WIPM Center Final Report

A. Grant Data

Grant Agreement #: 07-001492-CSU1
Title: Process Based Modeling of Ecological Thresholds: Managing *Bromus tectorum* Invaded Communities
Type: Addressing Critical Issues in IPM
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B. Nontechnical Summary.

Bromus tectorum (hereafter, *Bromus*) has been present in the southern Rocky Mountains since the early 20th century, but has become more abundant in recent decades. Its spread is a concern to land managers and livestock producers who fear loss of valuable wildlife habitat and grazing resources. The Rocky Mountain Cheatgrass Management Project was formed to address these concerns through multidisciplinary research that will generate integrated ecological and economic decision support tools in the form of a handbook and outreach materials. These tools will enable land managers, producers and extension specialists to assess the condition of rangeland with respect to *Bromus* invasion and its effects, evaluate management inputs necessary to improve the land's condition, weigh the costs and benefits of the options, and improve the ecological state of the land and economic status of the rancher. Focus groups were held to elicit input from natural resource managers and livestock producers and guide development of a stakeholder survey, which will further inform the development of

decision support tools and workshops. We have developed a preliminary conceptual model for *Bromus* ecology and management. One workshop was conducted, which provided valuable feedback on the conceptual model and input into the development of the decision support tools. A field study was conducted to identify topographic positions on the landscape that are at risk for persistent *Bromus* dominance, and a study to test the efficacy of control of *Bromus* with herbicide and restoration of native plant communities with seed, and sampling to parameterize a process-based, spatially explicit ecological model continues. The ecological model will be used to generate risk assessment maps and will be integrated with an economic optimization model to generate management scenarios, which will form the foundation of the decision support tools.

C. Introduction.

The impacts of invasive species result in losses of $120 billion per year in the US (Pimentel et al., 2005), and costs of invasive weeds on US rangelands alone have been estimated to be $2 billion annually (DiTomaso 2000). *Bromus tectorum* (hereafter, *Bromus*) has invaded 40 million ha in North America (DiTomaso 2000) and dominates 20% of the sagebrush-steppe vegetation zone (Knapp 1996). *Bromus* appears to be expanding into new areas at high elevation and latitudes in North America (Rice and Mack 1991, Bromberg et al. in review). Managers are especially concerned about losing valuable habitat for wildlife due to the invasion of *Bromus* and its ability to out-compete native perennial grass seedlings (Knapp 1996, Rafferty and Young 2002). *Bromus* also increases fire frequency and intensity (Knick & Rotenberry 1997), eliminating shrubs and perennial grasses, which are critical winter forage and habitat for wildlife. *Bromus* also changes ecosystem processes by altering nitrogen dynamics (Paschke et al. 2000, Evans et al. 2001, (Sperry et al., 2006), (Blank, 2008) and composition of microbial communities (Belnap and Phillips 2001, Kuske et al. 2002).

Changes in ecosystem function can breach ecological thresholds (Bestelmeyer 2006). A threshold exists where changes in ecosystem processes have occurred and historical conditions cannot be restored without major inputs (Westoby 1989). To avoid such transitions, ecosystem process changes must be arrested before the point at which negative feedbacks that stabilize a system switch to positive feedbacks that degrade resilience and promote the development of post threshold states (Briske et al. 2006). Sheley and Krueger-Mangold (2003) showed that traditional invasive plant control methods applied to sites without restoring ecosystem function often led to reinvasion. This idea of ecological thresholds has been integrated with economic thresholds in cropping systems to help guide management decisions (Auld and Tisdel 1987).

The work we conducted will help define ecological thresholds for *Bromus* in the southern Rocky Mountains. We used process-based simulation modeling and field experimentation to evaluate the ability of chemical control and reseeding to offset the effects of *Bromus* invasion under different ecosystems states represented by different times since burning. The work is part of a larger research program that will develop a decision-making tool to help land managers (1) assess the condition of their rangeland with respect to *Bromus* invasion and its effects, (2) evaluate what management inputs may be necessary to improve the condition of the land, (3) weigh the costs and benefits of the options, and, thus, (4) improve the ecological state of the land and economic status of the rancher. The work is being executed by a multi-disciplinary team of researchers (range scientists, weed ecologists, and agricultural economists) and land managers. The primary management collaborator is the Southeast Wyoming Cheatgrass Partnership, a group composed of representatives from the U.S. Forest Service, Division of Wildlife, Fish and Wildlife Service, county weed and pest departments, regional conservation districts, and private individuals. Management questions center around the need to develop sustainable solutions to *Bromus* invasion of low production agroecosystems.

