Revegetation Success and Weed Resilience of Wyoming Right-of-Way Reclamation

WYDOT Project Champion

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Problem Statement and Background

Right-of-way vegetation strips including road ditches represent significant acreage along roadways in Wyoming and affect a wide range of habitats (Omernik 1987). The Wyoming Department of Transportation (WYDOT) is responsible for maintaining approximately 6,700 miles of roadways including the vegetation within the adjoining right of way along each road corridor (WYDOT 2015). Ecological impacts of road construction are mitigated by land reclamation, and WYDOT is required to reseed roadsides after construction to stabilize exposed surfaces, minimize soil erosion and maintain visibility, as well as limit the spread of undesirable species. Roadside revegetation is a final step in road construction, and often occurs in areas that are difficult to reclaim due to harsh climate conditions and impacts of previous land disturbance, including top soil removal, soil compaction, and the presence of noxious and invasive weeds (Forman 1998; Tinsley et al. 2006).

Road corridors are vulnerable to introductions of undesirable species and serve as a first line of defense to limit biological invasion in adjacent federal, state, and private rangelands (Hansen and Clevenger 2005; Von der Lippe and Kowarik 2007). Roadside vegetation may also influence factors such as attractiveness to wildlife and livestock, and may be managed to reduce potential traffic safety concerns. WYDOT managers have focused on reseeding commercially available native rather than introduced plant species along roadways since the 1990s, and seed mixes are designed to be appropriate for application among six Level II ecoregions in the state (WYDOT 2013; FHA 2017). WYDOT reseeding practices aim to establish resilient, native plant communities beneficial to rangelands and residents in Wyoming, but long-term success rates have not been evaluated. There is a need for comprehensive assessment of the effectiveness of different seed mixes for: 1) the establishment of desirable native plant communities, and 2) the reduction of noxious and invasive weeds. Alien species alone result in environmental costs of more than $120 billion per year in the United States and different revegetation strategies can alter the number and impact of invasive weeds (Pimentel et al. 2005). An evaluation of the effectiveness of seeding treatments and associated site factors may therefore guide reclamation planning and assist in the development of cost-effective roadside revegetation practices in Wyoming.

Literature Search

Roadside vegetation can be useful in conservation and evidence suggests that vegetation strips may support a wide range of pollinators and some wildlife when appropriate (Ries et al. 2001; Hopwood 2008; Bissonette and Rosa 2009; McCleery et al. 2015). Vegetation benefits, however, are often attenuated by the presence of weeds such as cheatgrass (*Bromus tectorum*) and growing evidence suggests roadways serve as corridors for the spread of invasive species. A study of 42 roadways in Utah found a 50% increase in exotic species and three times the cover of cheatgrass along paved roads relative to four-wheel drive tracks (Gelbard and Belnap 2003). In a separate study in Canada, paved roads not only served as conduits for invasive species, but also were linked to the spread of alien plants in adjacent, undisturbed rangeland (Hansen and Clevenger 2005). Remote sensing analysis of the North American Great Basin determined that cheatgrass was 13% more likely to be found within 700 m of roadways (Bradley and Mustard 2006). And in most cases, alien species were more likely to occur near paved roads that supported higher traffic volume when compared to low traffic volume or non-paved roadways (e.g., Joly et al. 2011).

Despite the correlation between road corridors and the spread of invasive species, few studies have determined the efficacy of reclamation for reducing the frequency and occurrence of invasive weeds. Huntsman (2011) found one third fewer introduced species along reclaimed roadways in Australia relative to sites that were not planted. Tinsley et al. (2006) studied outcomes of three seed mixes planted along roadsides in Texas, but did not compare results with the levels of weed infestation at seeded sites. An experimental study of herbicide and seeding treatments along roads in Glacier National Park found no effect of native seeding on exotic species cover (Tyser et al. 1998), while seed addition did improve native species abundance in experimental plots in Iowa (Martin and Wilsey 2006). These studies rarely address roadway seeding outcomes for weed control and no research is yet published to compare and contrast roadside seeding with weed density in Wyoming.

