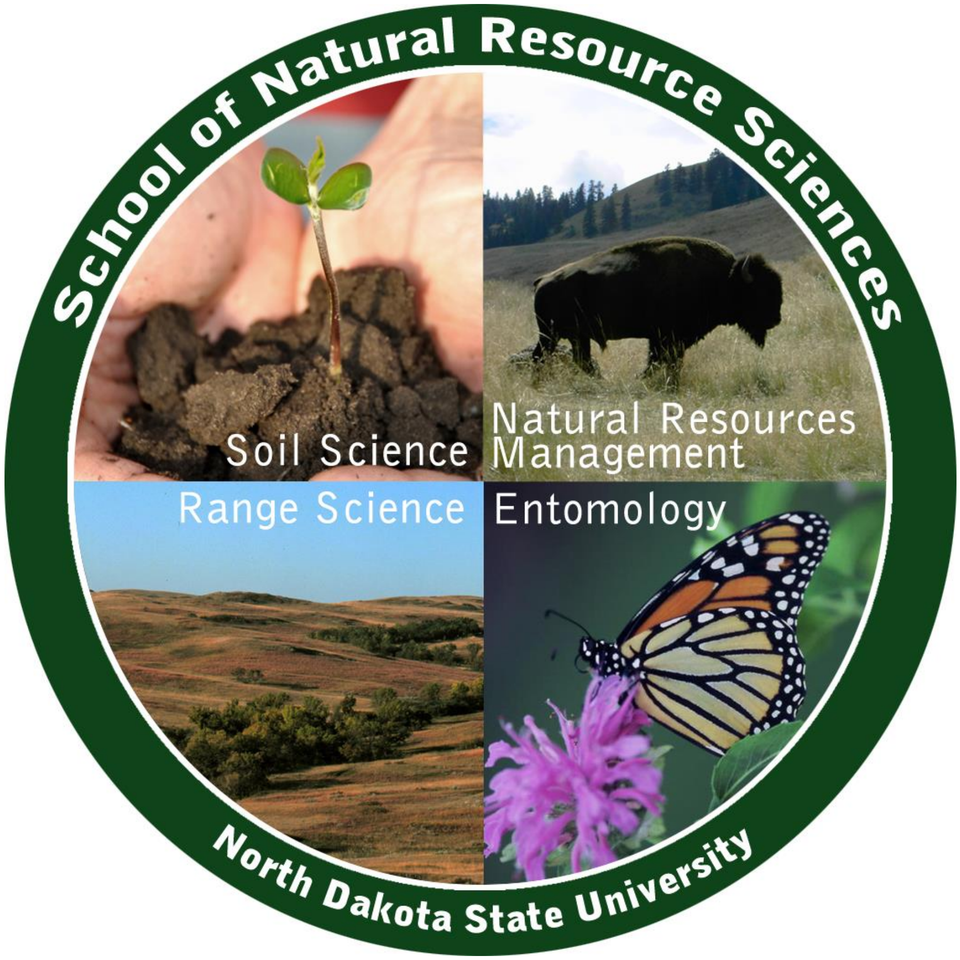
Management practices to improve soil and vegetation parameters on reclaimed North Dakota coal mine lands



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North Dakota State University

1 April 2016

Total Request to the Lignite Research Council - $578,187

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NDSU NORTH DAKOTA STATE UNIVERSITY

GRANT APPLICATION TRANSMITTAL

This page indicates university endorsement of the referenced proposal and is intended to be submitted to the sponsor organization.

Sponsor Organization: North Dakota Industrial Commission -

Project Title: *Management practices to improve soil and vegetation perimeters of reclaimed North Dakota Coal Mine Lands*

Project Director: Ryan Limb

Department: SNRS -Range

Project Budget:

Total Direct Costs		$427,766
F&A/In-direct Costs		$150,421
F&A/IDC Rate	45 %	
Total Requested		$ 578,187

Authorized University Representative: Amy Scott

Title: Assistant Director for Sponsored Programs Administration

Address: North Dakota State University
NDSU Dept. 4000, PO Box 6050
Fargo ND 58108-6050

Phone: (701) 231-8045

Signature: Amy B. Scott

Date: 4-1-16

Any future notifications regarding this proposal, including award notices, should be directed to the authorized university representative at the address listed above.
Thank you.

SPONSORED PROGRAMS ADMINISTRATION
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8045 | Fax 701.231.8098 | ndsu.research@ndsu.edu
Shipping address: Research 1 | 1735 NDSU Research Park Drive | Fargo ND 58102

1. ABSTRACT

Surface coal mining is a large-scale disturbance found on North Dakota crop and rangelands. Following the mining process, heavy machinery transports soil and applies severe pressure during the reclamation process causing soil compaction. These soils tend to have higher bulk density, less-defined structure, lower porosity, water holding capacity, infiltration rates, and shallower rooting depths than that of undisturbed sites. Following coal extraction and the reclamation process, reclaimed lands are placed into a performance bond for a minimum of 10 years until predetermined soil and vegetation parameters are satisfied. Even though the reclaimed land meets expectations, this does not mean the success of the ecosystem is performing at full potential. Below ground structure and function is largely overlooked in reclamation and therefore research is greatly needed in reclamation for a successful recovery of the ecosystem. To date, over 27,000 acres of land has gone through the formal bond release process. However, recent data collected at BNI Energy reveled that many of the soil and vegetation parameters were not improving with time as previously expected. **We propose partnering with BNI Energy, Coteau Properties Company, Coyote Creek Mining Company, and Falkirk Mining Company to evaluate existing soil management practices and implement and evaluate land remediation field trials designed to improve soil properties and native vegetation.** The project is broken into three phases spanning five years where we will evaluate management techniques incorporating both mechanical and biological actions to: 1) improve water movement between soil horizon boundaries, 2) decrease both shallow and deep soil compaction, 3) increase root abundance and depth and 4) reduce exotic grass abundance. The field-based trials will provide information to develop and deliver 1) a best management practice (BMP) document for reducing soil compaction on both crop and native reclaimed soils, 2) a BMP document for reducing exotic vegetation abundance on reclaimed lands 3) peer-reviewed publications, and 4) a final report from the experiments and pilot projects conducted from this study. **Total project costs are budgeted at $1,156,390 with the four mines contributing $420,000 collectively, North Dakota State providing $158,203, and our request to the Lignite Research Council is $578,187 over five years.** Our research team has over 75 years in both soil and vegetation expertise and experience in soil compaction, vegetation establishment and land reclamation.

2. PROJECT SUMMARY

Reclamation of surface coal mine lands is a highly regulated process affecting between 1,500 and 2,000 acres of both crop and rangeland in North Dakota. To achieve successful reclamation and, the soil horizons first need to be reconstructed followed by crop or perennial vegetation re-establishment. The working assumption on reclaimed mine land is that soil compaction and vegetation diversity will improve with time-since-reclamation due to the natural hydrologic freeze/thaw cycles and successional processes with species immigration from the soil seedbank. However, data indicates that soil compaction is not improving and plant communities are becoming increasingly non-native. Compacted soils are restricting root elongation and exotic species abundance remains higher than 80% 40 years after reclamation indicating that natural processes are soil and vegetation processes are restricted. **Therefore, there is a critical need to develop land reclamation strategies that work synergistically to reduce soil compaction and reduce exotic vegetation on reclaimed surface coal mine lands.**

We propose partnering with BNI Energy, Coteau Properties Company, Coyote Creek Mining Company, and Falkirk Mining Company to evaluate existing soil management practices and implement and evaluate land remediation field trials designed to improve soil properties and native vegetation. **We will evaluate management techniques incorporating both mechanical and biological actions to 1) improve water movement between soil horizon boundaries, 2) decrease both shallow and deep soil compaction, 3) increase root abundance and depth and 4) reduce exotic grass abundance.** The field studies are replicated across four surface coal mines in north central North Dakota to establish scientific credibility, and increase the transferability of our findings not only within the surface coal mining community, but across all North Dakota land reclamation organizations.

The field-based trials will provide information to develop and deliver 1) a best management practice (BMP) document for reducing soil compaction on both crop and native reclaimed soils, 2) a BMP document for reducing exotic vegetation abundance on reclaimed lands 3) peer-reviewed publications, and 4) a final report from the experiments and pilot projects conducted from this study. Our research team has over 75 years in both soil and vegetation expertise and experience in soil compaction, vegetation establishment and land reclamation.

3. BACKGROUND

Surface coal mining is a large-scale disturbance found on North Dakota crop and rangelands. In surface mining process, the original vegetation is removed and the soil structure is usually lost or buried. To achieve a successful reclamation, the soil needs to be remediated and the vegetation re-established (Bradshaw 1996); in order focus on species composition and long-term sustainability (Holl 2002). The process of natural succession reveals that nature can achieve reclamation independently and develop desirable soil characteristics (Bradshaw 1996). The goal of mine-land reclamation is not necessarily to re-construct the natural species composition, but rather to provide a stable and productive stand of perennial vegetation.

Surface coalmine reclaimed soils are developing on anthropogenically-altered landscapes and are pedologically young due to the excessive removal and re-spread of the soil horizons (Sencindiver and Ammons 2000). Following the mining process, heavy machinery transports soil and applies severe pressure during the reclamation process causing soil compaction (McSweeney and Jansen 1984, Chong et al. 1986; Chong and Cowsert 1997). The principal causes of compaction are from compressive forces derived from anthropogenic disturbances (Mulholland and Fullen 1991; Davies et al. 1992; Milne and Haynes 2004; Batey 2009), often associated with industrial activities (Batey and McKenzie 2006; Sinnett et al. 2006; Batey 2009). Soil compaction can occur on the surface, within and below the tillage zone, or at greater depths (Batey 2009). Industrial activities may have more severe impacts and can cause soil compaction at depths greater than one meter that persist up to 30 years (Spoor 2006; Batey 2009). These soils tend to have higher bulk density, less-defined structure, lower porosity, water holding capacity, infiltration rates, and shallower rooting depths than that of undisturbed sites (Indorante et al 1981; Thurman and Sencindiver 1986; Dunker and Barnhisel 2000; Shukla et al 2004a). Soil compaction is intensified by low soil organic matter content or heavy equipment at high soil moisture contents (Batey 2009). This results in higher resistance to root penetration and reduced root elongation and can limit the rooting depth of the vegetation (Fehrenbacher et al. 1982; Thompson et al. 1987; Bradshaw 1996; Chong and Cowsert 1997).

The mining and reclamation process is an extensive procedure, and reclamation success is largely determined by comparisons of above ground vegetative cover, species diversity, and productivity between reclaimed and undisturbed reference areas (Schumann et al. 1999; Ries and Nilson 2000; Wick 2007). Following coal extraction and the reclamation process, reclaimed lands are placed into a performance bond for a minimum of 10 years (SMCA 1977) until predetermined soil and vegetation parameters are satisfied. Even though the reclaimed land meets expectations, this does not mean the success of the ecosystem is performing at full potential. Below ground structure and function is largely overlooked in reclamation (Dangi et al. 2011), and therefore research is greatly needed in reclamation for a successful recovery of the ecosystem.

4. VALUE to NORTH DAKOTA

North Dakota surface coal mines have been and are currently active in post-mining reclamation with between 1,500 and 2,000 acres of land disturbed and reclaimed annually among mines. Collectively, more than 27,000 acres (approximately 40 square miles) of permitted land has gone through the final bond release process with reclamation costs ranging between $30,000 and $60,000 per acre. With reclamation costs far exceeding the land value, it is imperative that reclamation strategies implemented be both cost effective and successful. While yield and composition data is collected and compared to established references as part of the bond release protocol, a formal evaluation of reclamation procedures has not occurred since their implementation. Largely, previous research was focused on above ground data relevant to soil respreads, seeding rates, diversity, and production, but have not looked in detail at the below ground aspects of reclamation, soil health, and the interconnections between the reclaimed soil variables and vegetation.