D. Objectives.

Objective 1: *Model impacts of* Bromus *invasion under an array of IPM and environmental conditions.*
Aspects of this objective have been achieved, while we continue to work on others. We have developed a conceptual model for *Bromus* invasion and persistence, which is driven by soil texture, organic matter content, and nitrogen cycling, perennial plant cover, timing and amount of precipitation, and frequency and intensity of disturbance. Although this objective was not fully achieved by the completion of the WIPM Center grant, it will be realized by the end of 2011 through additional funding we received from USDA-NRI to expand the project.

Objective 2: *Measure effects of fire and IPM practices (imazapic application and seeding of native herbaceous species) on* Bromus *and the native plant community, and generate data vital to the accurate parameterization of the SAVANNA model.*
The objective has been met. Data were collected to evaluate the effects of imazapic and seeding on plant community composition. In addition to the measurements proposed, we collected or are collecting the following data: total C and N, net N mineralization, and potential N mineralization rates of soils, and aboveground and belowground C and N pools. An innovative photographic method was used in the second year of the study to estimate plant cover by functional group.

Objective 3: *Produce invasion risk assessment maps.*
This objective was not achieved. However, it will be realized by the end of 2011 through additional funding we received from USDA-NRI to expand the project.

Objective 4: *Publish findings. Peer-reviewed publication and website*.
Work on this objective is continuing. Development of manuscripts for submission to professional journals and outreach publication is still underway. The website has been developed and is available at http://rmcmp.agsci.colostate.edu. We are currently revising the web site and continue to develop and add content.

Objective 5: *Conduct a workshop*.
This objective has been achieved. We conducted a day-long workshop on December 3, 2009 in Cheyenne, WY.

E. Approach.

A conceptual model of *Bromus* invasion and persistence was developed by the research team using first-hand knowledge and information from the literature. Two years of field data were collected and the literature was surveyed. SAVANNA, a process-based, spatially explicit ecological model, was successfully parameterized. We are in the process of refining the model. SAVANNA represents responses to spatially varying conditions across the landscape that affect *Bromus* and has the capacity to provide spatially explicit maps of relative risk.

Imazapic and seeding treatments were applied to burned and unburned sites in September of 2008. Burns ranged in age from 1-14 years at the time of treatment. Baseline data of plant canopy cover (ocular estimates) and biomass by species were assessed in July of 2008. Monthly measurements of cover and biomass were made between May and August of 2009. A digital photo sampling method was used to make monthly measurements of plant cover to increase precision amongst estimates. *In situ* soil sampling was also conducted in the 2009 field season to determine N mineralization rates.

We invited stakeholders (i.e., ranchers and natural resource managers) to attend a day-long workshop in Cheyenne, WY on December 3, 2009. The agenda included presentations from the Rocky Mountain Cheatgrass Management team members punctuated by "Ah-ha moments and lingering questions" sessions to reinforce take-home messages and provide clarification when needed. In the afternoon, participants provided input and feedback through a small group break-out session, followed by reporting on their work to the whole group. During the break-out session, participants worked to answer questions based on the talks given by the team in the morning.

F. Progress.

The conceptual model was developed and used to inform and test the ecological model. The SAVANNA model was successfully parameterized for *Bromus* based upon literature and data from our field studies, and it appears to be providing realistic outputs. For example, it predicts a higher prevalence of *Bromus* on drier south facing slopes than on north facing slopes, which is consistent with data.

