyond the establishment phase. Annual or noxious weeds tend to be opportunistic early in the reconstruction process and following disturbances such as burning and grazing. Cool-season invasive grasses usually move

in gradually and over the long-term, although they will be problematic during establishment if seedbed preparation was not appropriate. .

Smooth Brome and Kentucky Bluegrass (*Poa pratensis*) are prevalent on the landscape in the Dakotas. Without proper planning and management, such as burning and grazing, these invasive species will invade and dominate reconstruction sites. Numerous data gaps exist for reducing cool-season invasive grass presence on native and reconstructed prairies. However, it is apparent that idleness without periodic burning and grazing is detrimental (Murphy and Grant 2005).

A.4.2. Step 6 - Evaluation

Patience is important and necessary when evaluating the establishment of prairie reconstructions. Warm-season plants may require three growing seasons for full establishment (USDA-NRCS 2015) and may even require as long as 3-5 years depending on site conditions (Packard and Mutel 1997, Smith, et al. 2010). Environmental factors such as precipitation, drought, and temperature can delay seedling emergence and development (USDA-NRCS 2015). Developing a well-thought out plan and method for evaluation provides optimal scenarios to measure outcomes for land managers who want to measure progress during the establishment phase.

Identifying an adequate method for evaluation depends on the intended outcomes. Monitoring prairie reconstructions often involves evaluating vegetation (examples provided in the ‘Setting Goals and Determining Objectives’ section). Prior to implementing any monitoring program, resources such as ‘A Technical Guide for Monitoring Wildlife Habitat’, Measuring and Monitoring Plant Populations’, and ‘How to Develop Survey Protocols’ (Rowland and Vojta

2013; Elzinga, et al.1998; USFWS 2013) might be useful in developing an evaluation plan and methods.

The following section details a tiered approach for monitoring reconstructions. Each tier describes potential methods for monitoring certain characteristics of prairie reconstructions. The amount of time, effort and detail needed by each approach varies based on the tier and intended outcomes.

A.4.2.1. Tier 1 Monitoring Approach

Example Outcome: Reconstruct prairie to a mixture of native plants that is specific to the site, where $\geq 90\%$ of the seeded species are documented within the first eight years of seeding.

The ‘Tier 1’ option provides minimal inputs based on the specifics needed to meet the objective. Create a checklist of the seeded species in a spreadsheet or database. Annually walk (or use an all-terrain vehicle) through the seeded field within the same 2-3 week time period and place a check by a species when it is identified. If species are unidentifiable because they are not flowering, multiple walks a year may be necessary. Walk the full-length of the field at various segments across the seeded area. Capture data in the associated spreadsheet or database after each monitoring walk to ensure that an accurate evaluation can take place following year eight.

A.4.2.2. Tier 2 Monitoring Approach

Example Outcome 1:

Provide a site specific native seed mixture that on average provides the following composition: <25% non-native plants, 30-40% native forb, 50-70% native grass over the next 15 years.

‘Tier 2’ requires more intensive effort and specific information than ‘Tier 1’ because of the need for quantitative data to meet the needs of the outcome. The ‘Belt Transect Method’ (Grant et al. 2004) provides one option for monitoring of this outcome. This method requires the evaluator to develop a list of plant groupings that will be identified along a transect (in this example outcome, the plant groupings could be based the plants included in the seed mix). Gathering data with this method is relatively rapid considering that plant groupings along a transect are often similar (Grant et al. 2004). Transect length and placement varies dependent on the field size, slope and aspect, and ecological sites. For example, a transect length could vary from 10-meters (large variations in ecological sites) to 100- meters (maybe only a couple of ecological sites). It is recommended that a statistician be consulted to ensure that the design is appropriate for evaluating the intended outcome. Data from this method can be entered in a spreadsheet or database to quantitatively measure the percent composition of the targeted plant groupings annually. Grant et al. (2004) provides examples for analyzing data with this method.

Example Outcome 2: Reconstruct prairie to a site specific mixture of native plants that provides an average Visual Obstruction (height and density) of 2-4 decimeters over the next 10 years.

