WESTERN COORDINATING COMMITTEE ON REVEGETATION AND STABILIZATION OF DETERIORATED AND ALTERED LANDS

WCC-21

Annual Report 2003

PURPOSE:

Natural and human-altered environments in the western United States are impacted by disturbances that result in the loss of topsoil, introduction of contaminants, reduction in productivity, and/or loss in structural and functional components of the affected and surrounding ecosystems. These disturbances may result from natural causes such as fire, floods, drought and wind storms, or from human-related causes associated with use or extraction of natural resources such as mineral extraction, cropping practices, timber harvesting, livestock grazing, pipeline development, roads, power corridors, and waste disposal. Disturbances occur on a wide range of ecosystems ranging from arid rangelands to mesic forests to alpine and arctic tundra. Severe disturbances have allowed the creation and expansion of many invasive non-indigenous species (weedy species) in many ecosystems leading to near monocultures of these species. Some ecosystems are capable of recovering after disturbance through natural successional processes, but some disturbances are so severe or have occurred on fragile ecosystems that require intervention to restore or rehabilitate them, retain quality soils and to reestablish natural ecological processes.

WCC-21 was conceived initially to focus on mined-land reclamation, but was expanded to include stabilization and reclamation of all types of land disturbances. The committee has emphasized the application of reclamation technology to the restoration and sustainability of ecosystems and biodiversity. The main goal of reclamation is to protect the soil resource by reducing wind and water erosion while simultaneously reducing air and water pollution. The current focus reflects three of the four Environment and Natural Resources research priorities identified by Western AES Directors in 1994. Currently, federal land management agencies are emphasizing the use of native plants in revegetation, however, this is hindered both by a lack of native seed availability and by technology on how to establish and maintain these native species. WCC-21 is participating in the development of a revegetation decision support system to assist land managers in selecting appropriate species for sites and in using the appropriate establishment methods.

The committee compiles information yearly regarding completed and current research efforts by agencies represented on the committee. Each member submits to the secretary an annual report of research and publications. These annual reports are compiled and distributed to the agencies. A poster depicting current research is maintained by the vice-chairperson and made available to members upon request for presentation at regional and national meetings of professionals involved in revegetation and stabilization of lands. Two subcommittees have been formed for the following purpose: (1) develop symposia for professionals regarding revegetation and reclamation technology with emphasis on new science and technology developments; and (2) develop

and maintain a list of available reference material generated by its members and educational materials for stabilization and revegetation of deteriorated and altered lands.

OBJECTIVES:

- Promote interdisciplinary approaches to the stabilization and revegetation, and where appropriate to the restoration of biodiversity and ecological function, of altered and disturbed lands using WCC-21 member expertise in the fields of soil science, hydrology, plant science, ecology, rangeland sciences, geomorphology, forest science, wildlife biology, and animal science.
- Conduct field tours of altered/deteriorated and revegetated lands to review technology, make recommendations and broaden experience of WCC-21 participants and hosts.
- Promote technology development and transfer on all aspects of revegetation and reclamation of lands in the western U.S.
- Disseminate information about WCC-21 activities through a web site, poster presentation at meetings, and workshops of professional societies and related associations.
- Discuss current issues, determine research needs, and coordinate future research activities relating to the area of revegetation and reclamation.
- Identify resources available through the committee that can be used for instruction through the inclusion of materials on the WCC-21 home page.

EDUCATIONAL PLAN:

WCC-21 works closely with university extension and federal and state technology transfer offices to distribute results from work conducted by the contributing agencies. The committee publishes numerous journal articles, bulletins and other sources of information on the revegetation and stabilization of deteriorated and alter lands that will be compiled into source lists for distribution. These lists will be updated regularly and sent to state extension and federal land management regional and state offices for dissemination to their personnel. Participation of WCC-21 members at regional, national and international conferences and committees on technology transfer and strategic planning also results in educating both professionals and the public on our research and extension activities.

EXPECTED OUTCOMES:

- Prepare an annual report of project summaries and publications of participating institutions; coordinate and participate in annual field tours of innovative technologies.
- Maintain a web site home page that lists WCC-21 past, present and future activities and contains links to sites of related interest.

- Develop a list of research needs and priorities involving revegetation and land stabilization.
- Sponsor or co-sponsor symposia or technical sessions on identified key issues/topics at regional, national and possibly international professional meetings (e.g., American Society for Surface Mining and Reclamation, Billings Reclamation Symposium, Society for Ecological Restoration, Society for Range Management, Soil Science Society of America).
- Prepare guidelines on native species seed collection, processing and documentation; update and present a WCC-21 poster at professional meetings documenting the committee's activities and available information.
- Provide a list of instructional materials available from the committee.
- Produce a CD slide set for instruction use.
- Maintain a mix of committee members that represent a wide variety of disciplines involved with revegetation and land stabilization.

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ALASKA

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INTRODUCTION

This report summarizes the revegetation research projects at the Agricultural and Forestry Experiment Station (AFES) of the University of Alaska Fairbanks from January 1, 2003, to December 31, 2003. Current AFES revegetation research is shifting from monitoring earlier studies to survey of mycorrhizae on disturbed lands, both natural and mined.

COMPLETED PROJECTS

1. Evaluation of Field Techniques to Describe Vegetation on Forest Inventory Plots. (D.J. Helm, AFES, and B.R. Mead, USFS)

   Objective was to compare techniques for estimating forest understory in a reproducible manner for long-term and large-scale projects involving many observers. While this project was oriented toward the USFS Forest Inventory plots, the same sampling techniques are potentially useful for monitoring revegetation and restoration efforts and documenting disturbance responses. The USFS Anchorage Forestry Science Laboratory initiated a study to test five different techniques for reproducibility among six observers in two forest types in southcentral Alaska: overall community estimates, ocular estimates in quadrats, horizontal-vertical profiles, nested rooted frequency, and points. Three general methods of evaluating reproducibility were considered: standard deviations (precision among observers), analysis of variance (significance of observer effect), and components of variance (proportion attributable to observer). Most techniques were reasonably reproducible with a standard deviation among observers of 20%, but not 10%. The analysis of variance and components of variance both had significant observer effects. However, observations tended to be more consistent when more detail was

required in recording. For instance, in complex communities, most observers could not agree on dominant plant species when standing at center of circle, but cover estimate variability tended (not significant) to be less with horizontal-vertical profile and point techniques, which require more detailed observations, and might be improved with more training. (Funded by US Forest Service, journal article published)

2. Abandoned Coal Mined Land Revegetation Monitoring (D.J. Helm, AFES; N. Moore, Plant Material Center; B. Novinska, B. McMillen, Division of Mining, Land, and Water)

   The objective is to evaluate use of slow-release organic fertilizers on abandoned mined lands in southcentral Alaska with the intent to slow development of seeded vegetative cover to encourage natural colonization. The plots were set up and implemented by Plant Material Center but monitored by AFES researchers. In 1999, three commercially-available organic fertilizers (Biosol, Fertil-Fibers, and Humi-zyme) were applied at standard rates on overburden while mineral fertilizer was applied on overburden (control) and a plot with replaced grub material. All plots were seeded with the same grass seed mix at the same rate. After 5 years, growth is best on the topsoiled plots. Growth on the mineral fertilizer (control) plots has declined to the same level as organic fertilizers. Woody colonizers have become significant in year 5 on the topsoiled plot as well as a sheltered control, which is also closer to a seed source and inoculum than the main plots. Undesirable colonizers ("weeds") are negligible on all plots. Potential disadvantages of this slow ground cover development include possible erosion, delayed time for organic matter buildup, and possible colonization by undesirable species. After 5 years, it appears the treatment most suitable for short-term soil protection is mineral fertilizer, especially if grubbed material is available. (Funded by Alaska Department of Natural Resources, Division of Mining, Land, and Water, Abandoned Mined Land Program)