We are simulating the spatial heterogeneity present in our study areas. Despite the small scale of the areas relative to that of entire regions, there is a wide range of sites and conditions. There is a full range of slope/aspect positions, a variety of soil textures and fertility levels. Spatial data inputs for study sites were developed, including GIS coverages of elevation, soils and vegetation. Vegetation attributes included biomass and proportions of perennial grasses, forbs, and annual grasses, as well as shrub and tree cover. Soil attributes include texture, depth, carbon, and nitrogen. *Bromus* growth responded to this wide range of variability.

In the past year all study plots have been monitored and we have begun to assess the data collected relative to output from SAVANNA. The effects of imazapic herbicide and seeding have been analyzed and results will be presented at the Ecological Society of America meetings in August, 2010. Preliminary results of the digital sampling technique were presented at the Society for Range Management Meetings in February, 2010 and final results of the methodology will be presented at the GIS in the Rockies conference in

September, 2010. Results are currently being analyzed and will be fully incorporated into the SAVANNA model shortly. Preparation has also begun to analyze biomass samples collected in the last field season for carbon and nitrogen to continue to parameterize the SAVANNA model and help us understand how imazapic and *Bromus* invasion may affect the plant community through plant soil feedbacks.

The website described in Objective 4 has been developed and launched. It is available for public access at http://rmcmp.agsci.colostate.edu. Materials are still being developed to enhance the content of the website to make it more useful to land managers in their quest to better understand management of *Bromus* invasion. The format and layout of the web site are currently under revision. Development of manuscripts that will be submitted to professional journals for publication is underway. Additional outreach publications will be derived from these works.

The workshop was a success. The 22 invited attendees (8 NRCS or Conservation District, 8 public land managers, 3 ranchers, and 4 wildlife managers) were individuals who are likely to spread the word to the larger land management community. This was the ideal size for small group discussions and getting good input on our progress so far.

G. Results.

The WIPMC funding provided the essential foundation allowing the establishment of the Rocky Mountain Cheatgrass Management Project and making it possible for us to achieve what we have thus far. It is only the beginning.

The conceptual model was employed at the workshop in December 2009 and helped stakeholders understand *Bromus* invasion and persistence and provided stakeholders with new insights about rangeland systems.

SAVANNA proved to contain processes that are consistent with our conceptual model of the risks of *Bromus* invasion. For example, the model represents the effects of soil texture on the temporal patterns of soil water availability. The model represents the fact that sandy soils hold water for a shorter period of time, a resource that can be better utilized by early, fast cycle annuals such as *Bromus*. The model represents warmer temperatures and shorter periods of water availability on south facing slopes. The temporal pattern of precipitation and its effects on different plant functional groups is represented. For example, winter and early growing season precipitation favors cool season, rapidly growing annuals such as *Bromus*. As soil nitrogen increases, *Bromus* is expected to increase. In the model, nitrogen is released from the decomposition of dead plant materials, for example from dying perennial grass roots. Competition between perennials grasses and *Bromus* is represented, including the sequestration of nitrogen by the perennials. Decreased cover of perennials thus increases the risk of *Bromus* invasion. Shrubs compete with *Bromus* for moisture, nitrogen, and light. The build-up of litter due to *Bromus* increases both fire severity and intensity, which decreases shrub cover in the model. Thus, *Bromus* creates more habitat for itself by promoting fire. Grazing affects perennial grass cover and excessive grazing can create increased resource availability for *Bromus* due to increased bare ground, increased nitrogen released from dying perennials, and decreased competition for water.

Imazapic reduced *Bromus* cover across burned sites. Response of *Bromus* to imazapic application was similar in new burned and old burned sites. No establishment of native plants was detected in seeded treatments in any of the sites.

Monitoring plots within areas that had burned within the previous 3 years or burned more than 3 years ago paired with plots in unburned sites indicate the following trends that were not statistically significant: 1) Annual grass (primarily *Bromus*) cover was higher on north and south facing burned sites than on their unburned counterparts and did not decrease with time since burning. 2) North facing sites had lower annual grass cover than south facing sites. 3) Unburned south facing sites had very low annual grass cover. 4) Perennial grass cover was lower on south facing new burn sites than south facing old burn sites, while the opposite was true of north facing sites. 5) On south facing sites, forb cover was higher on old burn sites than new burn sites. 6) Forb cover was lower on old burn sites than new burn sites on north facing aspects. 7) Shrub cover was lower on burned sites than unburned sites regardless of time since burning.