The Robel Pole (Robel, et al. 1970) is a common method to collect Visual Obstruction data for grasslands. A Robel Pole is a 1-meter tall pole with a spike on the base for securing in the ground. Red or black marks occur on the pole in half and whole decimeter increments, starting with 0 at the base, and ending with 10 at the top. This rapid technique measures the height and vertical density of standing vegetation, by reading the last mark visible on the pole. Data are used to measure residual forage or are correlated with grassland bird nesting cover. Accuracy of data depends on appropriate training of the observers, since ocular estimations can

be variable. Data from this method can be entered in a spreadsheet or database to quantitatively measure the average visual obstruction of the prairie over the stated time frame. It is recommended that a statistician be consulted to identify the number of Robel Pole readings needed for a prairie reconstruction. More information on the Robel Pole method is available on the following document: http://www.wyomingextension.org/agpubs/pubs/MP111_10.pdf

Example Outcome 3: Enable ecological processes on reconstructed prairie by ensuring that litter depths remain in the range indicated for the respective ecological sites across 10-year time frames.

Ecological Processes generally refer to the area's water cycle, energy flow, and nutrient cycle. Due to the complexities of grasslands, ecological processes are difficult to measure or observe; therefore as a metric for reconstruction purposes, litter depth is suggested as an overall representation. Based on the 'Indicators of Rangeland Health' (Pellant et al. 2005), litter amount is an indicator for two out of three attributes (i.e., hydrologic function and biotic integrity), suggesting that this is a reasonable metric to monitor for ecological processes. Litter is defined as dead plant material that is detached from the base of the plant and is in contact with the ground (Pellant et al. 2005). References for the appropriate thickness of the litter are provided within the Ecological Site Descriptions on the 'Rangeland Health Reference Sheet'. Again, it is recommended that a statistician be consulted to identify the number of litter measurements needed on a site based on the number and acreages of ecological sites. Data collected can be put in a spreadsheet or database to qualitatively measure the average litter depths across the indicated time frame. Proper techniques to measure litter depths in grasslands are found in the 'Interpreting Indicators of Rangeland Health' document (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043944.pdf).

A.4.2.3. Tier 3 Monitoring Approach

Example Objective: Reconstruct prairie to a site-specific mixture of native plants that annually produces flowering species throughout the growing season, averaging cover percentages of 30-40% forbs and 60-70% native grasses.

Tier 3 requires intensive monitoring because of the need to collect data on the percent of canopy cover for each species. A suggested protocol involves 25- meter transects with three frames (6-meters, 12-meters, and 18-meters) per transect. Each ¼-meter frame requires identification of each species and an associated canopy cover percent. The number of transects per field should be determined based on consultation with a statistician. Each transect should be monumented to insure that the survey is completed at the same location every year. Data are summarized using the average canopy cover for each plant identified. An associated spreadsheet or database can be developed to facilitate analysis. Because of concerns with variability with measuring canopy cover, the same individual should monitor the field every year if possible. Another method for reducing observer variability is to train all observers using photographs and computer generated canopy covers (e.g., use GIS software for this) so that everyone involved in the monitoring has been calibrated. Each observer should be re-calibrated every year. Double observer methods can also be utilized to help reduce variability.

A.4.2.4. Photo Points

Photographs can be used to supplement monitoring approaches by providing an overall view of the dominant vegetative cover and site conditions. Considerations for photo points include:

- 1) Mark permanent locations where your photos will be taken (e.g., a monumented transect start point).

- 2) Ensure that the identical scene is photographed each year.
- 3) Take the photo at exactly the same time each year.
- 4) Use the same camera at the same zoom or focus.
- 5) On subsequent years, bring the previous year's photo to assist with taking the photo from exactly the same position.

As a final suggestion, you may want to use a fence post or survey pole as the center point of the photo each year just as a benchmark for the vegetation height.