The working assumption on reclaimed mine land is that soil structure and composition and plant community diversity will increase with time-since-reclamation due to successional processes and species immigration from soil seedbanks and seed rain. Reclamation and soil development can be left to natural processes such as vegetation establishment, and freeze-thaw cycles. However, the natural succession process is time consuming, and can take many decades before an acceptable vegetation cover establishes (Bradshaw 1996). Recent data collected on reclaimed lands at BNI Energy indicated that root biomass had no positive relationship in rooting depths per year, yet, there was a significant inverse relationship of rooting depth and biomass constant over all reclamation years (Figure 1). Shallow root biomass in the top 15 cm was substantially more than root

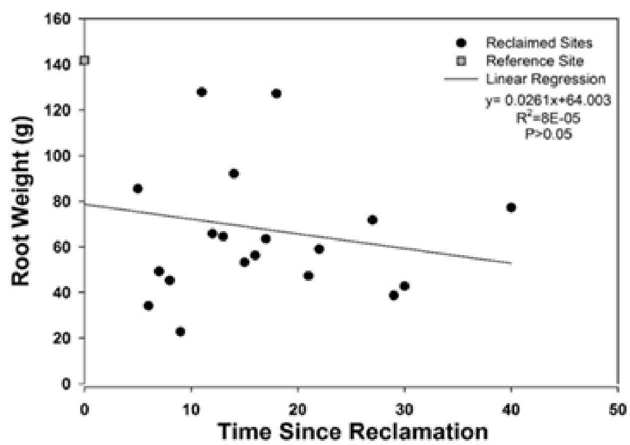

Figure 1: Total root biomass per reclamation year at BNI Energy sites.

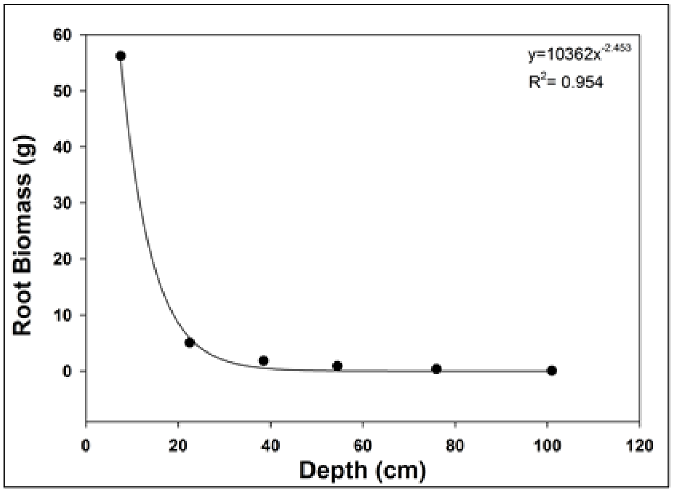

Figure 2: Root biomass incrementally with soil depth. Subsurface soil compaction restricts root elongation below 20 cm.

biomass below 15 cm (Figure 2) indicating that subsurface compaction is limiting root elongation. Further, data revealed no relationship between rooting biomass and compaction over the reclamation gradient, indicating soil compaction is not decreasing and vegetative roots are not penetrating the compaction layers as time progresses (Figure 3).

Root depths vary with prior research suggesting that compacted reclaimed soils have significantly higher penetration resistance than the reference soils throughout the profile indicating the potential for restricted root growth (Bengough et al. 2011). However, roots that are impeded in a compacted layer can still elongate, but at a reduced rate due to mechanical resistance when continuing down soil profile (Targieu 1994). Further, improved soil structure, decrease compaction, and increased porosity of the reclaimed soils is not progressing with time as previously thought (Figure 3). Loose zones, cracks or soil macro fauna channels are preferential to roots because they help lead the way for root penetration (Targieu 1994).

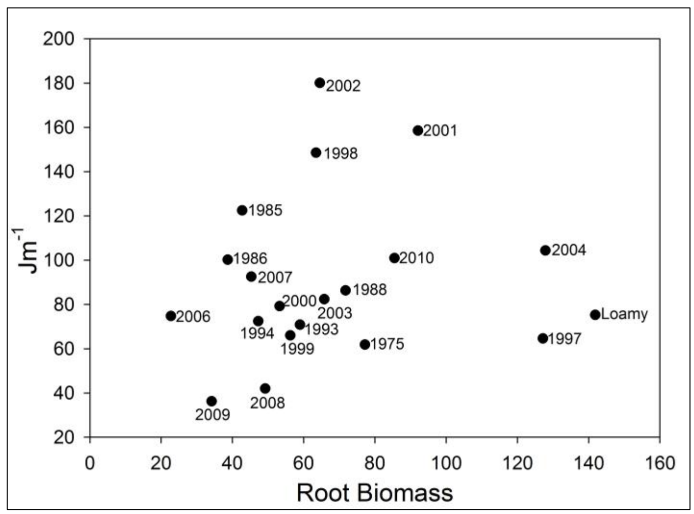

Figure 3. Root biomass (g) with regards to soil strength (J). Older sites are expected to have higher root biomass, and less soil strength, but no trend is apparent.

Similar to belowground processes, aboveground vegetation "recovery" is not progressing toward a more native community with time (Figure 4). Native plant species are present in early years post-reclamation, but quickly get displaced by increased Kentucky bluegrass and reclaimed sites are becoming less native over time. Kentucky bluegrass creates a positive feedback between above and belowground processes, stalling soil development and vegetation succession. The shallow and fine roots of Kentucky bluegrass are capable of taking advantage of abundant soil water held close to the soil surface by compacted subsoil found on reclaimed sites. Once established, thick thatch layers restrict native plant establishment and growth. Native grasses and forbs have larger and deeper roots, which facilitate vertical soil water movement and freeze/thaw cycles capable of decreasing soil compaction. Without the deeper-rooted plant species creating fractures in the soil, soil water stays shallow, Kentucky bluegrass abundance increases and soil compaction remains high. **Therefore, there is a critical need to develop land reclamation strategies that work synergistically to reduce soil compaction and reduce exotic vegetation on reclaimed surface coal mine lands.**

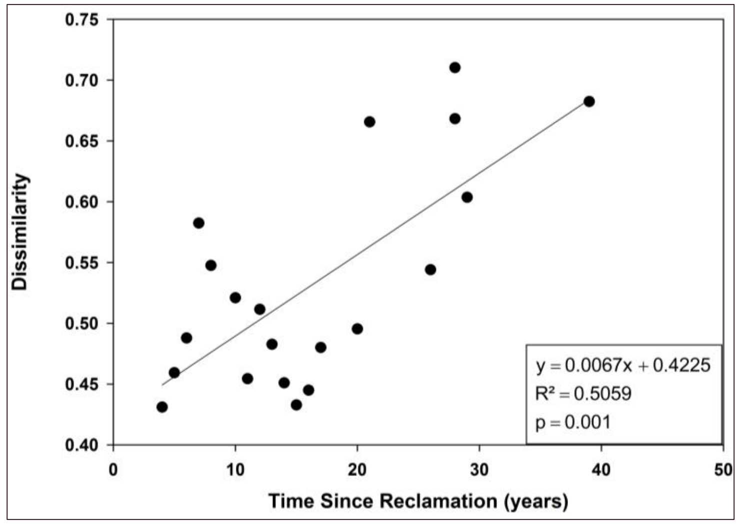

Figure 4. Mean dissimilarity to reference sites over a 40-year reclamation gradient. Sites are becoming less native with time.

Beyond surface coal mining, North Dakota is active in energy production with 10,438 active oil wells, and 12 wind farms producing 6.34 billion kilowatt-hours of electricity. Associated with each of these oil wells and wind turbines are pad sites, access roads, pipelines, transfer stations, etc. that will need to be reclaimed when their usefulness expires. Similar to surface coal land, soil compaction and exotic species will limit reclamation success. Reclamation strategies developed by this project for the surface coal industry will be directly transferable to other industries to increase reclamation success across North Dakota.

5. PROJECT DESCRIPTION

This project is divided into three phases with the first two phases addressing soil compaction on: 1) previously reclaimed land with established perennial vegetation, 2) reclaimed native sites without perennial vegetation and 3) reclaimed crop sites prior to crop establishment. The third phase of the project will address native and exotic vegetation abundance on reclaimed land. Collectively, treatments will be implemented across each of the four mines, with each of the three phases implemented on two of the active mines depending on the availability of reclaimed native and cropland sites.

5.1 Phase I

Mines are currently incorporating soil management practices to address soil compaction during the reclamation process. The North Dakota Public Service Commission regulations allow the use of subsoilers within soil horizons to break up soil. However, this technique has not been formally evaluated for surface and sub-surface soil compaction. We will evaluate a series of sites treated with subsoilers ranging in years since reclamation. We expect that all treated sites will have less surface soil compaction than non-treated sites and that sub-surface soil compaction will not be different than non-treated sites. Further we expect that surface soil compaction on recently treated sites will not be different than older sites.

5.2 Phase II

To reduce surface and sub-surface soil compaction on reclaimed sites, novel treatments incorporating both mechanical and biological practices will implemented and examined on non-vegetated crop and native sites and previously vegetated sites.

5.2.1 Non-reclaimed sites

Treatments will combine the mechanical action of subsoilers both within soil horizons and across soil horizons and the biological action of dry mulch and freeze/thaw cycles to reduce soil compaction (Figure 5). Using a factorial design, half of the sites will be treated with the subsoiler across surface and sub-surface soils and half will be treated within surface soils only. A super absorbent polymer will be incorporated into the soil behind the subsoiler splitting each plot in half. The polymer absorbs available soil water and hold it in place, which will maintain the space created by the subsoiler and facilitate the freeze/thaw cycle to further fracture the soil. Additionally, dry mulch (hay/straw) will be spread between subsoil and topsoil layers on half of the sites to increase organic matter content. After subsoiler, polymer and mulch treatment are in place, sites will be planted back to either grass, grass with native forbs, or crop. Treatments will be at least 1 acre in size, to allow equipment to run at working speeds, and replicated three times at each of the two locations. All treatments will be compared to adjacent controls. We expect that interactions of subsoil treatments, polymer and mulch treatments will reduce compaction beyond any of the independent treatments.

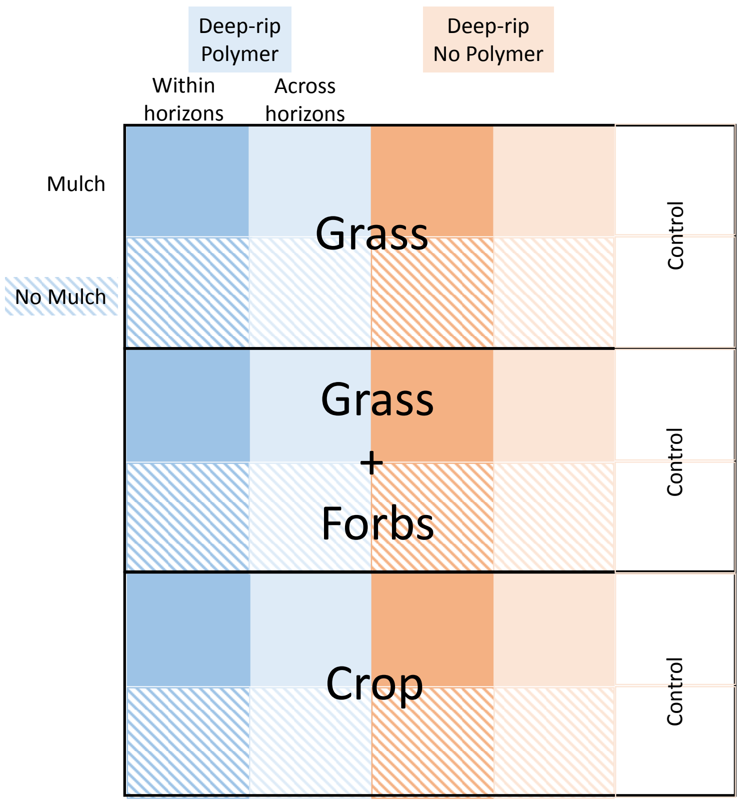

Figure 5. Factorial treatment layout on non-reclaimed sites. Each treatment block will be replicated three times at two locations.