ONGOING PROJECTS

1 .Ectomycorrhizae on Disturbed Lands in Southcentral and Interior Alaska: A Comparison of Regional Similarities and Differences (D.J. Helm, AFES, McIntire-Stennis Forestry Research Program)

   Ectomycorrhizal fungi (EMF) range from generalists to specialists and may be associated with specific plants and/or substrates. Selection of appropriate fungi or mixes for inoculum in revegetation are important for success. The primary objective of this project is to compare ectomycorrhizal communities in early successional sites across a latitudinal gradient in Alaska to determine whether there are similarities in EMF morphotypes (fungus-root structure appearance) to assess feasibility of a common inoculum or strategy

for revegetation. Materials are being collected from sites ranging from the Kenai Peninsula to the Brooks Range, including deglaciated, burned, and mined sites. Roots of seedlings or soil/litter cores were collected by substrate from three primary locations during summer 2003: Exit Glacier in Kenai Fjords National Park, the FrostFire prescribed burn in the Caribou-Poker Creek Research Watershed northeast of Fairbanks, and Bonanza Creek LTER site. Laboratory analyses are ongoing. The ectomycorrhizal communities analyzed so far appear different, largely as a result of different plant communities. Some EMF species do appear in common through at least some of these communities. The most reliable inoculum still appears that it would come from local communities since they would match the plant species and would be adapted to that latitude and other environmental conditions. However, as laboratory analysis continues, we may be able to find a few in common, such as *Cenococcum*. (Funded by Mcintire - Stennis Forestry Research Program)

2. Inoculated Woody Seedlings: A New Alaskan Crop for Alaskan Revegetation. (D.J. Helm, AFES, and D. Ianson, ARS)

The objectives of this study are to determine whether initial year growth and mycorrhizal colonization of *Shepherdia canadensis* (buffaloberry, soapberry), a shrub used for ornamental and revegetation purposes, could be improved by inoculating seedlings indoors, growing the plants, then transplanting on revegetation sites that might be devoid of mycorrhizae and *Frankia* inoculum. This would provide local growers with a product in a niche market not occupied by large companies outside Alaska. Preliminary results after one growing season suggest no dramatic improvement in mycorrhizal colonization of *Shepherdia* roots in inoculated plants compared to uninoculated ones, possibly because of small size of plants when transplanting on site. Although seedlings were started indoors, germination for many was quite slow (3 months), and indoor lighting may not have been adequate for normal growth of the plant nor for mycorrhizal formation. Some individuals were only 1 or 2 months old before they were hardened. Some *Shepherdia* seeds may take over one year to germinate. Because of the long startup time for this species, it might be better to seed in pots closer to spring with longer daylight in greenhouse, harden off in screenhouse over the summer, then overwinter either indoors or sheltered environment, then plant the following spring when plants are larger. (Funded by USDA, New Crop Opportunities).

CURRENT PUBLICATIONS AND PAPERS

Helm, D.J., and B.R. Mead. 2003. Reproducibility of vegetation cover estimates in southcentral Alaska forests. Journal of Vegetation Science 14:33-40.

Helm, D.J. 2003. Evolution of Revegetation Success Criteria and Monitoring for Usibelli Coal Mine, Alaska. Northern Latitudes Mining Reclamation Workshop, Fairbanks, AK, 10 pp.

CALIFORNIA

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Introduction

This report summarizes restoration research in the Department of Botany and Plant Sciences, the Department of Entomology, the Department of Environmental Sciences, and the Center for Conservation Biology, University of California, Riverside; and the USDA Forest Fire Laboratory, Riverside. The research is/was funded by the Metropolitan Water District of California, The National Science Foundation, and the Environmental Protection Agency. Experiments are being carried out primarily in parks and conservation reserves in vegetation types that are threatened by development. This includes especially coastal sage scrub vegetation, oak savannas, and Mojave desert areas. These vegetation types are being lost to urbanization and contain many threatened, endangered, and sensitive plant and animal species, and are the subject of many restoration and mitigation studies.

Ongoing Projects

Exotic weed control at the Shipley Ranch Reserve (E.B. Allen, M.F. Allen, UC Riverside, and Douglas Deutschman, San Diego State University); Animal use of restored vegetation at the Shipley Ranch (R. Redak, M.F. Allen, UC Riverside)

The Shipley Ranch Reserve is a habitat mitigation reserve that was purchased by the MWD in return for the land being flooded at the Diamond Valley Lake Reservoir. It was historically grazed, but the cattle were removed in about 1990 and the vegetation has been recovering since. However, a large fire in 1993 burned much of the ranch, and native species recovery has been slow. Large areas are dominated by exotic annual grasses that were once native shrub- and forbland. Our objectives are to reduce the grass cover to allow native species to recolonize. We are using three methods, a grass specific herbicide, sheep grazing, and dethatching of grass litter to promote native species germination. The sheep grazed 1 ha plots for 48 hours in spring 1999, 2000, and 2001. The herbicide Fusilade was applied to 1 ha plots during the 1999 and 2000 spring seasons. Dethatching was done during October-November 1999 prior to the winter rainy and spring growing season. The dethatching treatment allowed the recolonization of many annual plants, including many exotics. The density of

endangered Stephen's kangaroo rat quadrupled in the dethatched plots, indicating its preference for low-statured and sparse vegetation, compared to the surrounding denser grassland. Native insects had reduced cover after grazing but not in the other treatments. However, the insects recovered in the grazed plots in the next rainy season following grazing. Both grazing and Fusilade/dethatching decreased the abundance of exotic annual grasses as hoped, but grazing also decreased the native forbs. We had hoped to assess the recovery response of native forbs in spring 2002, but this was the driest year on record (only 10 cm precipitation in an area that averages 28 cm). There was very little germination of native annual forbs. The low productivity of exotic grass indicated there was a persistent beneficial effect of grazing and Fusillade on controlling grass, but this could be better assess during a normal rainfall year.

Some of the plots burned during the October/November 2003 fires, and will be sampled again in the spring of 2004.

Nitrogen Deposition Impacts on Coastal Sage Scrub and Mixed Coniferous Forest (T. Meixner, E.B. Allen, UC Riverside; M.E. Fenn, USFS).

Up to 50 kg/ha/yr of N is deposited on the natural vegetation of California, primarily nitrate originating from automobile emissions. The impact of N deposition is different on different vegetation types, depending upon their rate of productivity, rate at which N accumulates or flushes through the system, and amount of N deposition. This study will compare the impacts on native plants and ecosystem dynamics in two major vegetation types, coastal sage scrub and mixed coniferous forest. A hydrologic approach is employed to determine the potential for N movement out of these systems. We hypothesize that CSS will retain N in the soils longer than forest, even if air pollution regulations were to mandate reduced N emissions. Thus the potential for restoration of N-impacted soils will be diminished in CSS, and this vegetation is currently experiencing high rates of invasion by exotic annual grasses coupled with a decrease in native shrub cover. In addition to changes in vegetation, the soil microorganisms are undergoing change, with losses in diversity and density of mycorrhizal fungi. N movement through soil horizons was slight during the dry 2002 season, but we observed N accumulation at 75 cm deep during 2001. We are currently assessing the impacts of N deposition on the vegetation diversity along a rural to urban air pollution gradient in CSS.

Completed Projects

Impacts of mycorrhizal fungi on restoration in seasonal tropical forest, Mexico (E.B. Allen, M.F. Allen, A. Gomez-Pompa)

Field studies were done to determine the effects of mycorrhizal inoculum from early and late successional forest on growth of tree seedlings over four growing seasons in seasonal tropical forest, Quintana Roo, Mexico. Early successional inoculum was collected from a two year old burned forest, and late

successional from a mature forest. The early successional inoculum proved to be best for increasing growth of six tree species tested. The nonmycorrhizal seedlings were smallest for four of the six species, and two were smallest when late seral forest inoculum was used. The reason for the different growth responses to the early and late successional inoculum is probably due to different species composition of mycorrhizal fungi. The late seral inoculum had a high proportion of species in the Gigasporaceae, that are known to be poorer mutualists compared to the genus *Glomus* that dominated in the early seral inoculum. A second experiment was done with six additional tree species, and in this experiment the late successional inoculum produced the best growth response. Furthermore, one of the six tree species, *Cochlospermum vitifolium*, had 100% mortality due to a root fungal disease, *Fusarium*. While this tree is indigenous to the Yucatan, it does not occur at the field station. Our results indicate that the fungal disease limits its growth. The experiment also shows the advantage of using a restoration experiment to help learn more about the basic ecology of species. Two publications have arisen from this research, and a third has been submitted.