A.5. Appendix of A Prairie Restoration Guidebook for North Dakota

Seeding Calculators:	
Iowa Prairie Seed Calculator	http://www.jamess.com/IowaPrairieSeedCalculator-D2/
Natural Resources Conservation Service, Iowa	http://www.nrcs.usda.gov/wps/portal/nrcs/main/ia/technical/ecoscience/bio/
Natural Resources Conservation Service, North Dakota	https://efotg.sc.egov.usda.gov/references/public/ND/range_planting_550.pdf (see link to ND-CPA-9 – Planning or Data Sheet for Grass and/or Legume Seeding)
Information on Species:	
Prairie Moon Nursery	http://www.prairiemoon.com/pdf-catalogs.html Useful information across website including their annual catalogs.
Tallgrass Prairie Center Native Seed Production Manual	http://www.tallgrassprairiecenter.org/sites/default/files/pdfs/native_seed_production_manual.pdf
Natural Resources Conservation Service Herbaceous Vegetation Establishment Guide	https://efotg.sc.egov.usda.gov/references/public/ND/Herbaceous_Veg_Est_Guide.pdf

Natural Resources Conservation Service Plant Materials Center	http://www.nrcs.usda.gov/wps/portal/nrcs/main/plantmaterials/pmc/central/ndpmc/
Natural Resources Conservation Service Range Planting (North Dakota)	https://efotg.sc.egov.usda.gov/references/public/ND/range_planting_550.pdf
Natural Resources Conservation Service Range Planting (South Dakota)	https://efotg.sc.egov.usda.gov/references/public/SD/550_final.pdf
Daryl Smith, Dave Williams, Greg Houseal, Kirk Henderson (Book)	<i>The Tallgrass Prairie Center Guide to Prairie Restoration in the Upper Midwest</i> (2010), Developing a seed mix using a seed calculator - Pages 30-34 Details on seed dormancy – Pages 239-247
Prairie Seedling and Seeding Evaluation Guide	https://secure.iowadot.gov/lrtf/docs/PrairieSeedlingGuide.pdf

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APPENDIX B. DRAWING RUBRICS

Table B1
Bloodroot Drawing Rubric

Sign	0=No	1=Yes
<i>Stem</i>	No single or double line is drawn that could reasonably be assumed to be an indicator of a “plant stem”	A single or double line is present connected or unconnected to leaf structures that can reasonably be assumed to be an indicator of a “plant stem”
<i>Leaf</i>	No simple, long, dagger-like structure possibly drawn connected to or in close proximity to a “plant stem” can reasonably be identified	A simple, long, dagger-like structure, possibly drawn connected to or in close proximity to a “plant stem” can reasonably be identified
<i>Roots</i>	No series of hair like or thin branching lines or other structures such as “bulbs” are drawn below the “plant stem” or below an indicator of “ground” that can reasonably be assumed to be “roots”	A series of hair like, thin branching lines or other structures such as “bulbs” are drawn below the “plant stem” or below an indicator of “ground” that can reasonably be assumed to be “roots”
<i>Flower</i>	No structure is present that is drawn differently than the “leaf” signs, but is connected to the upper portion or end of a “plant stem” and can reasonably be assumed	A structure that is drawn differently than the “leaf” signs, but is connected to the upper portion or end of a “plant stem”
<i>Branching- clear indicator that leaf and flower are on separate stems but from the same root</i>	Only one “plant stem” is drawn in such a way that there is only a single line or double line that does not divide or give indicators to be reasonable assumed to be a petiole or second “stem”.	More than one “plant stem” is drawn in such a way that there is more than a single line or double line that divides or give indicators to be reasonable assumed to be a petiole or second “stem”.
<i>Color Variation from Stem to leaf</i>	No indication that the stem and leaf vary in color.	There is indication that the stem and leaf vary in color. May be indicated by darkening the color of the “stem” to “leaf” structure or varying of coloring pattern (i.e. cross hatch lines to indicated darker stem).