5.2.2 Reclaimed sites

Sites with existing perennial vegetation are somewhat restricted in available treatments without access to subsoil layers. Similar to the non-reclaimed sites, treatments will combine the mechanical action combined with biological action to reduce soil compaction (Figure 6). Two mechanical soil treatments will include deep ripping with a subsoiler across soil horizons with and without the super absorbent polymer, and the novel use of soil plugging to remove soil cores and create channels for vertical water movement and root elongation. A fourth treatment will interseed an annual Daikon radish (rootcrop). As the radish grows and subsequently dies, it will create pockets of organic matter to facilitate water movement from the surface down the soil profile and initiate the freeze/thaw cycle to reduce soil compaction. All treatments will be at least 1 acre in size to allow equipment to run at working speeds and replicated three times at two locations.

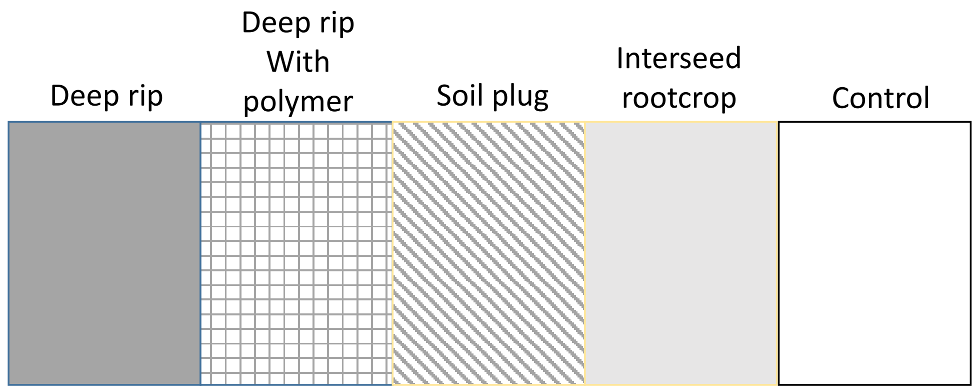

Figure 6. Treatment layout on reclaimed sites. Each treatment block will be replicated three times at two locations

5.3 Phase III

Previous reclamation research focused on topsoil respreads depths to maximize native plant establishment and productivity. While this work was vital to the timely reclamation of hay and rangeland plant communities, it occurred when Kentucky bluegrass was not problematic in North Dakota. Currently, respreads depths allow for the initial establishment of native grass species, but also facilitates the subsequent invasion of Kentucky bluegrass by holding abundant soil water. Kentucky bluegrass is not a drought tolerant plant and does not readily invade shallow ecological sites (USDA NRCS 2016). However, it is unclear what topsoil respreads depth is best to establish native species while minimizing exotic grasses. Therefore, we will investigate a series of increasingly shallow topsoil depths. Each respreads depth will be separated by a strip of Roundup Ready® crop to reduce the spread of plant species across soil depth treatments. Additionally, the timing of native planting will be evaluated with half of each soil depth being planted back to native species in year 1. The second half of each soil depth will be first planted to a Roundup Ready® covercrop and sprayed with a non-selective herbicide to reduce plant establishment from the soil seed bank. The second year, native species will be established. Each soil depth and timing of native planting combination will be at least 1 acre in size and replicated three times at each of two locations (Figure 7).

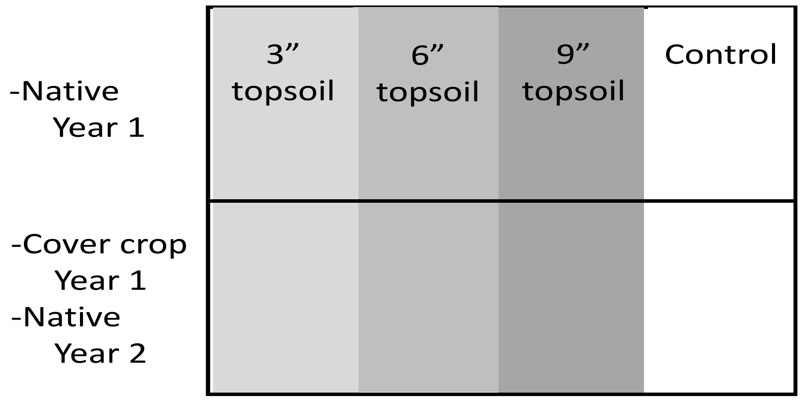

Figure 7. Soil respread depth and timing of native planting treatments. Each respreads depth and planting timing combination will be replicated three times at two locations.

5.4 Treatment evaluation and sampling

Common among all treatments, soil penetration resistance will be measured using a hydraulic cone penetrometer to a depth of at least 36 inches. The hydraulic cone penetrometer allows for consistent measurement between observers and soil types and provides continuous penetration resistance data with soil depth. Additionally, soil water content will be measured incrementally down to a depth of 36 inches.

Soil cores will be extracted at each location for laboratory analysis. Soil from each treatment will be analyzed for organic carbon and soil aggregate size incrementally down to a depth of 36 inches (van Genuchten and Wierenga 1976, Jaynes et al. 1995).

In addition to the previous analysis, reclaimed native sites will be surveyed for vegetation species composition, abundance and production. Root biomass and diameter will be measured incrementally to a depth of 48 inches and evidence of earthworm activity will be recorded. Crop yield will be measured on reclaimed crop sites.

6. STANDARDS of SUCCESS

Deliverables

6.1 Best management practice document for reducing soil compaction of reclaimed soils on cropland

6.2 Best management practice document for reducing soil compaction of reclaimed soils on rangeland

6.3 Best management practice document for reducing exotic vegetation abundance on reclaimed rangelands

6.4 Peer-reviewed scientific publications.

6.5 Quarterly reports to the NDIC LRC highlighting the results of ongoing reach and outlining upcoming activities.

6.6 Final report from the projects conducted in this study.

7. TIMETABLE

This project is anticipated to take effect on 1 June 2016 and extend five (5) years with a project end date of 31 May 2021.

	Year 1				Year 2				Year 3				Year 4				Year 5			
	2016		2017				2018				2019				2020				2021	
Project implementation																				
Phase 1 sampling	x	x																		
Phase 2 treatment implementation	x	x	x																	
Phase 2 sampling				x	x			x	x			x	x			x	x			
Phase 3 treatment implementation	x	x	x	x																
Phase 3 sampling				x	x			x	x			x	x			x	x			
Products																				
Best Management Practice compaction cropland														x						
Best Management Practice compaction rangeland														x						
Best Management Practice vegetation																				x
Submit scientific papers																			x	x
Reporting																				
Quarterly report		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Final report																				x

Table 1. Timeline of project milestones and products.

8. MANAGEMENT

This project has one principal investigator and project director, Dr. Ryan F. Limb, and 3 co-principal investigators, Drs. Kevin Sedivec, Aaron Daigh, and Thomas DeSutter with North Dakota State University (NDSU). As the project director, Dr. Limb will coordinate all research activities and oversee all expenditures. Dr. Jay Volk has agreed to be the principal contact representing the four mines. Coordinated meetings among NDSU personnel will occur monthly to discuss project development and timelines. Similarly, coordinated meeting among the four mines will occur monthly. Additionally, Dr. Limb and Dr. Volk will communicate monthly. Project meetings will occur semiannually prior to and at the end of each field season to facilitate treatment implementation and data collection.

The project was strategically divided into three phases to provide periodic check points. Quarterly reports to the Lignite Research Council will provide a consistent means of quantifying progress toward both 1) short-term goals (site selection, personnel, treatment implementation, etc) and 2) long-term goals (BMPs, and scientific publications). The research team at NDSU is well accustomed to managing large projects with complex budgets, treatments, and data acquisition. We pride ourselves on successfully managing large research labs and producing highly trained students and timely scientific output.

9. BUDGET

LIGNITE RESEARCH COUNCIL	2016	2017	2018	2019	2020	2021	TOTAL
1. PERSONNEL							
I. Salary							
a. Graduate Research Associate (4 M.S. and 1 Ph.D.)	0	39331	41144	43577	22442	0	**146494**
b. Undergraduate Research Technician (8@$13/hr)	0	0	0	0	0	0	**0**
II. Benefits	0	0	0	0	0	0	**0**
a. Graduate Research Associate (3%)	0	1180	1234	1307	672	0	**4393**
c. Undergraduate Research Technician (10%)	0	0	0	0	0	0	**0**
Total Personnel	**0**	**40511**	**42378**	**44884**	**23114**	**0**	**150887**
2. EXPENDIBLE MATERIALS and SUPPLIES							
I. Computer	0	0	0	0	0	0	**0**
II. Computer Software	0	0	0	0	0	0	**0**
III. Handheld GPS units	0	0	0	0	0	0	**0**
IV. Stacked polymer powder	0	5000	0	0	0	0	**5000**
V. Sampling equip.	3495	0	0	0	0	0	**3495**
Total Supplies	**3495**	**5000**	**0**	**0**	**0**	**0**	**8495**
3. EQUIPMENT							
I. Travel trailers (2@$12,000 ea)	24000	0	0	0	0	0	**24000**
II. Soil moisture probe	8500	0	0	0	0	0	**8500**
III. Soil plugger/aerator	9000	0	0	0	0	0	**9000**
IV. Hydraulic soil penetrometer	52000	0	0	0	0	0	**52000**
Total Equipment	**93500**	**0**	**0**	**0**	**0**	**0**	**93500**
4. TRAVEL							
I. Travel to field sites	14600	15450	15914	16392	16884	0	**79240**
II. Travel to scientific meetings	0	0	0	0	0	0	**0**
a. In-state	0	0	0	0	0	2320	**2320**
b. National	4000	4120	4244	4372	4504	4640	**25880**
II. Travel to safety training	0	0	0	0	0	0	**0**
Total Travel	**18600**	**19570**	**20158**	**20764**	**21388**	**6960**	**107440**
5. FEES							
I. Journal Publication Fees	0	0	0	0	0	1000	**1000**
II. Lot rental (Travel trailer)	1500	3000	3090	3183	3279	0	**14052**
III. Travel trailer maintenance	1200	1236	1274	1313	1353	0	**6376**
IV. Soil organic content	2500	2575	2653	2733	2815	0	**13276**
V. Soil leaching	2800	2884	2971	3061	3153	0	**14869**
VI. Track vehicle/soil core rental ($200/day)	3000	3090	3183	3279	3378	0	**15930**
VII. MSHA training	1525	416	0	0	0	0	**1941**
Total Fees	**12525**	**13201**	**13171**	**13569**	**13978**	**1000**	**67444**
6. TOTAL DIRECT COSTS	**128120**	**78282**	**75707**	**79217**	**58480**	**7960**	**427766**
7. INDIRECT COSTS							
I. 45% of Modified Total Direct Costs	15579	35227	34069	35648	26316	3582	**150421**
Total Indirect Costs	**15579**	**35227**	**34069**	**35648**	**26316**	**3582**	**150421**
8. TOTAL REQUEST	143699	113509	109776	114865	84796	11542	**578187**

Budget Justification
The primary portion of the proposed research to be conducted at North Dakota State University (NDSU) will be a field experiment that measures a suite of reclamation practices to improve soil and vegetation parameters. Limb et al. will be performing the field studies at BNI Energy, Coyote Creek Mining Company LLC, Coteau Properties Company, and Falkirk Mining Company. Supportive work will be done on the main campus of NDSU where PI's have adequate laboratory and greenhouse space. A 3% increase for inflation is included each year.