Study Objectives

Our objectives are to evaluate different reclamation seed mixes over the years to determine the rate of reseeding success and better define combinations of species and site variables that contribute to successful revegetation outcomes. We will also compare sites and seed mixes for resilience to invasion by high impact species such as cheatgrass. Data will contribute to recommendations to maximize seeding success and minimize weeds, and will assist future evaluations of other vegetation factors, such as minimizing traffic/wildlife conflicts.

Study Approach

We propose to implement a research study to evaluate WYDOT's reclamation program with a focus on aspects tied to revegetation. WYDOT maintains a database of seed mixes applied along roadways throughout the state. This database represents a valuable resource that, when combined with field surveys, can assess revegetation outcomes in light of study objectives. We will conduct surveys of 26 or more roadside sites for which reseeding data are available to determine the extent to which different seed mixes establish and invasive or noxious weeds are minimized. Subsequently, native plant species with high establishment rates will be reviewed for wildlife palatability. As a final step, we will develop recommendations for species mixes to maximize reseeding success, minimize weeds, and address species composition concerns relevant for wildlife/traffic conflicts.

Methods

We will select a minimum of 26 roadside revegetation sites along the I-80 corridor and its arterial roadways in Wyoming with the goal to conduct vegetation surveys and compare plant community data with the original seed mix. Sites will represent a range of Level III ecoregions common in southern Wyoming, including rolling sagebrush steppe, foothill shrublands and salt desert shrub basins (Chapman et al. 2004). Transects will be located perpendicular to the paved road, and transect length will vary from 15 to 30 m depending on the size of the roadside disturbance. Transect data will be stratified to represent microhabitats such as the road shoulder, side slope, ditch, and back slope (Karim and Mallik 2008). Sampling will follow the

Bureau of Land Management Assessment, Inventory, and Monitoring (AIM) Strategy, a standardized monitoring method developed by the BLM in collaboration with the USDA Agricultural Research Service, the Environmental Protection Agency, and the Natural Resource Conservation Service (Herrick et al. 1996). Line-point intercept sampling will include a plot-level species inventory, individual plant species occurrence and frequency, average vegetation height, and soil stability by estimating the proportion of bare ground. To the extent feasible, we will compare reclamation transects with paired transects at nearby undisturbed sites that are not affected by road construction and represent similar topography, elevation and exposure. Vegetation sampling may also include photogrammetric techniques to test differences in the proportion of functional groups (grasses, forbs, and shrubs) among reclamation and undisturbed sites using SamplePoint image analysis software (Both and Cox 2008).

Variation in reclamation seeding outcomes may not only be a consequence of the seed mix, but also a result of site variables such as soil properties or invasive species cover in surrounding rangelands. Paired comparisons of undisturbed and reclaimed sites will allow us to test differences in weed cover as a result of wider site conditions as well as seed mix composition. To test variation in soil properties, we will collect three soil samples at depths of 20 cm along each transect for analyses at the Colorado State University Soil, Water and Plant Testing Laboratory. Soil samples will be sieved and evaluated for pH, texture, salt concentration, total organic matter, nitrate, and a range of micronutrients (e.g., iron, copper, manganese and zinc). Soil properties can significantly alter plant community composition and soil data, in combination with the stratified sampling design, will tease out factors that drive community composition within and among sampled sites (Hufford et al. 2014).

Vegetation surveys will be conducted in spring and summer of 2018 with repetition of surveys in 2019 if feasible. Sample sites will be selected in consultation with WYDOT personnel and will include I-80 as well as nearby roads where access is granted and appropriate safety measures can be taken for project personnel.

Analyses

For each site and transect, species data will be classified into five groups including native grasses, alien or introduced grasses, native forbs, alien forbs, and native shrubs (Tyser et al. 1998). We will conduct analysis of variance tests to compare variation in subgroups among seed mixes and sites. Statistical analyses will separately test transect and SamplePoint image data.

We will compare plant community diversity among sites and seed mixes by plotting dominance-diversity curves. Shannon's diversity index (H') will also be calculated within and among sites for all species as well as subgroups of native and invasive plant species and contrasted among seeding treatments, and reclaimed and undisturbed sites. The multi-response permutation procedure (MRPP) will be used to test the hypothesis that plant communities differ among microhabitats and reclamation/undisturbed sites (Zimmerman et al. 1985). MRPP avoids assumptions of normality and equal variance of data. Differences in microhabitats will be compared with soil properties to determine if soil data distinguish microhabitat variation.