In areas where the ecological model predicts higher *Bromus* growth and cover, risks of *Bromus* invasion are presumed to be greater. Importantly, the spatial distribution of risk of invasion is affected by the distribution of grazing pressure on the landscape. Since the model represents the spatial distribution of grazing, this is accounted for as well. Since grazing distribution is a management variable that can be assessed, the model can be used to identify patterns that minimize risk of *Bromus* invasion.

As described above, the publication is under development and the website is available and being continually updated and expanded.

The workshop was a big success and provided the research team with critical information about stakeholder concerns, prioritites, and perceptions. Stakeholders provided important feedback on the conceptual model, and information about what features will be most helpful to them in the decision support tools.

H. Impacts.

1. Innovations:

The use of linked economic and ecological models to inform on-the-ground decisions for integrated use of grazing, herbicides, and restoration for invasive plant management is novel, and we expect it will greatly improve management efficiency. These models will facilitate identification of management actions that will be most effective given economic constraints, and identify thresholds beyond which efficacy of a given management method changes.

The tools we are developing have the potential to be useful on hundreds of thousands of hectares of land currently invaded or at risk of invasion by cheatgass. For example, in 2007 *Bromus* was conservatively estimated to infest at least 90,000 ha of land in Wyoming, and is increasing in abundance in 22 of 24 counties in the state (Wyoming Pest Detection Program 2007).

The use of photographic imaging for monitoring is a relatively new approach to estimate plant canopy cover. We felt it would be more precise (i.e., repeatable) than ocular estimates with a new crew each field season. We also believe that the approach will allow land managers to increase monitoring and assessment of the effects of management activities by permitting individuals with limited botanical knowledge to take images during the field season, while highly trained personnel conduct detailed image analysis during the off season.

2. Safeguarding human health and the environment:

The primary benefit to human and environmental health will be as a result of the ability to minimize pesticide use by applying herbicides only when they will be most effective.

3. Economic benefits:

Although we have made substantial progress, the full scope of the proposed work has not yet been achieved, however, the work continues with funding from additional sources. Thus, it is too soon to tell what the economic benefits of our work will be and how many clients will be positively affected. We believe that the ecological and economic models and field experiments will result in economic benefits to public and private land managers through our extension efforts. We expect that the work we are doing will aid managers in identifying when incurring the expense of purchasing seed for seeding or other management activities are warranted.

4. Implementation of IPM:

An integrated pest management system that includes seed addition, herbicides, and grazing with respect to time since burning will be tested in a small-plot study and through ecological and economic modeling.

Educational materials will be a product of subsequent funding that will allow us to continue the project. They will be distributed to public and private land managers in Colorado and Wyoming.

The workshop we conducted included 22 participants. We expect to train at least twice this many mangers through future workshops, and we expect that these participants will share what they learn with others in their communities, extending the impact of our project. The web site has the potential to provide critical information to even more managers, which we expect to stimulate more to participate and apply the tools we are developing.

We have not tracked web site usage, but will begin doing the new version of the website being launched.

It is too soon to tell how many will adopt IPM practices as a result of our project. Although evaluation of the project success in terms of adoption of the decision support tool that we will develop was not part of the WIPMC project, we will gather this information from a post-project survey, which will be funded by a USDA-NRI grant.

5. Has your project or study enhanced collaboration among stakeholders *interested in the development and implementation of improved IPM strategies and systems? (For example, number of growers or other types of stakeholders that have participated in advisory committees, surveys)*

Our project has enhanced stakeholder collaboration through interactions at the pre-project focus groups, and the workshop held in February 2009. We obtained feedback from the workshop indicating that interaction with other managers was one of the real benefits of the workshop to those who attended. We will get more information about this from the post-project survey.

I. Appendices.

Please visit the project website at http://rmcmp.agsci.colostate.edu/ to see photographs, the conceptual model figure, presentations made at workshops and conferences, and project newsletters.

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