TOTAL REQUEST - $578,187

Personnel - $150,887
The funds requested will partially support two M.S. and 1 Ph.D. graduate students for years 2, 3, 4 and 5 (Research Assistantship $39,331, $41,144, $43,577, and $22,442/yr respectively + 3% Fringe - $1,180, $1,234, $1,307, $1913, $672/yr respectively who will be coordinating much of the research.
Travel - $107,440
Annual travel for years 1, 2, 3, 4, 5 and 6 ($18,600, $19,570, $20,158, $20,764, $21,388, and $6,960/year respectively)

- *Annual Travel to and from field site (19,467 miles/yr @ $0.75/mile)*
- *Travel to in-state scientific conference in year 6 ($500 mileage, $700 meeting registration, $1,120 lodging and per diem)*
- *Annual Travel to the national scientific conference ($1,400 airfare, $600 meeting registration, $2,000 lodging and per diem)*

Expendable Materials and Supplies - $3,495
Soil and Vegetation Field Supplies in year 1 ($3,495) (clipboards, pencils, flagging, paper, field tapes, sampling frames, clippers identification books, plant presses, plot markers, scratch tags, clipping exclosures, soil collection tubes, metal detectors, coolers, digital camera, hand lenses etc.)
Equipment - $93,500

- Travel trailers ($24,000) will be used to save money on travel expenses, field crews will stay in travel trailers deployed in between the four mines respectively rather than hotels. Two travel trailers will be purchased ($12,000 ea) in year one and use for the duration of the study.
- Soil moisture probe ($8500) will be purchased in year one to measure soil moisture at variable depths
- Soil plugger/aerator ($9,000) will be constructed in year one to mechanically remove soil plugs.
- Hydraulic soil penetrometer ($52,000) will be purchased to accurately quantify soil penetration resistance across treatments.
- Stacked polymer powder (Super Slurper®) ($5,000) will be purchased in year 2 to hold soil water in place and initiate the freeze/thaw cycle.

Fees - $67,444

- Publication page charges are requested in years 6 ($1,000) to publish results in scientific journals.
- Monthly lot rental for travel trailers for all years ($14,052).
- Annual travel trailer maintenance and winterization ($6,376)
- Annual soil testing for organic content ($13,276)
- Annual soil leach testing for aggregate stability ($14,869)
- Track vehicle/soil core rental ($15,930 - $200/day)
- MSHA safety training for project personnel in years 1 and 2 ($1,941)

Indirect Costs - $148,171
University indirect costs are assessed at 45% of the total direct costs request for the North Dakota Lignite Research Council less any equipment exceeding $5,000.

10. MATCHING FUNDS

NDSU	2016	2017	2018	2019	2020	2021	TOTAL
1. PERSONNEL							
I. Salary							
a. Graduate Research Associate (4 M.S. and 1 Ph.D.)	0	0	0	0	0	0	0
b. Undergraduate Research Technician (8@$13/hr)	0	0	0	0	0	0	0
II. Benefits							
a. Graduate Research Associate (3%)	0	0	0	0	0	0	0
c. Undergraduate Research Technician (10%)	0	0	0	0	0	0	0
Total Personnel	0	0	0	0	0	0	0
2. EXPENDIBLE MATERIALS and SUPPLIES							
I. Computer	0	0	0	0	0	0	0
II. Computer Software	0	0	0	0	0	0	0
III. Handheld GPS units	0	0	0	0	0	0	0
IV. Stacked polymer powder	0	0	0	0	0	0	0
V. Sampling equip.	0	0	0	0	0	0	0
Total Supplies	0	0	0	0	0	0	0
3. EQUIPMENT							
I. Travel trailers (2@$12,000 ea)	0	0	0	0	0	0	0
II. Soil moisture probe	0	0	0	0	0	0	0
III. Soil plugger/aerator	0	0	0	0	0	0	0
IV. Hydraulic soil penetrometer	0	0	0	0	0	0	0
Total Equipment	0	0	0	0	0	0	0
4. TRAVEL							
I. Travel to field sites	0	0	0	0	0	0	0
II. Travel to scientific meetings							
a. In-state	0	0	0	0	0	0	0
b. National	0	0	0	0	0	0	0
II. Travel to safety training	0	0	0	0	0	0	0
Total Travel	0	0	0	0	0	0	0
5. FEES							
I. Journal Publication Fees	0	0	0	0	0	0	0
II. Lot rental (Travel trailer)	0	0	0	0	0	0	0
III. Travel trailer maintenance	0	0	0	0	0	0	0
IV. Soil organic content	0	0	0	0	0	0	0
V. Soil leaching	0	0	0	0	0	0	0
VI. Track vehicle/soil core rental ($200/day)	0	0	0	0	0	0	0
VII. MSHA training	0	0	0	0	0	0	0
Total Fees	0	0	0	0	0	0	0
6. TOTAL DIRECT COSTS	0	0	0	0	0	0	0
7. INDIRECT COSTS							
I. 45% of the Total Direct Costs	9310	9590	9878	10174	10148	0	49100
Total Indirect Costs	9310	9590	9878	10174	10148	0	49100
8. CASH CONTRIBUTION							
I. Personnel (approx. 17-18% effort includes FB)	20688	21309	21949	22608	22549	0	109103
II. Equipment						0	0
III. Supplies	0	0	0	0	0	0	0
Total Cash Contribution	20688	21309	21949	22608	22549	0	109103
9. TOTAL REQUEST							
I. Cash Contribution + Non-cash Contribution	29998	30899	31827	32782	32697	0	158203
Total Request	**29998**	**30899**	**31827**	**32782**	**32697**	**0**	**158203**

Falkirk Mining	2016	2017	2018	2019	2020	2021	TOTAL
1. PERSONNEL							
I. Salary							
a. Graduate Research Associate (4 M.S. and 1 Ph.D.)	6306	6306	6584	6284	5975		31455
b. Undergraduate Research Technician (8@$13/hr)							0
II. Benefits							
a. Graduate Research Associate (3%)	189	189	197	189	180		944
c. Undergraduate Research Technician (10%)	0	0	0	0	0		0
Total Personnel	6495	6495	6781	6473	6155	0	32399
2. EXPENDIBLE MATERIALS and SUPPLIES							
I. Computer		2000					2000
II. Computer Software							0
III. Handheld GPS units							0
IV. Stacked polymer powder							
V. Sampling equip.	3505	661	861	1067	1280		7374
Total Supplies	3505	2661	861	1067	1280	0	9374
3. EQUIPMENT							
I. Travel trailers (2@$12,000 ea)							
II. Soil moisture probe							
III. Soil plugger/aerator							
IV. Hydraulic soil penetrometer							
Total Equipment	0	0	0	0	0	0	0
4. TRAVEL							
I. Travel to field sites							0
II. Travel to scientific meetings							0
a. In-state	2000	2060	2122	2186	2252		10620
b. National							0
II. Travel to safety training							0
Total Travel	2000	2060	2122	2186	2252	0	10620
5. FEES							
I. Journal Publication Fees			1000	1000	1000		3000
II. Lot rental (Travel trailer)							0
III. Travel trailer maintenance							0
IV. Soil organic content							0
V. Soil leaching							0
VI. Track vehicle/soil core rental ($200/day)							0
VII. MSHA training		784	1236	1274	1313		4607
Total Fees	0	784	2236	2274	2313	0	7607
6. TOTAL DIRECT COSTS	12000	12000	12000	12000	12000	0	60000
7. NON-CASH CONTRIBUTION							
I. Personnel	12000	12000	12000	12000	12000		60000
II. Equipment	0	0	0	0	0		0
III. Supplies	0	0	0	0	0		0
Total Non-cash Contribution	12000	12000	12000	12000	12000	0	60000
8. TOTAL REQUEST							
I. Cash Contribution + Non-cash Contribution	24000	24000	24000	24000	24000	0	120000
Total Request	24000	24000	24000	24000	24000	0	120000

Coteau Properties	2016	2017	2018	2019	2020	2021	TOTAL
1. PERSONNEL							
I. Salary							
a. Graduate Research Associate (4 M.S. and 1 Ph.D.)	4986	4785	4578	4367	4147		22863
b. Undergraduate Research Technician (8@$13/hr)	6240	6428	6621	6820	7025		33134
II. Benefits							
a. Graduate Research Associate (3%)	150	144	138	131	125	0	688
c. Undergraduate Research Technician (10%)	624	643	663	682	703	0	3315
Total Personnel	12000	12000	12000	12000	12000	0	60000
2. EXPENDIBLE MATERIALS and SUPPLIES							
I. Computer							
II. Computer Software							
III. Handheld GPS units							
IV. Stacked polymer powder							
V. Sampling equip.							
Total Supplies	0	0	0	0	0	0	0
3. EQUIPMENT							
I. Travel trailers (2@$12,000 ea)							
II. Soil moisture probe							
III. Soil plugger/aerator							
IV. Hydraulic soil penetrometer							
Total Equipment	0	0	0	0	0	0	0
4. TRAVEL							
I. Travel to field sites							
II. Travel to scientific meetings							
a. In-state							
b. National							
II. Travel to safety training							
Total Travel	0	0	0	0	0	0	0
5. FEES							
I. Journal Publication Fees							
II. Lot rental (Travel trailer)							
III. Travel trailer maintenance							
IV. Soil organic content							
V. Soil leaching							
VI. Track vehicle/soil core rental ($200/day)							
VII. MSHA training							
Total Fees	0	0	0	0	0	0	0
6. TOTAL DIRECT COSTS	12000	12000	12000	12000	12000	0	60000
7. NON-CASH CONTRIBUTION							
I. Personnel	12000	12000	12000	12000	12000		60000
II. Equipment	0	0	0	0	0		0
III. Supplies	0	0	0	0	0		0
Total Non-cash Contribution	12000	12000	12000	12000	12000	0	60000
8. TOTAL REQUEST							
I. Cash Contribution + Non-cash Contribution	24000	24000	24000	24000	24000	0	120000
Total Request	24000	24000	24000	24000	24000	0	120000

Coyote Creek	2016	2017	2018	2019	2020	2021	TOTAL
1. PERSONNEL							
I. Salary							
a. Graduate Research Associate (4 M.S. and 1 Ph.D.)							0
b. Undergraduate Research Technician (8@$13/hr)							0
II. Benefits							
a. Graduate Research Associate (3%)							0
c. Undergraduate Research Technician (10%)							0
Total Personnel	0	0	0	0	0	0	0
							0
2. EXPENDIBLE MATERIALS and SUPPLIES							0
I. Computer	4000						4000
II. Computer Software							0
III. Handheld GPS units	1600						1600
IV. Stacked polymer powder							0
V. Sampling equip.		3940	3878	3814	3748		15380
Total Supplies	5600	3940	3878	3814	3748	0	20980
3. EQUIPMENT							0
I. Travel trailers (2@$12,000 ea)							0
II. Soil moisture probe							0
III. Soil plugger/aerator							
IV. Hydraulic soil penetrometer							0
Total Equipment	0	0	0	0	0	0	0
4. TRAVEL							0
I. Travel to field sites	400						
II. Travel to scientific meetings							
a. In-state		2060	2122	2186	2252		8620
b. National							0
II. Travel to safety training							0
Total Travel	400	2060	2122	2186	2252	0	9020
5. FEES							
I. Journal Publication Fees							0
II. Lot rental (Travel trailer)							0
III. Travel trailer maintenance							0
IV. Soil organic content							0
V. Soil leaching							0
VI. Track vehicle/soil core rental ($200/day)							
VII. MSHA training							0
Total Fees	0	0	0	0	0	0	0
6. TOTAL DIRECT COSTS	6000	6000	6000	6000	6000	0	30000
7. NON-CASH CONTRIBUTION							
I. Personnel	3000	3000	3000	3000	3000		15000
II. Equipment	0	0	0	0	0		0
III. Supplies	3000	3000	3000	3000	3000		15000
Total Non-cash Contribution	6000	6000	6000	6000	6000	0	30000
8. TOTAL REQUEST							
I. Cash Contribution + Non-cash Contribution	12000	12000	12000	12000	12000	0	60000
Total Request	12000	12000	12000	12000	12000	0	60000