Canonical correspondence analysis (CCA) will be conducted to compare differences in species abundance with environmental variables (soil properties or invasive species cover) (Chang et al. 2016). CCA results will be tested with Monte Carlo randomizations to evaluate statistical significance of correlations between plant community diversity and environmental variation. As a final step, we will conduct indicator species analyses to determine if individual species play a significant role in measured outcomes of reclamation seeding (Dufrene and Legendre 1997). All analyses will be conducted using R software (R Core Team 2013). Identification of indicator species will guide literature investigations of palatability of those species in order to provide recommendations for reclamation seed mixes to improve wildlife/traffic safety as well as revegetation outcomes (Mastro et al. 2008).

Study Benefits

The effectiveness of reclamation seeding is rarely examined outside of short-term site visits for regulatory assessment. Evaluation of both the rate of success, as well as the factors that

contribute to the success of WYDOT revegetation practices, will allow identification of optimal seed mixes and site factors, and lead to practical recommendations for cost-effective plant materials for reseeding of road corridors. Infestations of weedy species such as cheatgrass are costly and threaten nearby wildlife habitat and rangeland services (Clements and Young 1997; Weltz et al. 2014). Project data will help to identify the seed mixes that are most likely to minimize noxious and weedy species and reduce associated environmental costs. Lastly, among desirable species, a preliminary assessment of palatability or attractiveness to wildlife, may inform reclamation planning and improve safety in vegetation management and wildlife/traffic interactions (e.g., Eloff and van Niekerk 2005; Mastro et al. 2008).

Output and Output Measures

Outputs of this study support WYDOT's strategic goal of exercising good stewardship of land resources. In addition, output will support measures to maintain roadside safety and minimize costs. Output measures include valuable information about seed mixes to enable reclamation practitioners to better select among mixes and species given different environmental conditions. Improvements in species and seed mix selection will contribute to best management practices with the promise of greater success in roadside revegetation. Particularly, data derived from this study will lead to practices that minimize reclamation failures and reduce corresponding costs, time and effort required when reseeding fails and sites require additional management measures.

Information derived from this project will inform WYDOT reclamation activities in the southern half of the state and should also contribute to state-wide revegetation guidelines. This will enable appropriate selection and application of seed mixes to minimize negative impacts (revegetation failure, biological invasion and control costs, and the potential for wildlife and traffic conflicts) and provide the highest potential for reclamation success.

Performance Measures

Performance measures will be derived directly from data assessment to determine practices that reduce infestations of noxious and invasive weeds, reducing costs through decreased

application of herbicides. Results of field surveys combined with assessment of site characteristics will also be evaluated to provide performance measures to reduce reclamation costs through reduction of revegetation failures.

Applicable Questions

Barriers to successful completion of this study will include recruitment of an M.S. graduate student and summer intern to complete field work. The Hufford laboratory at the University of Wyoming has successfully recruited nearly a half dozen graduate students who continued with standard graduation rates, and several avenues exist to advertise the position and interview applicants. We routinely hire undergraduate students as research interns over summer and we've had great success provided we advertise at least three months prior to the field season.

Barriers also include the location of appropriate sites that meet acceptable safety standards for field sampling and are linked with accurate, historical reclamation data. We intend to work closely with personnel at WYDOT to locate sites for which we have an accurate reclamation history and that meet expectations for student safety. Vegetation sampling can be negatively impacted by weather conditions, and so we will plan accordingly to alter sample scheduling when necessary. All sampling will occur once we receive permission to enter sampling sites, and we will contact landowners and receive permission prior to conducting research on private as well as state or federal lands.

Statement of Work

Work Plan/Scope

We will use WYDOT's revegetation database within Environmental Services to select among completed road right-of-way reclamation projects representing a variety of ages since completion. Sites will be evaluated for ecoregion status and accessibility through GIS comparisons and initial site visits. We will subsequently document the seed mix and environmental conditions present at each site, including soil characters, average annual precipitation, planting method, and other covariates such as weed cover. Site visits will be conducted a minimum of once per year for two years and measurements will include percent

plant canopy cover (bare ground, litter, grass, forb, shrub) using AIM monitoring protocols. AIM sampling will focus on transects perpendicular to roadways and placed randomly within reclaimed areas. Undisturbed sites will be located on nearby public lands and sampled following the same methods as reclaimed sites. Quadrat sampling will be used for SamplePoint imagery as well as to accurately assess weed cover among all sampling locations and treatments (e.g., undisturbed versus reclaimed and among all seed mixes). Data will be analyzed with accepted methods to characterize differences among plant community, soil, climate and microhabitat variables. Statistical procedures are described in proposal methods.