New Projects

Abandoned farmland is being purchased as part of the Western Riverside County Habitat Conservation Plan. This plan includes some 130 sensitive, threatened and endangered species (plants, birds, herptiles, fish, insects). The farmland is destined to become habitat for these species, if ic can be restored. Two such projects have been initiated, one funded by the NRCS (for restoration) and the Renewable Resources Extension Act (for planning and monitoring), the second by the US Fish and Wildlife Service to begin this growing season. Both sites were once coastal sage scrub vegetation. They have variable problems including fertilization with manure and possibly sewage sludge, that are making restoration difficult. Areas that were seeded in spring 2003 had a successful stand of CSS shrubs if they had no past organic amendments, while areas with organic amendments produced such dense stands of agricultural weeds that native species could not establish. Several growing seasons of weed control are proposed for the organic soils.

Publications (since last report)

Yoshida, L.C. and E.B. Allen.15N uptake by mycorrhizal *Artemisia californica* and the invasive *Bromus madritensis* of a N-eutrophied shrubland. Biology and Fertility of Soil, in press.

Allen, E.B. 2004. Restoration of *Artemisia* shrublands invaded by exotic annual *Bromus*: A comparison between southern California and the Intermountain Region. Pp. in press *in* A.L. Hild, N.L. Shaw, S.E. Meyer, E.W. Schupp, and T. Booth, compilers. Seed and Soil Dynamics in Shrubland Ecosystems: Proceedings; August 12-16, 2002, Laramie, Wyoming, Proceedings RMRS-

P-000.. U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Renker C, Zobel M, Öpik M, Allen MF, Allen EB, Vosátka M, Rydlová J, Buscot F (in press) Structure, dynamics and restoration of plant communities: does arbuscular mycorrhiza matter? In: Temperton VM, Hobbs RJ, Nuttle TJ, Halle S (eds.) Assembly Rules and Restoration Ecology. Bridging the Gap Between Theory and Practice. Island Press, California.

Publications in press at last report, now published:

Johnson, N.C., D.L. Rowland, L. Corkidi, L. Egerton-Warburton, and E.B. Allen. 2003. Nitrogen enrichment alters mycorrhizal allocation at five mesic to semiarid grasslands. Ecology 84:1895-1908.

Allen, E.B., M.F. Allen, L. Egerton-Warburton, L. Corkidi, and A. Gomez-Pompa. 2003. Impacts of early- and late-seral mycorrhizae during restoration in seasonal tropical forest, Mexico. Ecological Applications 13:1701-1717.

Fenn, M.E., Baron, J. S., Allen, E. B., Rueth, H. M., Nydick, K. R., Geiser, L., Bowman, W. D., Sickman, J. O., Meixner, T., and Johnson, D. W. 2003. Ecological Effects of Nitrogen Deposition in the Western United States. Bioscience 53:404-420.

Burger, J.C., R.A. Redak, E.B. Allen, J.T. Rotenberry, and M.F. Allen. 2003. Restoring arthropod diversity in coastal sage scrub. Conservation Biology 17:460-467.

Allen, E.B., H.A. Violi, M F. Allen,and A. Gómez-Pompa. 2003. Restoration of Tropical Seasonal Forest in Quintana Roo. Pages 587-598 in: Gomez-Pompa, A., M.F. Allen, S. L. Fedick, and J. Jimenez-Osornio, editors. The Lowland Maya Area: Three Millenia at the Human-Wildland Interface. Haworth Press, Binghamton, NY.

COLORADO

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INTRODUCTION

This report summarizes my activities related to surface mine reclamation for the calendar year 2003.

COMPLETED PROJECTS

The principal project completed during this year was the development and delivery of workshops focusing the utilization of the Revised Universal Soil Loss Equation, Version 2, (RUSLE2) on severely disturbed lands. These workshops ranged from one-half day sessions for the OSM to a two-day session for the ASMR. Workbooks, users manuals, and program disks were prepared for these workshops, as described below.

ONGOING PROJECTS

1. Application of RUSLE 2.0 erosion prediction technology to severely disturbed lands. I continue to work with Dr. George Foster (Agricultural Research Service, retired) to adapt the Revised Universal Soil, Loss Equation, Version 2.0, for use on mine and construction lands. We are focusing on the incorporation of reclamation and erosion-control practices into the C- and P-factors for the RUSLE2 program.

2. Topographic Reconstruction for severely disturbed lands. I am still working with Ms. Willow Chuse, a graduate student at the University of Denver, to develop and test procedures for incorporation geomorphic variables into the topographic reconstruction for mine and construction lands. This project should be completed this year.

3. Cover-management factors for severely disturbed lands. I am still working with Mr. Ron Karpilo, a graduate student at the University of Denver, to evaluate the scientific foundation and use of the published C-factor values on mine and construction lands. There may be sufficient data available to validate existing values or develop new and better values. This project will be completed this year.

PLANNED OR POTENTIAL PROJECTS

I expect that most of my work in the coming year will focus on the application of RUSLE 2.0 on severely disturbed lands and the refinement of training courses for the use of this model. Presently, Dr.George Foster and myself are scheduled to provide such a training course at the annual meeting of the International Erosion Control Association in February, 2004.

I will also supervise the research of Ms. Chuse and Mr. Karpilo as well.

I will also be chairing the committee that is planning the 2005 ASMR meeting to be held in Breckenridge, Colorado in June 2005.

CURRENT PUBLICATIONS AND PAPERS

Journal and Proceedings Articles

Toy, T.J. and Griffith, J.J. 2002, Recuperação Ambiental: Evolução das Práticas nas lavras de Minas Gerais, Parte I), Brazil Mineral, No 209, p. 34-40.

Toy, T.J. and Griffith, J.J. 2002, Recuperação Ambiental: Evolução das Práticas nas lavras de Minas Gerais, Parte II), Brazil Mineral, No 210, p. 26-33.

Toy, T. J., 2001, Topographic Reconstruction on mining sites: Landscape Stabilization and Erosion Control. Proceedings of Milos Conference: New Frontier in Reclamation: Facts and Procedures in Extractive Industry, G. Eliopoulos (ed.) p. 15-19.

Workbooks

Foster, G. R. and Toy, T. J. 2003 Estimating Construction Site Soil Loss Using RUSLE2. Workbook for the RUSLE2 workshop sponsored by the Minnesota Erosion Control Association. One and one-half day workshop. [includes workbook with 18 exercises, CD, and user's manual reproduced by MECA, 177pp.]

Foster, G. R. and Toy, T.J. 2003, Soil-Loss Estimation for Construction Lands Using RUSLE 2.0. Professional Development Course Training Manual, International Erosion Control Association. One-day workshop. [workbook, CD, and user's manual reproduced by IECA and later a number were sold through their online bookstore, for which we received "zip," 129pp.]

Toy, T.J. 2003, RUSLE2 For Mine Land Reclamation. Workbook for a workshop sponsored by the Office of Surface Mining, Regulation and Enforcement. One-half day workshop. [workbook and CD reproduced by the OSM, 66pp.]

Toy, T.J. 2003. RUSLE 2.0 for Reclamation. Workbook for the RUSLE2 workshop sponsored by the American Society for Mine Reclamation. Two-day workshop. [workbook with 14 exercises, CD, and user's manual reproduced by ASMR, 183pp.]