BNI	2016	2017	2018	2019	2020	2021	TOTAL
1. PERSONNEL							
I. Salary							
a. Graduate Research Associate (4 M.S. and 1 Ph.D.)	9708	9650	9590	9528	9464		47940
b. Undergraduate Research Technician (8@$13/hr)	0	0	0	0	0		0
II. Benefits							
a. Graduate Research Associate (3%)	292	290	288	286	284	0	1440
c. Undergraduate Research Technician (10%)	0	0	0	0	0	0	0
Total Personnel	10000	9940	9878	9814	9748	0	49380
2. EXPENDIBLE MATERIALS and SUPPLIES							
I. Computer							
II. Computer Software	1000	1030	1061	1093	1126		5310
III. Handheld GPS units							
IV. Stacked polymer powder							
V. Sampling equip.							
Total Supplies	1000	1030	1061	1093	1126	0	5310
3. EQUIPMENT							
I. Travel trailers (2@$12,000 ea)							
II. Soil moisture probe							
III. Soil plugger/aerator							
IV. Hydraulic soil penetrometer							
Total Equipment	0	0	0	0	0	0	0
4. TRAVEL							
I. Travel to field sites							
II. Travel to scientific meetings							
a. In-state							
b. National							
II. Travel to safety training	1000	1030	1061	1093	1126		5310
Total Travel	1000	1030	1061	1093	1126	0	5310
5. FEES							
I. Journal Publication Fees							
II. Lot rental (Travel trailer)							
III. Travel trailer maintenance							
IV. Soil organic content							
V. Soil leaching							
VI. Track vehicle/soil core rental ($200/day)							
VII. MSHA training							
Total Fees	0	0	0	0	0	0	0
6. TOTAL DIRECT COSTS	12000	12000	12000	12000	12000	0	60000
7. NON-CASH CONTRIBUTION							
I. Personnel	12000	12000	12000	12000	12000		60000
II. Equipment	0	0	0	0	0		0
III. Supplies	0	0	0	0	0		0
Total Non-cash Contribution	12000	12000	12000	12000	12000	0	60000
8. TOTAL REQUEST							
I. Cash Contribution + Non-cash Contribution	24000	24000	24000	24000	24000	0	120000
Total Request	24000	24000	24000	24000	24000	0	120000

Limb et al. Budget Justification NDSU
Management practices to improve soil and vegetation parameters on reclaimed North Dakota coal mine lands

North Dakota Lignite Research Council – Small Research

The primary portion of the proposed research to be conducted at North Dakota State University (NDSU) will be a field experiment that measures a suite of reclamation practices to improve soil and vegetation parameters. Limb et al. will be performing the field studies at BNI Energy, Coyote Creek Mining Company, LLC, Coteau Properties Company, and Falkirk Mining Company. Supportive work will be done on the main campus of NDSU where PI's have adequate laboratory and greenhouse space. A 3% increase for inflation is included each year.

TOTAL PROJECT - $158,203

Non-cash contribution – $158,203

- *Personnel – (109,103) $20,688, 21,309, 24949, 22608, 22549/yr*

Indirect Costs

- 45% of the non-cash contribution - $49,100

Limb et al. Budget Justification Falkirk
Management practices to improve soil and vegetation parameters on reclaimed North Dakota coal mine lands

North Dakota Lignite Research Council – Small Research

The primary portion of the proposed research to be conducted at North Dakota State University (NDSU) will be a field experiment that measures a suite of reclamation practices to improve soil and vegetation parameters. Limb et al. will be performing the field studies at BNI Energy, Coyote Creek Mining Company, LLC, Coteau Properties Company, and Falkirk Mining Company. Supportive work will be done on the main campus of NDSU where PI's have adequate laboratory and greenhouse space. A 3% increase for inflation is included each year.

TOTAL PROJECT - $120,000

Cash Contributions - $60,000

Personnel - $32,399
The funds requested will partially support two M.S. and 1 Ph.D. graduate students for years 1, 2, 3, 4 and 5 (Research Assistantship $6,306, $6,306, $6,584, $6,284, and $5,975/yr respectively + 3% Fringe - $189, $189, $197, $189, and $180/yr respectively) who will be coordinating much of the research.

Expendable Materials and Supplies - $9,374
Materials and Supplies for years 1,2,3,4 and 5 ($3,505, $2,661, $861, $1,067, and $1,280/year respectively).

- *Laptop computer ($2,000) The graduate students will be based off-campus and will not have access to the computer facilities. The laptop will be used for data entry and analysis.*
- *Soil and Vegetation Field Supplies* in years 1, 2, 3, 4, and 5 ($3,505, $661, $861, $1,067, and $1,280/year respectively) *(clipboards, pencils, flagging, paper, field tapes, sampling frames, clippers identification books, plant presses, plot markers, scratch tags, clipping exclosures, soil collection tubes, metal detectors, coolers, digital camera, hand lenses etc.)*

Travel - $10,620
Annual travel for years 1, 2, 3, 4, and 5 ($2,000, $2,060, $2,122, $2,186, and $2,252/year respectively)

- *Annual Travel to in-state scientific conference ($400 mileage, $600 meeting registration, $1,000 lodging and per diem)*

Fees - $7,607

- Publication page charges are requested for years 3, 4 and 5 ($1,000/yr) to publish results in scientific journals.
- Annual MSHA safety training for project personnel ($4,607)

Non-cash contribution – $60,000

- *Personnel - $12,000/yr for project management and treatment implementation*

Indirect Costs
Falkirk Mining Company does not pay university indirect costs. See attached letter.

Limb et al. Budget Justification Coyote
Management practices to improve soil and vegetation parameters on reclaimed North Dakota coal mine lands

North Dakota Lignite Research Council – Small Research

The primary portion of the proposed research to be conducted at North Dakota State University (NDSU) will be a field experiment that measures a suite of reclamation practices to improve soil and vegetation parameters. Limb et al. will be performing the field studies at BNI Energy, Coyote Creek Mining Company, LLC, Coteau Properties Company, and Falkirk Mining Company. Supportive work will be done on the main campus of NDSU where PI's have adequate laboratory and greenhouse space. A 3% increase for inflation is included each year.

TOTAL PROJECT - $60,000

Cash Contribution - $30,000

Expendable Materials and Supplies - $20,980
Materials and Supplies for years 1,2,3,4 and 5 ($5,600, $3,940, $3,878, $3,814, and $3,748/year respectively).

- *Laptop computer (2 @ $2,000 ea) The graduate students will be based off-campus and will not have access to the computer facilities. The laptop will be used for data entry and analysis.*
- *Handheld GPS unit (2 @ $800 ea)*
- *Soil and Vegetation Field Supplies in years 2, 3, 4 and 5* ($3,940, $3,878, $3,814, and $3,748/year respectively*) (clipboards, pencils, flagging, paper, field tapes, sampling frames, clippers identification books, plant presses, plot markers, scratch tags, clipping exclosures, soil collection tubes, metal detectors, coolers, digital camera, hand lenses etc.)*

Travel - $9,020
Annual travel for years 1, 2, 3, 4, and 5 ($400, $2,060, $2,122, $2,186, and $2,252/year respectively)

- *Travel to and from field site in year 1 (533 miles/yr @ $0.75/mile)*
- *Annual Travel to MSHA safety training ($400 mileage, $600 lodging and per diem)*
- *Annual Travel to in-state scientific conference in years 2, 3, 4, and 5 ($400 mileage, $600 meeting registration, $1,060 lodging and per diem)*

Non-cash contribution – $30,000

- *Personnel - $6,000/yr for project management and treatment implementation*

Indirect Costs
Coyote Creek Mining Company does not pay university indirect costs. See attached letter.

Limb et al. Budget Justification Coteau
Management practices to improve soil and vegetation parameters on reclaimed North Dakota coal mine lands

North Dakota Lignite Research Council – Small Research

The primary portion of the proposed research to be conducted at North Dakota State University (NDSU) will be a field experiment that measures a suite of reclamation practices to improve soil and vegetation parameters. Limb et al. will be performing the field studies at BNI Energy, Coyote Creek Mining Company, LLC, Coteau Properties Company, and Falkirk Mining Company. Supportive work will be done on the main campus of NDSU where PI's have adequate laboratory and greenhouse space. A 3% increase for inflation is included each year.

TOTAL PROJECT - $120,000

Cash Contribution - $60,000

Personnel - $60,000
The funds requested will partially support two M.S. and 1 Ph.D. graduate students for years 1, 2, 3, 4 and 5 (Research Assistantship $4,986, $4,785, $4,578, $4,367 and $4,147/yr respectively + 3% Fringe - $150, $144, $138, $131, $125/yr respectively who will be coordinating much of the research and undergraduate technicians for years 1, 2, 3, 4, and 5 ($13/hr for two students working 240 hrs/yr ($6,240, $6,428, $6,621, $6,820 and $7,025/yr respectively + 10% fringe ($624, $643, $663, $682, and $703/yr respectively) to provide hands-on assistance with all experiments and laboratory work.

Non-cash contribution – $30,000

- *Personnel - $12,000/yr for project management and treatment implementation*

Indirect Costs
Coteau Properties Company does not pay university indirect costs. See attached letter.

Limb et al. Budget Justification BNI
Management practices to improve soil and vegetation parameters on reclaimed North Dakota coal mine lands

North Dakota Lignite Research Council – Small Research

The primary portion of the proposed research to be conducted at North Dakota State University (NDSU) will be a field experiment that measures a suite of reclamation practices to improve soil and vegetation parameters. Limb et al. will be performing the field studies at BNI Energy, Coyote Creek Mining Company, LLC, Coteau Properties Company, and Falkirk Mining Company. Supportive work will be done on the main campus of NDSU where PI's have adequate laboratory and greenhouse space. A 3% increase for inflation is included each year.

TOTAL PROJECT - $120,000

Cash Contribution - $60,000
Personnel - $49,380
The funds requested will partially support two M.S. and 1 Ph.D. graduate students for years 1, 2, 3, 4 and 5 (Research Assistantship $9,708, $9,650, $9,590, $9,528, and $9,464/yr respectively + 3% Fringe - $292, $290, $288, $286, and $284/yr respectively) who will be coordinating much of the research.

Expendable Materials and Supplies - $5,310
Materials and Supplies for years 1,2,3,4 and 5 ($1,000, $1,030, $1,061, $1,093, and $1,126/year respectively).

- *Computer Software ($1,000/yr)*

Travel - $5,310
Annual travel for years 1, 2, 3, 4, 5 and 6 ($1,000, $1,030, $1,061, $1,093, and $1,126/year respectively)

- *Annual Travel to MSHA safety training ($400 mileage, $600 lodging and per diem)*

Non-cash contribution – $60,000

- *Personnel - $12,000/yr for project management and treatment implementation*

Indirect Costs
BNI Energy does not pay university indirect costs. See attached letter.

11. QUALIFICATIONS

Ryan F. Limb Ph.D.

Assistant Professor - Range Science
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Education:
Ph.D. in Natural Resource Ecology at Oklahoma State University in December, 2008
M.S. in Animal and Range Sciences at North Dakota State University in May, 2005
B.S. in Biological Sciences at the Montana State University in December, 2001

Professional Experience:
Assistant Professor, North Dakota State University, June 2013-present
Assistant Professor, Oregon State University, December 2010-June 2013
Senior Research Specialist, Oklahoma State University, January 2008-December 2010
Graduate Research Associate. Oklahoma State University, May 2005- December 2008
Graduate Research Assistant North Dakota State University, May 2003- May 2005

Grants and Contract Research
Scholarly activities have led to the funding of 16 grants/contracts totaling over $975,000 with North Dakota State University, Oregon State University and Oklahoma State University as lead PI to conduct applied research in rangeland environments. Areas of expertise include: 1) disturbance ecology, 2) rangeland restoration/reclamation, 3) livestock and wildlife grazing management and 4) grassland pollinator dynamics.