Deliverables

1. Documenting and consolidating WYDOT's reclamation procedures and seed mixes that have been used across the years.
2. Identification of a series of appropriate seed mixes suitable for specific conditions within Wyoming.
3. Identification of seed mix applications and/or site characteristics that minimize invasive weed potential.
4. Review of palatability of indicator species for successful revegetation.
5. Quarterly, annual, and final reports to WYDOT Environmental Services staff and District Staff.
6. Presentation of major findings to WYDOT field staff.
7. Presentations to interested members of the general public, WGFD, DEQ, BLM and USFS.
8. Publication in peer-reviewed scientific journals and presentations at scientific conferences such as regional or international meetings of the Society for Ecological Restoration.

Work Schedule

We anticipate the project timeline will encompass three years with an estimated completion date in December 2020.

Change Order Information and Agreements

We understand that any changes in the duration of the contract, work plan, scope, schedule, or costs must be submitted in writing and approved by the RAC.

Budget

A detailed budget is attached to this proposal in addition to table below.

	Budgeted Amount	Explanatory Note
Direct Cost		
Total Personnel Costs	94,117.00 (detailed below)	Student stipend, tuition & fees, fringe benefits
Principle Investigator	0	None requested
Other Personnel	64,440.00	M.S. Graduate student and intern stipend
Tuition and Fees	29,677.00	3 years
Research Travel	11,969.00	Vehicle, fuel, and limited temporary accommodation for two seasons
Report Generation	0	Electronic reporting
Equipment	8430.00	Trimble GPS unit and software
Supplies	3867.00	Field sampling items including hand tools such as shovels, plant press, sample bags, soil sieve, meter tapes etc. for two seasons
Other	4680.00	CSU soil analysis lab
Technical Transfer		
Conferences/Report	2995.00	Conference travel, publication costs
Indirect Costs		
Project Administration	25,212.00	Indirect costs (UW)
Overhead		
Total	151,270.00	Approximately $50,000 per year for three years

Implementation Process

We will work closely with WYDOT representatives and other project partners through the duration of the project to ensure our findings are relevant and useful. Our deliverables will provide valuable information and recommendations pertaining to the WYDOT roadside reclamation program to maintain and improve its implementation. We anticipate results will assist in the selection and application of species for seeding along Wyoming roadways.

Technology Transfer (including Data Management Plan)

Results from this project will be shared with WYDOT staff. WYDOT Environmental Services Manager Scott Gamo and Agronomist John Samson will be consulted and participate throughout the project to ensure the project meets their needs and expectations. In addition, WYDOT will receive written and/or verbal (presentations) quarterly reports over the course of the project timeframe.

Data will be stored at the University of Wyoming in electronic and paper form (when applicable) for the duration of the project and backup data files will be maintained for several years. At the conclusion of the project, we will provide a comprehensive final report, including research results, conclusions and recommendations, raw data and metadata.

Education, Outreach, and Scientific Products

1. Presentations: We will provide presentations to interested members of the general public, WYDOT and professional societies.
2. Scientific journal articles: We will prepare and submit one or more manuscripts detailing the findings of the study to appropriate scientific journals.
3. Project evaluation: We will evaluate the outputs of the education phase to ensure project outcomes were achieved.

Personnel

Dr. Kristina Hufford is an Associate Professor in the Ecosystem Science and Management Department in the UW College of Agriculture and Natural Resources. She has over 15 years of experience in applied research and more than 30 peer-reviewed journal and other related publications. Her expertise includes botany and restoration ecology.

Dr. Scott Gamo is the Environmental Services Manager for WYDOT. He has served as a wildlife biologist and rangeland manager for over 29 years. Most of his research has involved wildlife habitats and populations. He has worked cooperatively with agencies on restoration projects for many years.