Foster, G.R. and Toy, T.J. 2003. RUSLE2 User Manual for Highly Disturbed Lands: Construction, Reclaimed, Mined, Landfills, Military Training Grounds, and Similar Lands. [This is the user's manual included with the workshops and on the CDs, 76pp.]

Foster, G.R. and Toy, T.J. 2003. Summary RUSLE2 User Manual. This is a downloadable RUSLE2 user's manual available from the U.S. Department of Agriculture, National Sedimentation Laboratory, RUSLE2 web site. It differs from the above manuals in length and style, 122pp.

Workshops

Foster, G. R. and Toy, T.J. 2003, Soil-Loss Estimation for Construction Lands Using RUSLE 2.0. Professional Development Course Training Manual, International Erosion Control Association. Las Vegas NV, February, 2003. One-day workshop.

Toy, T.J. 2003. RUSLE 2.0 for Reclamation. American Society for Mine Reclamation. Billings, MT, June, 2003. Two-day workshop.

Foster, G. R. and Toy, T. J. 2003 Estimating Construction Site Soil Loss Using RUSLE2. Workbook for the RUSLE2. Minnesota Erosion Control Association. Minneapolis, MN, July, 2003. One and one-half day workshop

Toy, T.J. 2003, RUSLE2 For Mine Land Reclamation. Office of Surface Mining, Regulation and Enforcement. Denver, CO. August, 2003. One-half day workshop.

.**•Papers presented to professional groups**

Karpilo, R.D. and Toy, T.J. Non-agricultural C and P Values for RUSLE. Presented at the National meeting of the American Society for Mine Reclamation. Billings, MT, June, 2003.

Toy, T.J. and Chuse, W., 2003, Topographic Reconstruction on Mine Sites: Land Stability and Erosion Control. Presented at: An International

Conference: Disturbed Landscapes – Analysis, Modeling, and Valuation, Cottbus, Germany, September 2003.

COLORADO

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and

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INTRODUCTION

This report summarizes reclamation, restoration and related research projects at Colorado State University during 2003. Research was conducted by the Department of Forest, Rangeland and Watershed Stewardship, the Soil and Crop Science Department and the Center for Environmental Management of Military Lands with funding from the Colorado Agricultural Experiment Station, USDA, EPA, U.S. Army, and the Colorado Department of Public Health and Environment.

COMPLETED PROJECTS

1. Effects of Biosolids Application on Erosion Control and Ecosystem Recovery Following the Buffalo Creek Fire, Colorado (Ken Barbarick and Edward Redente, Soil and Crop Science and Rangeland Ecosystem Science Departments)

   This project was begun in the spring of 1997 and the objective was to determine appropriate organic matter and nutrient inputs from biosolids to facilitate post-burn ecosystem recovery in a forested system southwest of Denver. During the four years following treatment, total plant biomass ranged from approximately 50 to 230 g m^{-2} and generally increased with increasing biosolids application and the percentage of bareground ranged from 4 to 58% and generally decreased with increasing biosolids rate. Higher rates of biosolids application were associated with increased concentrations of N, P, and Zn in tissue of the dominant plant species, streambank wheatgrass (*Elymus lanceolatus*) relative to the unamended, unfertilized control.

2. Soil Erosion Survey: Sheridan Local Training Area, Wyoming (Steve Warren and Tom Ruzycki, Center for Environmental Management of Military Lands)

The objective of this project was to apply a new-generation 3-dimensional derivative of the Universal Soil Loss Equation (USLE) to predict the magnitude and spatial distribution of soil erosion and sediment deposition. The derivative, called the Unit Stream Power Erosion and Deposition (USPED) model, differs from the USLE in the manner in which it considers the role of topography on the erosion process. Whereas the USLE considers only a straight-line distance of runoff movement, the USPED considers the entire upslope contributing area. The USLE predicts only soil erosion, predicts erosion universally even where deposition takes place, and cannot be effectively applied to complex topography. The USPE predicts both erosion and deposition as a change in sediment transport capacity across GIS grid cells and is applicable to any terrain. A map was produced showing the extent and spatial distribution of erosion and deposition. Field validation showed the map to be 84% correct. An additional map was produced to show erosion risk. The maps can be used to plan erosion control measures.

ONGOING PROJECTS

1. Reclamation at the Summitville Super Fund Site (Edward Redente and Mark Paschke, Rangeland Ecosystem Science Department)

   This project began in the fall of 1995 and involves a greenhouse phase and a field phase. The objective of the project is to test reclamation alternatives for stabilizing acid generating waste rock material at an elevation of 11,000 feet.

2. Metal Toxicity Thresholds for Important Reclamation Species in the Western U.S. (Edward Redente, Mark Paschke, and Ken Barbarick, Rangeland Ecosystem Science and Soil and Crop Sciences Departments)

   This project began in June 1999. The objective is to establish heavy metal toxicity thresholds for approximately 35 plant species that are commonly used in reclamation work in western North America. The project involves large greenhouse screening studies and will eventually establish toxicity thresholds for a variety of grasses, forbs and shrubs for As, Cd, Cu, Mn, Pb, and Zn.

3. Integrated Control and Assessment of Knapweed and Cheatgrass on Department of Defense Installations (Mark Paschke and Edward Redente, Rangeland Ecosystem Science Department; Don Klein, Microbiology Department; Steve Warren, Center for Ecological Management of Military Lands; Northern Plains Agricultural Research Laboratory—USDA-ARS in Sidney, MT; Department of Energy Remote Sensing Laboratory, Las Vegas, NV)

This project began in April 2000 and will extend for four years. The objective is to develop a strategy for the control, monitoring, and prediction of knapweed and cheatgrass infestations at Fort Carson in Colorado and Yakima Training Center in Washington.

4. Diffuse Knapweed Invasion Ecology: Establishment, Competition, and Interactions with the Native Soil Community (Paul Meiman, Edward Redente, Mark Paschke, Rangeland Ecosystem Science Department; George Beck, Bioagricultural Sciences and Pest Management Department; and Don Klein, Microbiology Department)

   This project began in 2001 and will continue for three years. The objective is to evaluate conditions under which rangeland systems either resist or are susceptible to diffuse knapweed invasion.

5. Shrub Establishment Techniques of Coal Mine Lands in Colorado (Edward Redente and Mark Paschke, Rangeland Ecosystem Science Department)

   This project began in September 2000 and will extend for four years. The objective is to develop methods for the establishment of woody plants on coal mine disturbances in northwest Colorado. Three mines sites are included in the study and methods include strip seeding, transplanting, testing seed mixtures with relatively low-competitive grasses and forbs, soil depth, soil quality, and fencing to exclude deer and elk.

6. Erosion Control Master Plan for the Combat Maneuver Training Center, Hohenfels, Germany (Steve Warren and Michael O'Donnell, Center for Environmental Management of Military Lands)

   This project began during the spring of 2003. The goal is to produce an interactive expert system to assist in the selection and implementation of erosion and sediment control measures on an intensively used military training area. The user will click on a watershed, and the system will prompt the user with a list of best management practices (BMPs) appropriate for the conditions and military training requirements of the watershed. The user will select one or more practices and the system will assist in the design, placement and cost-estimation of the measure(s).

7. Cyanobacterial Inoculation for Stabilization of Disturbed Soils at Yuma Proving Ground, Arizona (Steve Warren, Center for Environmental Management of Military Lands; Paul Kugrens; Todd Hawkins, Midwest Industrial Supply)

Beginning in the Spring of 2003, this objective of this project is to develop, apply and evaluate inoculant material to restore biological soil crusts to disturbed soils. One of the primary pioneer species groups of biological soil crusts is cyanobacteria. Cyanobacteria were collected from Yuma Proving Ground, isolated in the laboratory, mass-cultured and incorporated into clay pellets. The pellets will be applied to disturbed soils during January 2004. The population of cyanobacteria in the surface soil of study plots will be monitored and compared to uninoculated plots.