Peer-reviewed Publications:

1. Klaustermeier*, A., H. Tomlinson*, A. Daigh, **R. Limb**, T. DeSutter, and K. Sedivec. *Accepted*. Comparison of soil-to-water suspension rations for determining electrical conductivity of brine contaminated soils. *Canadian Journal of Soil Science*.
2. Field*, A. K.K. Sedivec, J. Hendrickson, P. Johnson, B. Geaumont, X. Lan, R. Gates, and **R. Limb**. *Accepted*. Effects of short-term cattle exclusion on plant community composition: prairie dog and ecological site influences. *Rangelands*.
3. Kral*, K.C., **R.F. Limb**, T.J. Hovick, D.A. McGranahan, A.L. Field*, and P.L. O'Brien*. 2015. Simulating grassland prescribed fires using experimental approaches. *Fire Ecology* 11:34-44.
4. **Limb, R.F.**, D.M. Engle, A.L. Alford, and E.C. Hellgren. 2014. Plant community response following removal of *Juniperus virginiana* from tallgrass prairie: A test of restoration limitations. *Rangeland Ecology and Management* 67:397-405.
5. Strand, E.K., K.L. Launchbaugh, **R. Limb**, and L.A. Torell. 2014. Livestock grazing effects on fuel loads for wildland fire in sagebrush dominated ecosystems. *Journal of Rangeland Applications* 1:35-57.
6. Weir, J.R., and **R.F. Limb**. 2013. Seasonal variation in flammability characteristics of *Quercus marilandica* and *Quercus stellate* leaf litter burned in the laboratory. *Fire Ecology* 9:80-88.
7. Fuhlendorf, S.D., D.M. Engle, R.D. Elmore, **R.F. Limb**, and T.G. Bidwell. 2012. Conservation of pattern and process: Developing an alternative paradigm of rangeland management. *Rangeland Ecology and Management*. 65:579-589.
8. Alford, A.L., E.C. Hellgren, **R.F. Limb**, and D.M. Engle. 2012. Experimental tree removal in tallgrass prairie: variable responses of flora and fauna along a wood cover gradient. *Ecological Applications* 22:947-958.
9. Weir, J.R. and **R.F. Limb**. 2011. Use of waste oil as an alternative fuel in drip torches. *Fire Management Today*

71:12-14.
10. Dong, X., B. Patton, P. Nyren, **R. Limb**, L. Cihacek, D. Kirby, and E. Deckard. 2011. Leaf-water relations of a native and an introduced grass species on the mixed-grass prairie under cattle grazing. *Applied Ecology and Environmental Research* 9:311-331.
11. **Limb, R.F.**, S.D. Fuhlendorf, D.M. Engle, J.R. Weir, R.D. Elmore, and T.G. Bidwell. 2011. Pyric-herboviry and cattle performance in grassland ecosystems. *Rangeland Ecology and Management* 64:659-663.
12. **Limb, R.F.**, S.D. Fuhlendorf, D. M. Engle, J.D. Kerby. 2011. Comparing growing-season disturbance in tallgrass prairie: Evaluating fire and grazing on *Schizachyrium scoparium. Rangeland Ecology and Management 64:28-36.*
13. Fuhlendorf, S.D., **R.F. Limb**, R.F. Miller, D.M. Engle. 2011. Assessment of prescribed fire as a conservation practice. p. 75-104. *In:* D. Briske (ed.) Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge gaps. United States Department of Agriculture, Natural Resources Conservation Service.
14. **Limb, R.F.**, D.M. Engle, A.L. Alford, and E.C. Hellgren. 2010. Tallgrass prairie plant community dynamics along a canopy cover gradient of eastern redcedar (*Juniperus virginiana* L.). *Rangeland Ecology and Management 63:638-644.*
15. **Limb, R.F.**, D.M. Engle, T.G. Bidwell, D.P. Althoff, A.B. Anderson, P.S. Gipson, and H.R. Howard. 2010. Restoring biopedturbation in grassland with anthropogenic focal disturbance. *Plant Ecology* 210:331-342.
16. **Limb, R.F**., D.M. Engle, S.D. Fuhlendorf, D.P. Althoff, and P.S. Gipson. 2010. Changes in herbivore grazing selection associated with vehicle disturbance in a grassland ecosystem. *Rangeland Ecology and Management* 63:253-257.
17. **Limb, R.F.**, S.D. Fuhlendorf, and D.E. Townsend. 2009 Heterogeneity of thermal extremes: Driven by disturbance or inherent in the landscape. *Environmental Management.* 43:100-106.
18. **Limb, R.F.**, K.R. Hickman, D.M. Engle, J.E. Norland, and S.D. Fuhlendorf. 2007. Digital photography: reduced variation in visual obstruction measurements for southern tallgrass prairie. *Rangeland Ecology and Management.* 60:548-552.
19. **Limb, R.F.**, C.B. Marlow, and B. Jacobson. 2003. What Causes Willow Die-off. *Rangelands.* 25:14-17.

Extension Publications

1. Sedivec, K., C. Piper, J. Printz, A. Wick, A. Daigh, and **R. Limb**. 2014. Successful reclamation of lands disturbed by oil and gas development infrastructure construction. North Dakota State University Extension Bulletin R1728. p.16.
2. **Limb, R.F.** 2013. Livestock weight gain and patch-burn management. E-extension Prescribed Fire Community of Practice.
3. **Limb, R.F.** 2013. Using prescribed fire to control invasive plant species. E-extension Prescribed Fire Community of Practice.
4. **Limb, R.F.** 2013. Burning in the growing season: Effects on grass. E-extension Prescribed Fire Community of Practice.
5. Kennedy, P. L., T. DelCurto, S. J. DeBano, R. V. Taylor, T. N. Johnson, S. Wyffels, C. Kimoto, H. Schmalz, and **R. Limb**. 2012. Responses of a Pacific Northwest Bunchgrass Food Web to Experimental Manipulations of Stocking Rate. Pp 17-19 In: A. Glaser (ed.). America's Grasslands Conference: Status, Threats, and Opportunities. Proceedings of the 1st Biennial conference on the Conservation of America's Grasslands. August 15-17, 2011, Sioux Falls, SD. National Wildlife Federation and South Dakota State University, Washington, D. C. and Brookings SD, USA.
6. Weir, J.R., D. Elmore, **R.F. Limb**, D.M. Engle, B.W. Allred, T.G. Bidwell, and S.D. Fuhlendorf. 2012. Burning in the growing season. Fact Sheet E-1025 Oklahoma Cooperative Extension Service, Oklahoma State University, OK. 9 p.
7. **Limb, R.** and S. Fuhlendorf. 2010. Summer fire and grass mortality. *Natural Resource News* 4:1.
8. Allred, B., **R. Limb,** S. Robertson and S. Fuhlendorf. 2008. Learning land management: The new classroom. *Natural Resource News* 2:2-3.
9. **Limb, R.** 2007. Redcedar Control. *Natural Resource News.* 1:3. Kirby, D., **R. Limb**, E. DeKeyser, P. Nyren, and B. Patton. 2004. Drought and grazing intensity affect forage production on mixed-grass prairie. *North Dakota Beef Cattle Report*. p. 3-6.
10. **Limb, R**, D. Kirby, P. Nyren, and B. Patton. 2003. Interaction of Simulated Drought and Grazing on Rangeland.

Central Grasslands Research Extension Center grass and Beef Annual Report.

Synergistic Activities:

1. Co-PI and Board of Directors for the Great Plains Fire Science Exchange.
2. Society for Range Management Oil and Gas Committee
3. Society for Range Management Wildlife Habitat Committee
4. Leadership Team for the Prescribed Fire Community of Practice for eXtension
5. USDA, Cooperative State Research Extension and Education Service, Rangeland Assessment and Monitoring Committee (WERA 40
6. Owyhee Management Area Technical Team. Cooperated with scientists to develop objective driven management practices for the Owyhee Management Area.
7. Conservation Effects Assessment Project (CEAP) Prescribed Fire Team.

Awards and Honors:

2015 Recipient of the "Outstanding Young Range Professional Award" from the Society of Range Management.

2nd Place Graduate Oral Paper contest. Society for Range Management 60th Annual meeting, Reno, NV

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Education

B.S., 1987	North Dakota State University, Fargo, ND, Zoology
M.S., 1989	North Dakota State University, Fargo, ND, Animal and Range Sciences
Ph.D., 1994	North Dakota State University, Fargo, ND, Animal and Range Sciences

Professional Experience:

Jan. 2009 – present, *State Extension Rangeland Specialist/Professor/Range Program Leader*: School of Natural Resource Sciences, North Dakota State University, Fargo

May 2004 – present, *Range, Botany and Wildlife Consultation and Research Specialist*: Sedivec Natural Resource Consultation Services, Cummings, ND

Jan. 1995 – 2009, *State Extension Rangeland Specialist/Assoc. Professor*: Animal and Range Sciences Department, North Dakota State University, Fargo

July 1989 – Jan. 1995, *State Extension Rangeland Specialist*: Animal and Range Sciences Department, North Dakota State University, Fargo

Honors/Awards:

(1) *Program Excellence Award*, 1992, North Dakota State University Extension Service; (2) *Program Excellence Award*, 1992, North Dakota State University Extension Service; (3) *Certificate of Appreciation*, 1992, Morton County Extension Service, North Dakota State University Extension Service; (4) *Program Excellence Award*, 1994, North Dakota State University Extension Service; (5) *Commendation for Excellence in Research, Early Career*, 1996, Office of Vice President for Agricultural Affairs, North Dakota State University; (6) *Commendation for Excellence in Extension, Early Career*, 1997, Office of Vice President for Agricultural Affairs, North Dakota State University; (7) *Professional Award*, 1997, North Dakota Soil and Water Conservation Society; (8) *Honorary FFA State Degree*, 1998, North Dakota FFA; (9) *Outstanding Young Professional Award*, 1998, Society for Range Management International Organization; (10) *Leadership Award*, 1998, North Dakota Chapter of the Society for Range Management; (11) *GODORT Notable Document Awards*, 1998, North Dakota Library Association; (12) *Commendation for Excellence in Extension, Early Career*, 1999, Office of Vice President for Agricultural Affairs, North Dakota State University; (13) *Distinguished Service Award*, 2000, North Dakota Vocational Agriculture Teachers Association; (14) *Program Excellence Award*, 2001, North Dakota State University Extension Service; (15) *Outstanding Achievement – Research*, 2007, Society for Range Management International Organization; (16) *NDVATA Outstanding Cooperation Award*, 2007, ND Vo-Ag Teachers Assoc.

Grants and Contract Research

Professional activities have led to the funding of 145 grants/contracts with NDSU to conduct research and develop educational materials involving over $15.55 million, with $5.5 million used in my program. Areas of research and extension expertise include (1) rangeland monitoring, (2) rangeland and grassland nutrition, (3) grazing and wildlife interactions, and (4) develop educational programs for adults and youth on rangeland management. Funding for consulting projects have totaled 15 projects since 2004 with Sedivec Natural Resource Consultation Services totaling $1.8 million.

Presentations/News Releases (*synopsis*)

71 International, National, and Regional Meetings/Symposiums, 569 State/County Meetings/ Symposiums, 47 In-service Professional Training Workshops, 39 Rancher/farmer Workshops/ Programs, 26 Range Youth Camps, 129 Media interviews (TV, radio), 152 Popular press articles.