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Proposed Budget – Year 1, calculated by UW academic year

Year 1		**Amount**
2018		
Spring	MS Student	
	Stipend	$ 6,039.00
	Tuition and Fees	$ 4,910.00
	Supplies	
	Field Supplies	$ 480.00
	(transect tapes, compass, wood stakes)	
	Travel	
	UW Vehicle (sedan @ 30 days)	$ 1,470.00
	Fuel	$ 480.00
	Housing (when out of town)	$ 500.00
Summer		
	MS Student	
	Stipend	$ 4,026.00
	Tuition and Fees	$ 530.00
	Student Intern @ 14.00/hour approx. 72 days	$ 8,064.00
	Travel	
	UW Vehicle (sedan @ 30 days)	$ 1,470.00
	Fuel	$ 480.00
	Housing (when out of town)	$ 1050.00
Fall	MS Student	
	Stipend	$ 6,039.00
	Tuition and Fees	$ 4,506.00
	Supplies	
	Computer	$ 1,100.00

	Database/Stat Software	$ 530.00
	Field Supplies	$ 200.00
	(data notebooks, clinometer)	
	GPS	
	Trimble Geo 7X series*	
	Unit	$ 6,430.00
	Software	$ 2,000.00
	Travel	
	UW Vehicle (sedan @ 6 days)	$ 294.00
	Fuel	$ 90.00
	Accommodation	$ 195.00
	Indirect Costs (20%)	$ 10,177.00
	Annual Total	**$ 61,060.00**

Proposed Budget – Year 2, including soil sample collection and analysis

Year 2		Amount
2019		
Spring	MS Student	
	Stipend	$ 6,039.00
	Tuition and Fees	$ 4,910.00
	Supplies	
	Field Supplies (measuring equipment, flagging, camera)	$ 560.00
	Travel	
	UW Vehicle (sedan @ 12 days)	$ 588.00
	Fuel	$ 192.00
	Housing	$ 400.00
Summer		
	MS Student	
	Stipend	$ 4,026.00
	Tuition and Fees	$ 530.00
	Student Intern @ 14.00/hour approx. 72 days	$ 8,064.00
	Travel	
	UW Vehicle (sedan @ 30 days)	$ 1,470.00
	Fuel	$ 480.00
	Housing	$ 1,130.00
Fall	MS Student	
	Stipend	$ 6,039.00
	Tuition and Fees	$ 4,506.00

	Supplies	
	Field/Analysis Supplies (including digging tools and sample collection bags for soil sampling)	$ 597.00
	Soil Samples analyzed at CSU for ~ 30.00 per sample	$ 4,680.00
	(Approx. 156 soil = 26 transects X 2 undis/rec X 3 per transect)	
	Travel	
	UW Vehicle (sedan @ 10 days)	$ 490.00
	Fuel	$ 150.00
	Accommodation	$ 200.00
	Indirect Costs (20%)	$ 9,010.00
	Annual Total	**$ 54,061.00 ***

*Note we have received notice from Wyoming Game and Fish that $10,000 will be provided in year 2 to defray project costs.

Proposed Budget – Year 3, including attendance at one scientific conference

Year 3		**Amount**
2020		
Spring	MS Student	
	Stipend	$ 6,039.00
	Tuition and Fees	$ 4,910.00
	Supplies	
	Field Supplies	$ 100.00
	Travel	
	UW Vehicle (sedan @ 3 days)	$ 147.00
	Fuel	$ 50.00
Summer		
	MS Student	
	Stipend	$ 4,026.00
	Tuition and Fees	$ 369.00
	Travel	
	UW Vehicle (sedan @ 10 days)	$ 490.00
	Fuel	$ 153.00
	Housing(conference)	$ 650.00
	Airfare (conference)	$ 500.00
	Registration (conference)	$ 345.00
Fall	MS Student	
	Stipend	$ 6,039.00
	Tuition and Fees	$ 3,686.00
	Health Insurance	$ 820.00

	Supplies	
	Analysis/Office Supplies	$ 1800.00
	Includes ongoing database development, publication costs	
	Indirect Costs (20%)	$ 6,025.00
	Annual Total	**$ 36,149.00**
	Three-year Total	**$ 151,270.00**