8. Cyanobacterial Inoculation for Soil Stabilization on a Capped Landfill at Holloman Air Force Base (Steve Warren, Center for Environmental Management of Military Lands; Jeff Johansen, John Carroll University; Todd Hawkins, Midwest Industrial Supply)

   During 2002, cyanobacteria were collected from soils at Holloman Air Force Base near Alamogordo, NM. The cyanobacteria were isolated in the laboratory, mass-cultured and incorporated into clay pellets. Pellets were be applied to a capped landfill February 2003. An adjacent area was treated in August 2003. The population of cyanobacteria in the surface soil of treated plots will be monitored and compared to uninoculated plots.

9. Cyanobacterial Inoculation for Soil Stabilization at Following Wildfire in the Pinyon-Juniper/Sagebrush Ecosystem of Utah (Steve Warren, Center for Environmental Management of Military Lands; Jeff Johansen, John Carroll University; Todd Hawkins, Midwest Industrial Supply)

   During 2000, cyanobacteria were collected from soils surrounding a recently burned pinyon-juniper/sagebrush site in the Cedar Mountains 105 km west of Salt Lake City, UT. The cyanobacteria were isolated in the laboratory, mass-cultured and sprayed onto hemp cloth. The cloth was then cut into 1cm square pieces. The hemp pieces were applied and raked into plots in the understory of burned sagebrush during November 2001. Soil samples collected one year later revealed significantly higher chlorophyll content in inoculated plots than in uninoculated plots. Samples were collected again in 2003. Results are pending.

10. Cyanobacterial Inoculation for Soil Stabilization on Capped Waste Rock Piles at the Yucca Mountain Nuclear Repository, Nevada (Steve Warren and Kerri McConnell, Center for Environmental Management of Military Lands; Paul Kugrens, Biology Department; Todd Hawkins, Midwest Industrial Supply)

    During 2002, cyanobacteria were collected from soils at the Nevada Test Site, NV. The cyanobacteria were isolated in the laboratory, mass-cultured and incorporated into clay pellets. During January, 2004 pellets

will be applied to top soils capping waste rock piles. The population of cyanobacteria in the surface soil of treated plots will be monitored and compared to uninoculated plots.

PLANNED OR POTENTIAL PROJECTS

1. Integrated Management of *Centaurea maculosa* (Spotted Knapweed) in the Western United States while using its chemical weapons as ecologically benign herbicides. J. M. Vivanco, M. W. Paschke and S. Nissen. USDA. November 2003 to October 2005.

2. Allelochemical control of non-indigenous invasive plant species affecting military testing and training activities. J.M. Vivanco, M.W. Paschke, R.M. Callaway and S. Nissen. DoD-SERDP—pending approval.

3. Soil erosion survey of the Lovell Local Training Area, Wyoming Army National Guard. S.D. Warren and T.S. Ruzycki, Center for Environmental Management of Military Lands.

4. Development of a freeze-dried cyanobacterial inoculant for stabilization of disturbed arid soils. S.D. Warren and P. Kugren, Center for Environmental Management of Military Lands

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COLORADO

UPPER COLORADO ENVIRONMENTAL PLANT CENTER

PREPARED BY:

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INTRODUCTION:

The Upper Colorado Environmental Plant Center (UCEPC) is a non-profit corporation organized by two Rio Blanco County, Colorado, Soil and Water Conservation Districts. It is operated with technical assistance from the USDA Natural Resources Conservation Service (NRCS) as well as assistance from other federal and state agencies, and the private sector. The UCEPC is situated on a 269 acre site near Meeker, Colorado. The center's service area is the Upper Colorado River Basin. The region is mountainous with high plateaus, open parks, mesas, and river valleys.

The UCEPC has the following high priority areas identified in its long-range plan:

1. High altitude and disturbed lands revegetation
2. Vegetative treatment to improve water quality
3. Increased productivity and conservation of rangeland, pasture and woodland resources
4. Wildlife habitat enhancement
5. Xeriscape and horticulture uses of native plant materials

Annual Highlights

In 2003 the center participated in State Plant Materials Meetings in Colorado, Utah and Wyoming. Area needs were identified and potential plant materials for development were discussed.

The center made seed collections in 2003 of species that were identified by agreements with various agencies. Seed collections were generally better in 2003 as compared to 2002, due to more precipitation.

A new linear move sprinkler system was completed in 2003. We plan to use this system to irrigate our North 80 acres in 2004. The 80 acres has been flood irrigated in the past.

ONGOING PROJECTS:

1. The tested class release of Garnet mountain brome

   Mountain brome is for use in conservation systems for controlling erosion, improving water quality, and to improve livestock and big game ranges above 6,000 feet in elevation, that receive over 15 inches of annual precipitation. The accession has been selected for increased resistance to head smut, extended seed production and increased longevity over 'Bromar'. It is intended for use in revegetation of coal, and oil shale mined lands, transmission corridors, improvement of wildlife habitat and erosion control on cropland. Garnet was released in 2000 and seed has been provided to growers. In 2003, a 0.18 acre planting on the center was harvested.

2. Release of Maybell source antelope bitterbrush

   Antelope bitterbrush (*Prushia tridentata*) is a native shrub given high priority for oil shale restoration, wildlife habitat improvement, and rangeland seeding. The Maybell source (9024373) was collected near Maybell, Colorado, and a seed production orchard is planted at the plant center. A selected class release was approved in early 1997, and seed is available to commercial growers. A project has been initiated to re-establish Maybell bitterbrush on its original site after a series of fires destroyed most of the original stand. Bitterbrush has been planted and evaluated at the site. A study on the fate of fall-sown bitterbrush seed at Maybell, Colorado was completed in 2002. A project to examine the effects of seed age on bitterbrush establishment (COPMC-0202-WL) was evaluated in 2003.

3. A cooperative project with the USFS Shrub Lab in Provo, Utah

   Seed increase fields of silver sagebrush and western yarrow were planted on the center. These materials are needed to revegetate fire-damaged areas for the BLM and the USFS in Idaho and Utah. Seed from yarrow and silver sagebrush have been harvested. Seed from the western yarrow field was provided to a commercial grower in 2003. Seed fields of the two species have been removed.

4. Exxon planting

The project has reference plots for comparison to oil shale revegetation work done by Exxon at the Colony Site. The project was evaluated in 2003, however, the results from the project are under a non-disclosure agreement.

5. Northwest Colorado prairie junegrass crossing block

   Seed from the crossing block was bulked and used for a 1 acre planting in 2002. The 1 acre planting was harvested in 2003 and will be used to develop a Northwest Colorado release of prairie junegrass.

6. Increase of salina wildrye

   Salina wildrye is a native, cool season, bunchgrass found on rocky slopes and sagebrush hills in Colorado, Idaho, Utah and Wyoming. The grass is quite drought and alkali tolerant and should be important for reclamation of mined lands, roadsides, surface-distrubed areas, and areas of heavy use. Two plantings on the center are harvested, but have only provided only small quantities of seed. Both plantings were harvested in 2003.

7. Soda Lake, Wyoming field evaluation planting

   The project was completed in 2002, and was not evaluated in 2003.

8. Coyote Draw, Utah field evaluation planting

   The project evaluates various experimental and commercially available plant materials and planting techniques. Plots include shrubs, forbs, legumes and grasses. The project was not evaluated in 2003.

9. Shrub orchard – transplanted woody species

   Shrubs have been evaluated for survival, vigor, and wildlife usage. Certain accessions have been identified for xeriscape landscaping and horticulture plantings. An updated report on this project is developed each year.

10. Seed increase of thinleaf alder

    Seed from thinleaf alder from northwest Colorado has been collected. The seed will be used for a release of thinleaf alder. No seed was harvested in 2003.

11. Uintah basin willow evaluation and increase

    Willows for the project were collected in Wyoming, Colorado and Utah. The center cut and distributed the materials for testing in the region. At present the project is inactive.