Publications (*Principal author*: 2 refereed journal article, 29 refereed extension circulars, 16 published abstracts, 16 proceeding articles, 30 research review articles, 1 software analysis tool, 3 videos. *Co-author*: 22 referred journals articles, 21 refereed extension circulars, 1 book, 1 book chapter, 3 manuals, 92 published abstracts, 11 proceeding articles, 53 research review articles, 1 software analysis tool, 1 video).

<u>Peer-Reviewed (2010-2015)</u>:

1. Hendrickson, J., P. Johnson, M. Liebig, **K. Sedivec**, and G. Halvorson 2016. Use of Ecological Sites in managing wildlife and livestock: An example with prairie dogs. *Rangelands*. – Accepted 12.02.2015
2. Geaumont, B., **K. Sedivec**, and W. Mack. History of Occurrence and Present Home Territory Sizes for Black-tailed Prairie Dogs on The Standing Rock Sioux Reservation. 2016. *Rangelands*. – Accepted 11.30.2015
3. Field, A., **K. Sedivec**, J. Hendrickson, P. Johnson, B. Geaumont, X. Lan, R. Gates, and **R. Limb**. 2016. Effects of short-term cattle exclusion on plant community composition: prairie dog and ecological site influences. *Rangelands*. – Accepted 11.29.2015
4. Wick, A.F., B.A. Geaumont, K.K. Sedivec, and J. Hendrickson. 2015. 11.2 Grassland Degradation. In. R. Sivanpillai (Vol. Ed.), Biological and Environmental Hazards, Risk, and Disasters within J. Schroder (series ed.) Elsevier's Hazards and Disasters Series. http://dx.doi.org/10.1016/B978-0-12-394847-2.00016-4 (10016-SCHROEDER JR.-9780123948472)
5. Barth, C., M. Liebig, J. Hendrickson, **K. Sedivec**, and G. Halvorson. 2014. Soil Change Induced by Prairie Dogs across Three Ecological Sites. Soil Science Society of America Journal 87(6):2054-2060
6. Stackhouse, J., **K. Sedivec** and B. Geaumont. 2013. Evaluation of three nest searching methods for ringed-necked pheasant. Prairie Naturalist 45(2):114-117
7. A. Gearhart, D.T. Booth, **K.K. Sedivec**, and C.S. Schauer. 2012. Use of Kendall's Coefficient of Concordance to Assess Agreement among Observers of Very High Resolution Imagery. Geocarto International DOI:10.1080/10106049.2012.725775.
8. M.A. Meehan, E.S. DeKeyser, **K.K. Sedivec**, and J.E. Norland. 2012. Nutritional Composition of Sprengel's Sedge (*Carex sprengelii*). Canadian Journal of Plant Science 92:1-5.
9. C. S. Schauer, M. L. Van Emon, M. M. Thompson, D. W. Bohnert, J. S. Caton and **K. K. Sedivec**. 2010. Protein supplementation of low-quality forage: Influence of frequency of supplementation on ewe performance and lamb nutrient utilization. Sheep & Goat Research Journal 25:66-73.
10. DeKeyser, S., M. Meehan, **K. Sedivec**, and C. Lura. 2010. Potential management alternatives for invaded rangelands in the Northern Great Plains. Rangelands 32(6):26-31.
11. Geaumont, B.A., **K.K. Sedivec**, C.S. Schauer. 2010. Ring-necked Pheasant Nest Parasitism of Sharp-tailed Grouse Nests in Southwest North Dakota. The Prairie Naturalist 42(1/2):73-75.
12. Smart, A.J., J. D. Derner, J.R. Hendrickson, R.L. Gillen, B.H. Dunn, E.M. Mousel, P.S. Johnson, R.N. Gates, **K.K. Sedivec**, K.R. Harmoney, J.D. Volesky, and K.C. Olson. 2010. Effects of Grazing Pressure on Efficiency of Grazing on North American Great Plains Rangelands. Rangeland Ecology and Management 63(4):397-406.

<u>Referred Extension Publications (2009-2015):</u>

13. **Sedivec, K.** and E. Elemes. 2015. Range judging handbook for North Dakota, 5th Ed. DDB628. North Dakota State University, Fargo. 58 pp.

14. Meehan, M., F. Brummer, **K. Sedivec**, and J. Printz. 2015. The North Dakota grazing monitoring stick – a way to measure range and pasture utilization. R1780. North Dakota State University, Fargo. 8 pp.
15. **Sedivec, K**. and D. Saxowsky. 2015. Reclamation of oil and gas industry-impacted land – a guide anhd checklist. R1766. North Dakota State University, Fargo. 4 pp.
16. Brummer, F., **K. Sedivec**, P. Nester, E. Gaugler, and C. Schaunaman. 2015. Annual cover crop options for grazing and haying in the Northern Plains. R1759, North Dakota State University, Fargo. 12 pp.
17. **Sedivec, K.K**. and J.L. Printz. 2014. Ranchers Guide to Grassland Management IV. R1707, North Dakota State University, Fargo. 99 pp.
18. **Sedivec, K**., C. Piper, J. Printz, A. Wick, A. Daigh, and R. Limb. 2014. Successful Reclamation of Lands Disturbed by

Oil and Gas Development and Infrastructure Construction. R1728, North Dakota State University, Fargo. 15 pp.

19. **Sedivec, K.K.** and J.L. Printz. 2012. Ecological Sites of North Dakota. R-1556, North Dakota State Univ. Extension Service, Fargo. 27 pp.
20. **Sedivec, K.K.**, D.A. Tober, W.L. Duckwitz, and J.R. Hendrickson. 2011. Grass Varieties for North Dakota. R-794, North Dakota State Univ. Extension Service, Fargo. 20 pp.
21. Meehan, M.A., **K.K. Sedivec**, and E.S. DeKeyser. 2011. Riparian Ecosystems of North Dakota, R-1539. North Dakota State University Extension Service, Fargo, ND. 6 pp.
22. Meehan, M.A., **K.K. Sedivec**, and E.S. DeKeyser. 2011. Grazing Riparian Ecosystems: Grazing Systems, R-1540. North Dakota State University Extension Service, Fargo, ND. 8 pp.
23. Meehan, M.A., **K.K. Sedivec**, and E.S. DeKeyser. 2011. Grazing Riparian Ecosystems: Grazing Intensity, R-1541. North Dakota State University Extension Service, Fargo, ND. 6 pp.
24. Meehan, M.A., **K.K. Sedivec**, and E.S. DeKeyser. 2011. Grazing Riparian Ecosystems: Season of Use, R-1542. North Dakota State University Extension Service, Fargo, ND. 6 pp.
25. Meehan, M.A., **K.K. Sedivec**, and E.S. DeKeyser. 2011. Grazing Riparian Ecosystems: Water Development, R-1543. North Dakota State University Extension Service, Fargo, ND. 10 pp.
26. **Sedivec, K**., D. Vannurden, M. Doyle, M. Humann, D. Froemke, Joshua Peterson, and Amanda Gearhart. 2010. Range Judging Handbook for North Dakota (4th Ed.), DDB628. North Dakota State University Extension Service, Fargo, ND. 60 pp.
27. **Sedivec, K.K.** D.A. Tober, W.L. Duckwitz, D.D. Dewald, and J.L. Printz. 2010. Grasses for the Northern Plains. Volume I – Cool-season, R-1323 (2nd Ed.). North Dakota State University Extension Service. 89 pp.
28. **Sedivec, K.K.** D.A. Tober, W.L. Duckwitz, D.D. Dewald, J.L. Printz, Donovan Craig. 2009. Grasses for the Northern Plains. Volume II – Warm-season, R-1390. North Dakota State University Extension Service. 67 pp.

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Education:
Ph.D. Soil Science (Soil Physics) and Environmental Science, Iowa State University, 2013
M.S. Agronomy, University of Arkansas, 2009
B.S. Environmental, Soil and Water Sciences, University of Arkansas, 2007

Professional Experience:
Assistant Professor, North Dakota State University, December 2013-present
Post-Doctoral Associate, Soil and Drainage Water Quality, Department of Agricultural and Biosystems Engineering, Iowa State University, May 2013 – November 2013
Graduate Research Assistant, Agronomy Department, Iowa State University, June 2009 – May 2013
Graduate Research Assistant, Crops, Soils, and Environmental Sciences Department, University of Arkansas, June 2007 – May 2009
Undergraduate Research Assistant, Crops, Soils, and Environmental Sciences Department, University of Arkansas, August 2005 – May 2007

Grants
PI or Co-PI of 23 grants (> $1.3 million) awarded for research at North Dakota State University and Iowa State University with focus on soil physics and soil management.

Peer-reviewed Publications:
1. **Daigh, A.L.M.** and A.W. Klaustermeier. 2016. Approaching brine spill remediation from the surface: A new in situ method. Agric. Environ. Letters doi:10.2134/ael2015.12.0013
2. **Daigh, A.L.**, T. Sauer, X. Xiao, and R. Horton. 2015. Comparison of models for determining soil-surface carbon dioxide effluxes in different agricultural systems. Agron. J. 107:1077-1086.
3. **Daigh, A.L.**, X. Zhou, M.J. Helmers, C.H. Pederson, R. Horton, M. Jarchow, and M. Liebman. 2015. Subsurface drainage nitrate and total reactive phosphorus losses in biofuel-based prairies and corn systems. J. Envion. Qual. 44:1638-1646.
4. **Daigh, A.L.**, X. Zhou, M.J. Helmers, C.H. Pederson, R. Ewing, and R. Horton. 2014. Subsurface drainage flow and soil water dynamics of reconstructed prairies and corn rotations for biofuel production. Vadose Zone J. doi:10.2136/vzj2013.10.0177
5. **Daigh, A.L.**, T. Sauer, X. Xiao, and R. Horton. 2014. Soil-surface CO_2 emission spatial and temporal dynamics in corn rotations and reconstructed prairies. Soil Sci. Soc. Am. J. 78:1338-1350.
6. **Daigh, A.L.**, M.J. Helmers, E. Kladivko, X. Zhou, R. Goeken, J. Cavadini, D. Barker, and J. Sawyer. 2014. Soil water during the drought of 2012 as affected by rye cover crops in fields in Iowa and Indiana. Journal of Soil and Water Conservation. 69:564-573.
7. **Daigh, A.L.**, M.C. Savin, K.R. Brye, R. Norman, and D. Miller. 2014. Urea persistence in floodwater and soil used for flooded rice production. Soil Use and Management. doi:10.1111/sum.12142
8. McMullen, R.L., R.L., K.R. Brye, D.M. Miller, R.E. Mason, **A.L. Daigh**, B.C. Menjoulet, A.L. Pirani, E.E. Gbur, and M.A. Evans-White. 2014. Long-term runoff water quality as affected by broiler-litter application to a udult in the Ozark Highlands. Soil Sci. Soc. Am. J. doi:10.2136/sssaj2014.07.0291

9. McMullen, R.L., K.R. Brye, **A.L. Daigh**, D.M. Miller, E.E. Gbur, A.L. Pirani, M.A. Evans-White, and R.E. Mason. 2014. Long-term leachate water quality trends from a broiler litter-amended Udult in a karst region. Vadose Zone J. doi:10.2136/vzj2014.06.0064
10. McGranahan, D.A., **A.L. Daigh**, J.J. Veenstra, D.M. Engle, J.R. Miller, and D.D. Debinski. 2014. Connecting soil organic carbon and root biomass with land-use and vegetation in temperate grassland. Submitted to Sci. World J. doi:10.1155/2014/487563.
11. Wang, E., R. Cruse, X. Chen, and **A.L. Daigh**. 2012. Effects of moisture condition and freeze/thaw cycles on surface soil aggregate size distribution and stability. Canadian J. Soil Sci. 92(3): 529-536. doi: 10.4141/cjss2010-044.
12. **Daigh, A.L.** 2011. Bioenergy cropping systems effects on soil quality. Soil Surv. Horiz. 52(2):31-34. doi: 10.2136/ssh2011-52-2-1.
13. Brye, K.R., **A.L. Daigh**, B.C. Menjoulet, M.L. Pirani, and C.P. West. 2010. Trends in dry matter yield following differential broiler litter application from a soil enriched with organic matter and phosphorus. Forage and Grazinglands. doi:10.1094/FG-2010-0407-01-RS.
14. **Daigh, A.L.**, K.R. Brye, A.N. Sharpley, D. Miller, and E. Gbur. 2010. Broiler litter composition as affected by water extractant, dilution ratio, and extraction time. Comm. Soil Sci. Plant Anal. 41:2340-2357.
15. **Daigh, A.L.**, K.R. Brye, A.N. Sharpley, D.M. Miller, C. West, and J.V. Brahana. 2009. Five-year change in soil profile chemical properties as affected by broiler litter application rate. Soil Sci. 174: 531-542.
16. Savin, M.C., L.C. Purcell, **A.L. Daigh**, and A. Manfredini. 2009. Response of mycorrhizal infection to glyphosate applications and P fertilization in glyphosate-tolerant soybean, maize, and cotton. J. Plant Nutrition. 32:1702-1717.