Table B1. *Bloodroot Drawing Rubric (continued)*

Sign	0=No	1=Yes
<i>Venation</i>	No lines that are drawn on the “leaf” indicators that consists of a center lines with additional lines extending from OR a series of lines drawn across the leaf in a regular pattern that can be reasonable assumed to be veins. The presence of only a center line drawn through the center of the leaf will NOT count as venation	Lines that are drawn on the “leaf” indicators that consists of a center lines with additional lines extending from OR a series of lines drawn across the leaf in a regular pattern that can be reasonable assumed to be veins. The must be more than just a center line drawn down the center of the leaf
<i>Accurate Leaf #</i>	A number other than one to three leaves are indicated from the same or multiple origins on the “plant stem”	One only one leafs is originates from the “plant stem(s)”
<i>Accurate Venation</i>	Lines determined to be “venation” are drawn in a pattern similar to parallel or cross hatched OR no lines are present representing venation	Lines determined to be “venation” are drawn in a pattern resembling netting or netted venation.
<i>Accurate Branching</i>	The branching from the “plant stem” represent 1 or more petioles all originating from multiple origin points that the top or side of the “plant stem” OR there is no apparent branching or change in stem appearance to indicate petiole growth	The branching from the “plant stem” represent 1 or more petioles all originating from 1 origin point that the top of the “plant stem”
<i>Accurate Root Structure</i>	No root structure or hair-like or thin branching lines are drawn below an indicator or “ground” or below a structure that can be reasonably assumed to be “stem.”	A “bulb” or circular structure with or without small “hair-like” structures are at the base is drawn below an indicator or “ground” or below a structure that can be reasonably assumed to be “stem.”
<i>Leaf Symmetry</i>	The two sides of the “leaf” are NOT drawn to represent relative mirror images of each other.	The two sides of the “leaf” are drawn to represent relative mirror images of each other.
<i>Accurate Leaf Shape</i>	Edges of leaves are drawn to be smooth, with no indication of jagged edges.	Edges of leaves are drawn to be wavy or lobed and large.

Table B1. *Bloodroot Drawing Rubric (continued)*



Sign	0=No	1=Yes
<i>Large Leaf</i>	Leaf is jagged, lobed, small or smaller than the flower and/ or asymmetrical	“leaf” structure is large, lobed or wavy edges and symmetrical.
<i>Accurate Flower #</i>	More than 1 structure that can reasonable assumed to be a flower is indicated	Only 1 structure that can reasonable assumed to be a flower is indicated
<i>Accurate Flower Shape</i>	The indicated flower has a shaped like a tulip or any other shape that DOES NOT resemble: 	The indicated flower has a shape that resembles: 

Table B2
Poison Ivy Rubric

Sign	0=No	1=Yes
<i>Stem</i>	No single or double line is draw that could reasonably be assumed to be an indicator of a “plant stem”	A single or double line is present connected or unconnected to leaf structures that can reasonable be assumed to be an indicator of a “plant stem”
<i>Leaves</i>	No simple, lobed or serrated shape, possibly drawn connected to or in close proximity to a “plant stem” can reasonably be identified	A simple, lobed or serrated shape, possibly drawn connected to or in close proximity to a “plant stem” can reasonably be identified
<i>Roots</i>	No series of hair like or thin branching lines or other structures are drawn below the “plant stem” or below an indicator of “ground” that can reasonably be assumed to be “roots”	A series of hair like or thin branching lines or other structures are drawn below the “plant stem” or below an indicator of “ground” that can reasonably be assumed to be “roots”
<i>Flower</i>	No structure is present that is drawn differently than the “leaf.”	A structure that is drawn differently than the “leaf,” and may connected to the upper portion or end of a “plant stem”
<i>Branching</i>	The “plant stem” is draw in such a way that there is only a single line or double line that does not divide or give indicators to be reasonable assumed to be the petiole.	The “plant stem” is draw in such a way that there is first a single line or double line that then divides into two or more connected “branches”
<i>Woody Stem</i>	No shift in texture or stem thickness is represented at the branching point of the “plant stem”	A shift in texture or stem thickness is represented at the branching point of the “plant stem”
<i>Venation</i>	No lines drawn on the “leaf” that consists of a center lines with additional lines extending from it OR a series of lines drawn across the leaf in a regular pattern that can be reasonable assumed to be veins.	Lines drawn on the “leaf” that consists of a center lines with additional lines extending from it OR a series of lines drawn across the leaf in a regular pattern that can be reasonable assumed to be veins.