12. The UCEPC in 2003 had cooperative agreements with Rocky Mountain, Mesa Verde, Teton, Sequoia, Yosemite, Bryce Canyon, and Lassen Volcanic National Parks, and Great Sand Dunes and Dinosaur National Monuments.

13. Coal Basin Mine – seed increase for revegetation

    A seed increase effort has been initiated through a cooperative agreement between the UCEPC and the Division of Minerals and Geology for the State of Colorado. Seed from a single species, Calamagrostis purpurascens, was cleaned and planted in 1998. A small quantity of seed was harvested from a sparse stand in 2000. No seed was harvested in 2002 or 2003.

14. Summitville superfund site seed increase

    Seed production fields of alpine timothy, Bigelow goundsel (Senecio), slender wheatgrass, spike trisetum and tufted hairgrass, all high elevation plants, have been established at the plant center. Seed was harvested from all but tufted hairgrass in 2002. The senecio is from an alpine setting and vigorous plants are still present in the planting. As a result, we plan to evaluate the potential of the plant for use at high elevations.

15. In 2000, a small project was developed in the greenhouse to produce Native Plant Mats. In 2002 a field project was initiated to continue the development of these mats. The field project was evaluated in 2003 and a project report will be developed.

16. The UCEPC is currently responsible for breeder's class and/or foundation class seed of the following cultivars:

'San Luis' slender wheatgrass
Garnet mountain brome
'Bandera' Rocky Mountain penstemon
'Volga' mammoth wildrye
'Timp' northern sweetvetch
'Arriba' western wheatgras
'Montane' mountain mahogany
'Redondo' Arizona fescue
Maybell – source antelope bitterbrush
'Summit' Louisiana sage

‘Luna’ pubescent wheatgrass
‘Hatch’ winterfat
‘Hycrest’ crested wheatgrass
‘Peru Creek’ tufted hairgrass
'Hobble creek' mtn. big sagebrush
ARS-2678 kura clover

CURRENT PUBLICATIONS AND PAPERS:

Maybell bitterbrush – Division of Wildlife – 2003 project report 08A210, (which includes COPMC-T-9802-WL Caching and tubling plants in plots and COPMC-T-9803-WL Tubling plants in rows).

Seed production – a plant center report for 2003.

Live plant production – a plant center report for 2003.

Transplanted orchard woody species – 2003 project report 08I020J.

2003 reports for National Parks:

Mesa Verde, Sequoia and Kings Canyon
Rocky Mountain, Bryce Canyon
Grand Teton, Yosemite
Dinosaur National Monument, Lassen Volcanic
Great Sand Dunes National Monument

Exxon plant materials studies – 2003 report 08A194

Northwest Colorado junegrass – 2003 project report 08A207

Monthly and annual weather report for plant center, 2003

Effects of seed age on bitterbrush establishment - 2003 project report COPMC-0202-WL

Native vegetation mats - T-0201-CR

Willow planting at an alkaline site - 08A213

Smooth brome comparison – 08A209

IDAHO

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INTRODUCTION

This report summarizes revegetation and restoration research conducted at the USDA-ARS Northwest Watershed Research Center in Boise, Idaho for 2002. The focus of the NWRC revegetation/disturbed land program is to characterize establishment requirements of native grass and shrub species; evaluate impacts of wild and prescribed fire on vegetation, invasive weeds, soil erosion, streamflow and water quality; and to optimize restoration strategies for disturbed rangeland in the Great Basin region of the western United States.

COMPLETED PROJECTS

1. Seedbed Microclimate Modeling (Stuart Hardegree, Steve Van Vactor, USDA-ARS)

   The objectives of this project were to evaluate alternative models for estimating seed germination response to temperature. The most common thermal response models make a number of unnecessary assumptions about model shape. These include assumptions that temperature response is linear for a given subpopulation of seeds; all seeds have the same base temperature, and/or maximum temperature; and that the relationship between thermal time is sigmoidal among seed subpopulations. We tested a common probit model, best-fit regression models, and a statistical gridding technique (kriging) to determine whether alternative models would be as accurate at predicting germination time, and to improve computational efficiency. In general, most of the models tested fit relatively well overall. The linearity and base temperature assumptions of the probit model, however, caused significant errors in prediction of low-temperature germination response. The statistical gridding technique was the most computationally efficient but did not yield any parameter coefficients that could be used for direct comparison among seed lots.

2. NEXRAD Evaluation for Estimating Distributed Precipitation with Data from the ARS Watershed Monitoring Network (Stuart Hardegree, Steve Van Vactor, Kathleen Healy, Dave Levinson)

NWRC evaluated National Weather Service WSR-88D Next Generation Radar (NEXRAD) stage 1, Level 3 radar products using rain gauge information from 6 ARS research watersheds in Boise, Idaho; Tucson, Arizona; Tifton, Georgia; Watkinsville, Georgia; El Reno, Oklahoma; and Oxford, Mississippi. This radar system produces hourly precipitation estimates on a 4 x 4 km grid across the continental US. The purpose of this evaluation was to determine whether this information could be used to distribute precipitation estimates to remote field sites that do not have weather stations. It was determined that the current algorithm for converting radar reflectivity to rainfall underestimated total rainfall by between 17 and 73% for all locations except Tucson for which it overestimated rainfall by about 20%. Underestimation was primarily due to a precipitation detection function that was set too high to detect the bulk of low intensity rainfall events. The National Weather Service has also subsequently discovered a programming error in the software used to process the radar data that also contributes to an underestimation of actual rainfall. In 2003, the National Weather Service modified their program to lower the precipitation detection threshold and to fix the truncation error. NWRC will be monitoring rainfall estimates at these watersheds to determine whether these errors have actually been corrected.

ONGOING PROJECTS

1. Prescribed-Fire Research at the Reynolds Creek Experimental Watershed in Southwestern Idaho (Stuart Hardegree, Fred Pierson, Pat Clark, Gerald Flerchinger, Mark Seyfried)

   The Northwest Watershed Research Center has initiated a landscape-scale, prescribed-fire research program at the Reynolds Creek Experimental Watershed (RCEW) in southwestern Idaho. This program was initiated in 2001 in cooperation with the private-land owners at RCEW, the Bureau of Land Management Lower Snake River District and Owyhee Field Office, Idaho Department of Lands, and other ARS research locations in the sagebrush-steppe vegetation type (Burns, OR; Dubois, ID; Cheyenne, WY). The objectives of this research program are to assess prescribed-fire impacts on vegetation, soil, and water resources, post-fire grazing management, weed response, and the efficacy of fire treatments for fuels management and juniper control. The first in a series of four prescribed fires was conducted in September 2002. Additional prescribed fires are planned for 2004, 2005 and 2008. In the next year, a research and management plan will be developed to put the mountain-sage zone at RCEW on a 25-year fire cycle. Current research projects within the overall program have emphasized monitoring of vegetation response, soil infiltration and erosion, livestock grazing patterns, and soil water relations. NWRC welcomes collaboration with other research programs and projects

that could benefit from our long-term infrastructure and landscape-scale treatment emphasis.

2. Hydrologic Impacts of Western Juniper (Stuart Hardegree, Fred Pierson, Pat Clark, Gerald Flerchinger, Mark Seyfried, Danny Marks, Tony Svejcar, Jon Bates)
Wildfire played an important role in the control of western juniper in the Intermountain western United States prior to European settlement. The Northwest Watershed Research Center is cooperating with the Eastern Oregon Agricultural Research Center in Burns, Oregon, and the Bureau of Land Management, to establish a series of 8 watershed-research locations in southern Idaho and eastern Oregon to study the hydrologic impacts of juniper expansion and subsequent control. The basic experimental design will be to establish a weir, sediment-sampling and meteorological instrumentation in each watershed (~200 acres). These watersheds will be monitored for vegetation attributes, infiltration, erosion, streamflow, snow distribution, grazing animal behavior and forage utilization for an initial calibration period of 5-8 years. After a period of watershed calibration, half of the watersheds will undergo mechanical eradication of juniper. All watersheds will be monitored for an additional 8-10 year period, at which time, juniper eradication will take place on the second set of field sites. Subsequent control of juniper on these watersheds will be maintained by use of prescribed fire. NWRC welcomes collaboration with other research programs and projects that could benefit from our long-term infrastructure at these sites.