Synergistic Activities:

8. North Dakota Director of the Western Soil Physics Multi-state Project.
9. Associate Editor for Soil Science Society of America Journal
10. Associate Editor for Agricultural and Environmental Letters
11. Provided 31 scientific peer-reviews of manuscripts for 22 international journals
12. Chair of the Soil Science Early Career Members Committee, ASA-CSSA-SSSA Societies
13. Past Chair of the ACS Early Career Members Committee, ASA-CSSA-SSSA Societies
14. Past Chair of the Undergraduate Research Symposium, ASA-CSSA-SSSA Societies
15. 220 lectures for 23 courses at North Dakota State University, Iowa State University, and the University of Arkansas

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School of Natural Resource Sciences
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email: thomas.desutter@ndsu.edu

EDUCATION

Ph.D. Agronomy May 2004. Kansas State University (KSU), Manhattan, KS.
Dissertation: Impacts of animal waste lagoons on the environment. Advisors: G.M. Pierzynski (Major Professor), J.M. Ham, G.J. Kluitenberg, A. Bhandhari.

M.S. Plant Science May 1998. South Dakota State University (SDSU), Brookings, SD.
Thesis: Agrichemical concentrations on wind and nonwind-erodible sediment sizes as influenced by time, sediment size, and sorption-desorption characteristics. Major Professor: Dr. S.A. Clay.

B.S. Geography, Environmental Management May 1994. SDSU. (minors in Soil Science and Chemistry)

EMPLOYMENT HISTORY

2013-present Associate Professor-Department of Soil Science, North Dakota State University (NDSU), Fargo, ND
2011-present Program Leader for Department of Soil Science, NDSU
2006-2013 Assistant Professor-Department of Soil Science, NDSU

PUBLICATIONS

Peer-Reviewed (2010-2015)

1. Reitsma, K.D., B.H. Dunn, U. Mishra, S.A. Clay, T. DeSutter, and D.E. Clay. 2015. Land-use change impact on soil sustainability in a climate and vegetation transition zone. Agron. J. 107:2363-2372.
2. Amarakoon, D., D. Thavarajah, D.S. Gupta, K. McPhee, T. DeSutter, and P. Thavarajah. 2015. Genetic and environmental variation of seed iron and food matrix factors of North-Dakota-grown field peas (*Pisum sativum* L.) J. Food Comp. Anal. 37:67-74.
3. Chatterjee, A., B. Geaumont, T.M. DeSutter, D. Hopkins, and M. Rakkar. 2015. Rapid shifts in soil organic carbon mineralization within sodic landscapes. Arid Land Res. Mngt. 29:255-263.
4. DeSutter, T., D. Franzen, Y. He, A. Wick, B. Deutsch, and J. Lee. 2015. Relating percent sodium to sodium adsorption ratio and its utility in the northern Great Plains. Soil Sci. Soc. Am. J. 79:1261-1264.
5. Dose, H., A.M. Fortuna, L. Cihacek, J. Norland, T. DeSutter, D. Clay, J. Bell. 2015. Biological indicators provide short term soil health assessment during sodium soil reclamation. Ecol. Ind. 58:244-253.
6. He, Y., T.M. DeSutter, D.G. Hopkins, D. Wysocki, D. Clay. 2015. Relationship between 1:5 soil/water and saturated paste extract sodium adsorption ratios by three extraction methods. Soil Sci. Soc. Am. J. 79:681-687.
7. Jyoti, V., B. Saini-Eidukat, D. Hopkins, and T. DeSutter. 2015. Naturally elevated metal contents of soils in northeastern North Dakota, USA with a focus on cadmium. J. Soils Sed. DOI 10.1007/s11368-015-1122-6.
8. Fasching, S., J. Norland, T. DeSutter, S. DeKeyser, F. Casey, and C. Hargiss. 2015. The use of sediment removal to reduce phosphorus levels in wetland soils. Ecol. Rest. 33:131-134.
9. He, Y., T. DeSutter, F. Casey, D. Clay, D. Franzen, and D. Steele. 2015. Field capacity water as influenced by Na and EC: Implications for subsurface drainage. Geoderma 245-246: 83-88.
10. Shelver, W., T. DeSutter. 2015. Ractopamine soil uptake by alfalfa (*Medicago sativa*) and wheat (*Triticum aestivum*). J. Env. Sci. 34:86-92.

11. Squillace, M.K., H.H. Betemariam, N.R. Urban, M.R. Penn, T.M. DeSutter, S.R. Chipps, and J.J. Stone. 2015. Historical sediment mercury deposition trends for South Dakota lakes. J. Paleolimn. Sci. Tot. Environ. (released)
12. Chambers, K.B., F.X. Casey, H. Hakk, T.M. DeSutter, and N.W. Shappell. 2014. Potential bioactivity and association of 17-β estradiol with the dissolved and colloidal fractions of manure and soil. Sci. Tot. Env. 494:58-64.
13. Bai, X., F.X.M. Casey, H. Hakk, T.M. DeSutter, P.G. Odour, E. Khan. 2014. Sorption and metabolism of 17β-estradiol-17-sulfate in sterilized soil-water systems. Chemosphere doi:10.1016/j.chemosphere.2014.02.016
14. Kolka, R., S. Fraver, P. Townsend, B. Sturtevant, P. Wolter, J. Miesel, and T. DeSutter. 2014. Forest floor and upper soil canopy carbon, nitrogen and mercury pools shortly after fire and comparisons to fire severity indices. Soil Sci. Soc. Am. J. 78:S58-S65.
15. Rahman, M.M., Z. Lin, X. Jia, D.D. Steele, and T.M. DeSutter. 2014. Impact of subsurface drainage on streamflows in the Red River of the North basin. J. Hydrol. 511:474-483.
16. Bai, X., F.X.M. Casey, H. Hakk, T.M. DeSutter, P.G. Odour, E. Khan. 2013. Dissipation and transformation of 17β-estradiol-17-sulfate in soil-water systems. J. Haz. Mat. 260:733-739.
17. Akkajit, P., T.M. DeSutter, and C. Tongcumpou. 2013. Effects of sugarcane waste-products on Cd and Zn fractionation and its uptake by sugarcane (*Saccarum officinarum* L.). J. Environ. Monit. DOI: 10.1039/c3em00403a
18. He, Y., T. DeSutter, and D. Clay. 2013. Dispersion of pure clay minerals as influenced by Ca to Mg ratios, SAR and EC. Soil Sci. Soc. Am. J. 77:2014-2019.
19. Akkajit, P., T.M. DeSutter, and C. Tongcumpou. 2013. Fractionation of Cd and Zn in Cd contaminated soils amended by sugarcane waste products from ethanol production plant. J. Soils Sediments DOI: 10.1007/s11368-013-0691-5
20. Akkajit, P., T.M. DeSutter, and C. Tongcumpou. 2013. Short-term effects of sugarcane waste products from ethanol production plant as soil amendments on sugarcane growth and metal stabilization. Environ. Sci.: Processes Impacts DOI: 10.1039/c3em00073g
21. Betemariam, H., A. Davis, L. Stetler, C. McCutcheon, T. DeSutter, M. Penn, and J.J. Stone. 2013. Geochemical behavior and watershed influences associated with sediment-bound mercury for South Dakota lakes and impoundments. Water, Air, Soil Pollut. 224:1497 doi:10.1007/s11270-013-1497-1
22. DeSutter, T., L. Cihacek, and S. Rahman. 2013. Application of flue gas desulfurization gypsum (FGDG) and its impact on wheat grain (*Triticum aestivum* L.) and soil chemistry. J. Environ. Qual. 43:303-311.
23. He, Y., T. DeSutter, L. Prunty, D. Hopkins, X. Jia, and D. Wysocki. 2013. Relating the value of EC1:5 to EC of the saturated paste extract. Can. J. Soil Sci. 93:585-594.
24. Kandel, H.J., J.A. Brodshaug, D.D. Steele, J.K. Ransom, T.M. DeSutter, and G.R. Sands. 2013. Subsurface drainage effects on soil penetration resistance and water table depth on a clay soil in the Red River of the North Valley, USA. Agric. Eng. Inter.: CIGR J. 15:1-10.
25. Jia, X, T.M. DeSutter, Z. Lin, W.M. Schuh, and D.D. Steele. 2012. Controlled drainage and subirrigation effects on water quality in southeast North Dakota. Trans. ASABE. 55:1757-1769.
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Synergistic Activities:

16. Technical Editor for *Agricultural and Environmental Letters*.
17. Science Policy Committee, Soil Science Society of America
18. Section Chair, Environmental Quality; American Society of Agronomy

AWARDS AND HONORS

2015	Teaching Award of Merit, North American Colleges and Teachers of Agriculture
2015	Announcer for Recognition of Donors and Students, Scholarship Recognition Luncheon, CAFSNR
2014	Guest Professor for the Coastal Agricultural Research Institute, Hebei Academy of Agricultural and Forestry Sciences
2014	Adjunct status in the Plant Science Department at South Dakota State University
2014	Vice President of the Professional Soil Classifiers Association of North Dakota
2014	Nominated for the NDSU Awards for Excellence in Advising of Undergraduates
2012	Recipient of the NDSU College of Agriculture, Food Systems, and Natural Resources Larson/Yaggie Excellence in Research Award
2011	Nominated for the NDSU College of Agriculture, Food Systems, and Natural Resources William J. and Angelyn A. Austin Advising Award.
2010	Nominated for the NDSU College of Agriculture, Food Systems, and Natural Resources William J. and Angelyn A. Austin Advising Award.
2010	Citation for Excellence in Manuscript Review from the Soil Science Society of America.
2010	Education research “Integrating Field-based Research into the Classroom” highlighted in Crops, Soils, Agronomy News (October).
2009	Nominated for the NDSU College of Agriculture, Food Systems, and Natural Resources Earl and Dorothy Foster Excellence in Teaching Award.
2008	Nominated for the NDSU College of Agriculture, Food Systems, and Natural Resources Earl and Dorothy Foster Excellence in Teaching Award.
2005	Emil Truog Soil Science Award presented by the Soil Science Society of America.
2005	Certificate of Merit, United States Department of Agriculture. “For Superior Performance in the Development of a Soil Carbon Monitoring System.”

12. TAX LIABILITY

NDSU NORTH DAKOTA STATE UNIVERSITY

February 29, 2016

To Whom It May Concern,

North Dakota State University regularly pays taxes to the State of North Dakota for state income tax withholding, state sales taxes collected, and unrelated business income taxes. To the best of my knowledge, North Dakota State University is current and paid up on all tax liabilities with the State; with no past due balances.

Sincerely,

Gary Wawers

Controller

ACCOUNTING OFFICE | DIVISION OF FINANCE AND ADMINISTRATION
NDSU Dept 3100 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.7432 | Fax 701.231.6194 | www.ndsu.edu

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