Table B2. *Poison Ivy Rubric (continued)*

Sign	0=No	1=Yes
<i>Accurate Leaf #</i>	A number other than three leaves are indicated from the same or multiple origins on the “plant stem”	Three leaves are indicated either clustered in groups of 3 or represented singly on the end of three separate petioles.
<i>Accurate Venation</i>	Lines determined to be “venation” are drawn in a pattern other than pinnate OR no lines are present representing venation	Lines determined to be “venation” are drawn in a pattern resembling pinnate
<i>Accurate Branching</i>	The branching from the “plant stem” or more petioles all originating from multiple origin points at the top or side of the “plant stem” OR there is no apparent branching or change in stem appearance to indicate petiole growth	The branching from the “plant stem” represent 1 or more petioles all originating from 1 origin point at the top of the “plant stem”
<i>Leaf Serrations</i>	“leaf” appearance has smooth or lobed edges	“leaf” appearance is jagged without smooth edges
<i>Leaf Asymmetry</i>	The two sides of the “leaf” are drawn to represent relative mirror images of each other.	The two sides of the “leaf” are not drawn represent relative mirror images of each other.
<i>Leaf Clusters</i>	Leaves originate from multiple origins	All drawn leaves originate from one point/one petiole.
<i>Thorns</i>	No Thorns or short lines that can be reasonably assumed to be “thorns” are drawn originating from the “plant stem” in an alternating or parallel fashion	Thorns or short lines that can be reasonably assumed to be “thorns” are drawn originating from the “plant stem” in an alternating or parallel fashion
<i>Leaf Scars</i>	No Bumps or circles that can be reasonable assumed to be intentionally drawn on the “plant” stem”	Bumps or circles that can be reasonable assumed to be intentionally drawn on the “plant stem” in the region that would be the “Woody stem” portion.

Table B3
Wild Leek Rubric

Sign	0=No	1=Yes
<i>Stem</i>	No single or double line is draw that could reasonably be assumed to be an indicator of a “plant stem”	A single or double line is present connected or unconnected to leaf structures that can reasonable be assumed to be an indicator of a “plant stem”
<i>Leaves</i>	No simple, long, dagger-like structure possibly drawn connected to or in close proximity to a “plant stem” can reasonably be identified	A simple, long, dagger-like structure, possibly drawn connected to or in close proximity to a “plant stem” can reasonably be identified
<i>Roots</i>	No series of hair like or thin branching lines or other structures such as “bulbs” are drawn below the “plant stem” or below an indicator of “ground” that can reasonably be assumed to be “roots”	A series of hair like, thin branching lines or other structures such as “bulbs” are drawn below the “plant stem” or below an indicator of “ground” that can reasonably be assumed to be “roots”
<i>Flower</i>	No structure is present that is drawn differently than the “leaf” signs, but is connected to the upper portion or end of a “plant stem” and can reasonable be assumed	A structure that is drawn differently than the “leaf” signs, but is connected to the upper portion or end of a “plant stem”
<i>Branching</i>	Only one “plant stem” is drawn in such a way that there is only a single line OR double line that does not divide or give indicators to be reasonable assumed to be a petiole or second “stem”.	More than one “plant stem” is drawn in such a way that there is more than a single line or double line that divides or give indicators to be reasonable assumed to be a petiole or second “stem”.
<i>Color Variation from Stem to Leaf</i>	No indication that the stem and leaf vary in color.	There is indication that the stem and leaf vary in color. May be indicated by darkening the color of the “stem” or “leaf” structure OR varying of coloring pattern (i.e. cross hatch lines to indicated darker stem).