3. Risk Assessment of Fuel Management Practices on Hillslope Erosion (Fred Pierson, Pete Robichaud, Ken Spaeth, Corey Moffet)

The NWRC in cooperation with the Forest Service, Rocky Mountain Research Station in Moscow, Idaho have developed a web-based erosion risk management tool (ERMiT) for natural resource managers to use following wildfires, prescribed fires and areas treated with different fuel management practices. Field data needed to establish ERMiT infiltration and erosion parameters for a variety of forested and rangeland conditions have been collected over the past five years from wild and prescribed fires across Nevada, Idaho, Montana and Colorado. Field experiments have been conducted to test the efficiency of post-fire mitigation practices such as contour-felled logs, straw wattles, hand trenches, straw mulch, contour raking, wood mulch for controlling soil erosion. A number of small burned watersheds have been instrumented to collect post-fire erosion data for testing erosion mitigation practices at the landscape scale and for validating ERMiT results. A prototype ERMiT was used by several post-fire rehabilitation teams during the 2003 fire season to identify areas of high erosion risk based on variability in climate, soil properties, and

burn severity. A completed version of ERMiT is planned for release prior to the 2004 fire season.

4. Cooperative Model Development and Enhancements at NWRC: SPUR/WEPP Rangeland Hydrology and Erosion Tool (Fred Pierson, Ken Spaeth, Corey Moffet)

   The enhancement of the SPUR/WEPP (Simulation, Production, and Utilization of Rangeland and Water Erosion Prediction Project) model has been a cooperative project between ARS and NRCS since 1995. The objective of SPUR/WEPP was to take advantage of the complementary strengths of both SPUR and WEPP by integrating the two models into a more functional rangeland ecosystem model responsive to the needs of resource managers. The Simulation, Production, and Utilization of Rangeland (SPUR) model was released in 1987 by the USDA-ARS as a comprehensive rangeland simulation model for research and management. The technology included a stochastic climate generator, plant growth, hydrology, soils, livestock, wildlife, nutrient cycling, and economic modules. It was designed to predict changes in runoff and sediment resulting from management practices, simulate the spatial heterogeneity of rangeland communities, and predict the response of vegetation to herbivory, nitrogen, and water availability. The SPUR/WEPP model continues to evolve with enhancements to the hydrology, erosion, and management modules. The SPUR/WEPP model merges the WEPP hydrology which uses physically-based infiltration, runoff, and erosion algorithms that are dynamically interactive with storm characteristics, soils, and vegetation. The NWRC has been working on rainfall simulation, infiltration, and erosion research in conjunction with both wild and prescribed-fires since 1996. The results of this research will provide the basis for model enhancements focused on soil water repellency and rill erosion processes. Potential applications of enhanced SPUR-WEPP technology include: evaluating the impacts of management (grazing, fire, range improvement practices); developing hydrologic information for Ecological Site Descriptions; assisting in conservation planning, and evaluating the outcome and benefits of conservation practices.

5. Prescribed Fire Effects on Livestock Grazing Activity, Habitat Usage and Foraging Strategies (Pat Clark, David Ganskopp, Doug Johnson)

   Since the summer 2001, NWRC scientists have been investigating prescribed fire affects on livestock range use patterns and evaluating the effectiveness of post-fire grazing management strategies. Mature beef cows on the Breaks Study Site at the Reynolds Creek Experimental Watershed were fitted with GPS telemetry collars in July 2001 and 2002. The collars acquired GPS locations every 10 minutes providing accurate records of cattle movement (+/- 16 feet) throughout a fenced pasture (434

ac) prior to prescribed burning. On-collar activity sensors also allowed researchers to estimate what activities the cows were engaged in along their movement tracks. The Breaks was burned in September 2002. Post-fire cattle GPS telemetry data were collected on the Breaks during July 2003 and will continue to be collected for at least 5 more years. Collection of pre- and post-fire data will allow evaluation of fire effects on cattle habitat usage, activity budgets and foraging strategies. A similar project was initiated at the Whiskey Hill Study Site at RCEW in May 2003. This site will be burned in August/September 2004 allowing collection of 2 years of pre-fire cattle telemetry data.

6. Post-Fire Grazing Utilization in Sagebrush-Steppe Plant Communities (Pat Clark, David Ganskopp, Doug Johnson)

   Following the prescribed fire at the Breaks Study Site at the Reynolds Creek Experimental Watershed in 2002, livestock exclosure sets were constructed on the site in areas representing low (3 sets) and moderate (3 sets) fire intensity. Each exclosure set contained 4 adjoining exclosures (0.1 ha each) and 1 unfenced area (0.1 ha). Moderate cattle stocking was be applied outside the exclosures during August of 2003 and will continue to be applied for the next 5 years. At each set, sequential removal of exclosure fences will allow comparison of 4 post-fire grazing treatments including: 1) deferred (grazed 2003), 2) 1-year rest (2004), 3) 2-year rest (2005), and 4) 3-year rest (2006). The remaining exclosure per set will be retained as an ungrazed control. During summer 2003, plant species diversity, abundance and cover measurements were made in each exclosure both before and after cattle grazing was applied. With continuation of these vegetation measurements for at least the next 5 years, researchers will be able to evaluate of the impact each of these 4 post-fire grazing management strategies has on the ecological status of sagebrush steppe rangeland. A similar project will be initiated during fall 2004 at the Whiskey Hill Study Site.

7. Remote Sensing of Prescribed Fire Effects on Vegetation (Pat Clark, Doug Johnson, Ken Spaeth, Fred Pierson)

   NWRC scientists began assessing the pre-fire vegetation conditions at the Breaks Study Site in the RCEW during the summers of 2001 and 2002. Remote sensing flights were conducted during peak vegetation growth in 2001 (hyperspectral) and 2002 (color-infrared). Vegetation maps were developed from these remote sensing data. Habitat patch size, connectivity, edge length and other habitat parameters were determined from these maps using GIS techniques. Production, cover, leaf area, abundance, diversity, and forage quality of the shrub and herbaceous species were measured in the field within the 3 dominant vegetation types present on the site. Juniper tree age and size were also sampled and

individual trees were permanently tagged for later evaluation. A prescribed burn was applied to the study site using a strip-backfire ignition pattern during September 2002. A post-fire remote sensing flight was conducted in September 2002 to evaluate fire severity patterns on the study site. Post-fire vegetation conditions, including production, cover, forage quality and other measures, were assessed in the field during summer and fall of 2003. Re-sprouting of antelope bitterbrush relative to fire severity were also evaluated. Tagged juniper trees were revisited and examined for mortality or fire-damage during fall of 2003. Additional remote sensing flights to examining post-fire vegetation and wildlife habitat responses are planned for summer 2004. Field measurements of post-fire vegetation response at the Breaks Study Site will be conducted annually for at least the next 5 years. Similar projects will be initiated at the Whiskey Study Site during summer 2004. These remote sensing data will be used to assess prescribed fire effects on vegetation diversity and productivity, livestock forage, wildlife habitat and the efficacy of using prescribed fire for juniper control.

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IDAHO

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INTRODUCTION

This report summarizes revegetation and restoration research conducted by members of the USDA Forest Service, Rocky Mountain Research Station, Shrubland Biology and Restoration Research Work Unit stationed in Boise, Idaho and their cooperators during calendar year 2003. Research emphasizes invasive species biology, development of native plant materials, primarily broadleaf herbs, for use in the Great Basin, and technology for their use. This research is partially funded by the USDI Bureau of Land Management, Great Basin Restoration and Native Plant Initiatives, the National Fire Plan, the Joint Fire Sciences Program, and the National Research Institute.