Table B3. *Wild Leek Rubric (continued)*

Sign	0=No	1=Yes
<i>Venation</i>	No lines drawn on the “leaf” that consists of a center lines with additional lines extending from OR a series of lines drawn across the leaf in a regular pattern that can be reasonable assumed to be veins. The presence of only a center line drawn through the center of the leaf will NOT count as venation	Lines drawn on the “leaf” that consists of a center lines with additional lines extending from OR a series of lines drawn across the leaf in a regular pattern that can be reasonable assumed to be veins. The must be more than just a center line drawn down the center of the leaf
<i>Accurate Leaf #</i>	A number other than one to three leaves are indicated from the same or multiple origins on the “plant stem”	One to Three leaves are indicated from origins on the “plant stem(s)”
<i>Accurate Venation</i>	Lines determined to be “venation” are drawn in a pattern other than parallel OR no lines are present representing venation	Lines determined to be “venation” are drawn in a pattern resembling parallel
<i>Accurate Branching</i>	The branching from the “plant stem” represent 1 or more petioles all originating from multiple origin points that the top or side of the “plant stem” OR there is no apparent branching or change in stem appearance to indicate petiole growth	The branching from the “plant stem” represent 1 or more petioles all originating from 1 origin point that the top of the “plant stem”
<i>Accurate Root Structure</i>	No root structure or hair-like or thin branching lines are drawn below an indicator or “ground” or below a structure that can be reasonably assumed to be “stem.”	A “bulb” or circular structure with or without small “hair-like” structures are at the base is drawn below an indicator OR “ground” or below a structure that can be reasonably assumed to be “stem.”
<i>Leaf Symmetry</i>	The two sides of the “leaf” are NOT drawn to represent relative mirror images of each other.	The two sides of the “leaf” are drawn to represent relative mirror images of each other.
<i>Leaf Serrations</i>	Edges of leaves are drawn to be smooth, with no indication of jagged edges.	Edges of leaves are drawn to be consistently or partially jagged.
<i>Dagger Shaped Leaf</i>	“Feaf” structure is lobed, serrated, asymmetrical, or oval.	Leaf is “dagger” shaped. That is, it is a symmetrical Linear leaf.

APPENDIX C. SPECIES LIST AND SPIKE STATISICAL RESULTS

Table C1
Species List and Seeding Rates (Seeds/m²) for USFWS Sites

Species	Ekre	CGREC
Big bluestem (<i>Andropogon gerardii</i>)	42	37
Black-eyed Susan (<i>Rudbeckia hirta</i>)*	750	750
Common yarrow (<i>Achillea millefolium</i>)*	750	750
Green needlegrass (<i>Nassella viridula</i>)		37
Indiangrass (<i>Sorghastrum nutans</i>)	42	
Lewis flax (<i>Linum lewisii</i>)*	750	750
Little bluestem (<i>Schizachyrium scoparium</i>)	42	37
Prairie coneflower (<i>Ratibida columnifera</i>)*	750	750
Purple prairie clover (<i>Dalea purpurea</i>)	42	37
Side oats grama (<i>Bouteloua curtipendula</i>)	42	37
Slender wheatgrass (<i>Elymus trachycaulus</i>)		37
Stiff sunflower (<i>Helianthus pauciflorus</i>)	42	37
Western wheatgrass (<i>Pascopyrum smithii</i>)		37
White prairie clover (<i>Dalea candida</i>)	42	37

Table C2
Richness and Diversity Analysis for 2015 of the Spike Seedings T-Test. Paired Two Sample for Means

	Spike	Not
Mean	23.42857	20.71429
Variance	14.28571	7.904762
Observations	7	7
Pearson Correlation	0.876056	
Hypothesized Mean Difference	0	
df	6	
t Stat	3.8	
P(T<=t) one-tail	0.004484	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.008968	
t Critical two-tail	2.446912	

Table C3
Planted Diversity for 2015 T-Test. Paired Two Sample for Means

	Spike	Not
Mean	2.276571	2.035429
Variance	0.123187	0.351988
Observations	7	7
Pearson Correlation	0.878131	
Hypothesized Mean Difference	0	
df	6	
t Stat	1.92834	
P(T<=t) one-tail	0.051039	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.102079	
t Critical two-tail	2.446912	

Table C4
Planted Richness and Diversity Analysis for 2016 T-Test. Paired Two Sample for Means

	Spike	Not
Mean	19.28571	15.71429
Variance	10.2381	9.571429
Observations	7	7
Pearson Correlation	0.699916	
Hypothesized Mean Difference	0	
Df	6	
t Stat	3.872983	
P(T<=t) one-tail	0.004119	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.008237	
t Critical two-tail	2.446912	

Table C5
Planted Diversity 2016 T-Test. Paired Two Sample for Means

	Variable 1	Variable 2
Mean	2.430286	2.184571
Variance	0.094192	0.223546
Observations	7	7
Pearson Correlation	0.961982	
Hypothesized Mean Difference	0	
df	6	
t Stat	3.310794	
P(T<=t) one-tail	0.008094	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.016189	
t Critical two-tail	2.446912	

Table C6
Planted Species Richness T-Test. Paired Two Sample for Means

	Spike	Not
Mean	23.42857	20.71429
Variance	14.28571	7.904762
Observations	7	7
Pearson Correlation	0.876056	
Hypothesized Mean Difference	0	
df	6	
t Stat	3.8	
P(T<=t) one-tail	0.004484	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.008968	
t Critical two-tail	2.446912	

Table C7
Planted Richness and Diversity Analysis for 2016 of the Spike Seedlings T-Test. Paired Two Sample for Means

	Spike	Not
Mean	2.276571	2.035429
Variance	0.123187	0.351988
Observations	7	7
Pearson Correlation	0.878131	
Hypothesized Mean Difference	0	
Df	6	
t Stat	1.92834	
P(T<=t) one-tail	0.051039	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.102079	
t Critical two-tail	2.446912	

Table C8
2016 Forb Cover T-Test. Paired Two Sample for Means

	Spike	Not
Mean	28.07796	25.64167
Variance	96.6195	132.8311
Observations	7	7
Pearson Correlation	0.643967	
Hypothesized Mean Difference	0	
Df	6	
t Stat	0.705215	
P(T<=t) one-tail	0.253558	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.507116	
t Critical two-tail	2.446912	

Table C9
2016 Planted Relative Cover T-Test. Paired Two Sample for Means

	Spike	Not
Mean	70.44044	64.72021
Variance	33.15133	82.51133
Observations	7	7
Pearson Correlation	0.473831	
Hypothesized Mean Difference	0	
Df	6	
t Stat	1.861504	
P(T<=t) one-tail	0.055995	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.11199	
t Critical two-tail	2.446912	

Table C10
 2016 Thistle Cover T-Test. Paired Two Sample for Means

	Spike	Not
Mean	10.00794	4.988095
Variance	29.03285	10.1746
Observations	7	7
Pearson Correlation	0.960969	
Hypothesized Mean Difference	0	
Df	6	
t Stat	5.344742	
P(T<=t) one-tail	0.000877	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.001753	
t Critical two-tail	2.446912	

Table C11
2015 Canada Thistle Cover T-Test. Paired Two Sample for Means

	Spike	Not
Mean	8.565476	3.625
Variance	28.11103	2.73669
Observations	7	7
Pearson Correlation	0.784159	
Hypothesized Mean Difference	0	
Df	6	
t Stat	3.161712	
P(T<=t) one-tail	0.009761	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.019523	
t Critical two-tail	2.446912	

Table C12
Planted Forb Species 2016 T-Test. Paired Two Sample for Means

	Spike	Not
Mean	20.77792	16.23035
Variance	129.5942	160.0727
Observations	7	7
Pearson Correlation	0.886676	
Hypothesized Mean Difference	0	
Df	6	
t Stat	2.055823	
P(T<=t) one-tail	0.042775	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.08555	
t Critical two-tail	2.446912	

Table C13
Planted Forb Species 2016 T-Test. Paired Two Sample for Means

	Spike	Not
Mean	20.77792	16.23035
Variance	129.5942	160.0727
Observations	7	7
Pearson Correlation	0.886676	

Table C14
 2015 Planted Relative Cover T-Test. Paired Two Sample for Means

	Spike	Not
Mean	63.51641	55.03775
Variance	268.5572	309.23
Observations	7	7
Pearson Correlation	0.875972	
Hypothesized Mean Difference	0	
Df	6	
t Stat	2.627003	
P(T<=t) one-tail	0.019608	
t Critical one-tail	1.94318	
P(T<=t) two-tail	0.039217	
t Critical two-tail	2.446912	