ONGOING RESEARCH

1. Invasion of rush skeletonweed (*Chondrilla juncea* L.) into sagebrush communities (C. Lynn Kinter, University of Wyoming; Nancy L. Shaw, USDA-FS-RMRS; Ann L. Hild, University of Wyoming)

   Rush skeletonweed (*Chondrilla juncea* L.), an invasive Eurasian apomictic perennial weed, has spread southward through Idaho and recently invaded sagebrush steppe communities of the Lower Snake River Plain. The process by which the southern Idaho genotype of this species invades this low precipitation, frequently cheatgrass (*Bromus tectorum* L.) infested, and generally highly disturbed area is poorly understood. Data are needed to aid land managers in slowing invasion and managing the spectrum of shrub steppe communities. Research was conducted to examine the process by which rush skeletonweed is spreading Components of the research to date include (1) A survey of the Lower Snake River Plain to identify the extent and characteristics of invaded areas; (2) Examination of population dynamics of rush skeletonweed comparing density, phenology, spread from seeds and rhizomes, and soil seed banks on burned and adjacent unburned plots in shrub steppe communities, most of which were dominated by exotic annual grasses; (3) On these same plots, assessment of rush skeletonweed seed

germination and establishment; and (4) Laboratory studies of rush skeletonweed seed biology.

2. Germination ecology of Great Basin *Penstemon* species. (N.L. Shaw, D.L. Scholten, M.D. Scholten and J.E. Gurr, USDA-FS-RMRS; A.D. Madrigal Morfin, Universidad de Guadalajara, Guadalajara, Jalisco, Mexico)

   Adequate seed supplies of locally adapted populations of native species are required for revegetation of degraded sagebrush steppe communities of the Great Basin. Although native forbs are essential elements of these communities, seed availability of most forb species is limited or nonexistent. We are examining intraspecific variability and developing seed production practices and seeding technology for three penstemons of the northern Great Basin. Sand penstemon (*Penstemon acuminatus*), hotrock penstemon (*P. deustus*), and sagebrush penstemon (*P. speciosus*) occupy different habitats and may be valuable for use in postfire seedings, mixed plantings, roadway revegetation, and low water use landscaping. Preliminary work indicated that newly harvested seed of all three species is dormant, exhibiting less than 15% germination under favorable conditions. Germination was improved by moist prechilling for 8 to 12 weeks. The prechilling requirement for sagebrush penstemon, but not hotrock penstemon, was reduced by a liquid smoke treatment. Treatments permitting more rapid and uniform germination are desirable for production of nursery stock and establishment of seed production fields for seed increase or commercial seed production.

3. Development of Native Forb Plant Materials for the Great Basin**.** (Durant McArthur, Nancy L. Shaw, Scott Jensen, and Ann DeBolt, USDA-FS-RMRS; Tyler Thompson, Utah Division of Wildlife Resources)

   Select germplasms of common native forb species of the Great Basin will be released following common garden, laboratory and genetic studies. About 15 species are included in this effort.

COMPLETED RESEARCH

1. Restoration of western ranges and wildlands (in press) (Stephen B. Monsen [retired]) USDA-FS-RMRS; Richard Stevens [retired], Utah Division of Wildlife Resources). Final chapters of a book on plant materials and seed and seeding technology for western wildlands were completed by Nancy Shaw following retirement of the authors.

2. Native Plant Community Response to Long-Term Infestation of *Centaurea repens* and *Cardaria draba* in Idaho and Wyoming.

Brian A. Mealor and Ann L. Hild, University of Wyoming; Nancy L. Shaw, USDA-FS-RMRS) Little emphasis has been placed on native species' responses to invasions by exotic species. We investigated old (>25 y) infestations of the invasive perennials *Centaurea repens* and *Cardaria draba* to determine impacts of these 2 exotics upon resident native communities. We examined four *Centaurea* and three *Cardaria* sites in Wyoming and Idaho and documented species presence and abundance in five $1m^2$ plots within infestations and in adjacent, non-infested areas. We randomly collected seed from native plants within and adjacent to each infestation. A greenhouse study was initiated to compare competitive effects of invaders on natives collected from within infestations to effects on natives from non-infested areas. Native diversity (Shannon-Weiner) and community similarity (Morisita) was variable across sites. In greenhouse trials, *Sporobolus airoides* collected from inside *Centaurea* infestations grew larger than *Sporobolus* from non-infested areas, when grown with *Centaurea* competitors. We are continuing the greenhouse study to include propagules of *Poa secunda*, *Poa pratensis*, *Stipa comata*, and *Astragalus* spp. Genetic differences between source populations relative to invasive species will be documented using ISSR. Results suggest remnant native plants within old infestations may have diverged genetically from conspecifics in non-infested areas, resulting in greater growth under competition. These results hold great consequence for understanding native community resilience to invasions.

3. Evaluation of treatments for enhancing germination of *Gaura neomexicana* ssp. *coloradensis* (L.M. Burgess and A.L. Hild, University of Wyoming; N.L. Shaw, USDA-FS-RMRS).

   Management of riparian vegetation is difficult as these communities are frequently impacted by herbivores, invasive weeds and altered hydrologic regimes. Multiple and intertwined factors affecting rare species recruitment are particularly difficult to identify. *Gaura neomexicana* ssp. *coloradensis* Munz (*Gaura)* is a short-lived perennial forb endemic to riparian areas in mixed-grass prairies of Wyoming, Nebraska, and Colorado. It became a federally listed threatened species in October 2000. We studied the effects of six harvest dates, a 2-month cool-moist stratification, 24-hour leaching, and 24-hour imbibition on *Gaura* germination. Germinability did not vary with collection date. Capsules harvested from *Gaura* plants grown at the Bridger Plant Materials Center in Montana exhibited greater germination than capsules harvested from endemic populations near Cheyenne, Wyoming, suggesting maternal plant growing conditions impact germination success. Because cool moist stratification enhanced germination of *Gaura* and leaching did not, sufficient moisture during cool temperatures may be more critical than leaching of germination inhibitors as might occur with normal stream flows. Spring flooding may enhance *Gaura* recruitment by expanding sites that are inundated during periods of

cool temperatures. If so, hydrologic and climatic regimes must be considered in restoring the unique conditions needed for germination of this rare riparian endemic.

PLANNED OR POTENTIAL PROJECTS

1. Seed germination of *Lomatium grayi*, *L. dissectum*, and *L. triternatum* (Nancy Shaw and Ann Debolt ,USDA-FS-RMRS)

   Lomatium species are among the native forbs considered of high priority for restoration of Great Basin rangelands. Research examining germination requirements of members of this genus is extremely limited and initial efforts indicate seeds are highly dormant. Research will be conducted to examine the natural germination ecology of three species and to develop methods for releasing germination to facilitate nursery production and seeding for establishment of seed production fields.

2. Cultural practices for *Lomatium grayi*, *L. dissectum*, and *L. triternatum seed production* (Nancy Shaw and Ann Debolt, USDA-FS-RMRS and cooperators)

   Seed supplies of *Lomatium* species are currently not available for use on Great Basin rangelands. Production of seed fields will require development of appropriate cultural practices including seeding techniques, irrigation requirements, and control of weeds, diseases, and seed predators.

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DeBolt, A. *Celtis reticulata* Torr.

Shaw, N.L. *Chamaebatiaria millefolium* (Porter) Maxim.

Shaw, N.L. *Holodiscus discolor* (Pursh) Maxim.

Shaw, N.L. *Holodiscus dumosus* (Nutt.) Heller

Shaw, N.L. *Philadelphus lewisii* Pursh

Shaw, N.L. and S.B. Monsen. *Purshia tridentata* (Pursh) DC.

Shaw, N.L. and A.M. DeBolt. *Rhus trilobata* Nutt. In T. & G.

Kansas

Introduction

This report summarizes NRCS plant materials projects relative to the revegetation of altered or drastically disturbed lands.

Completed Projects

None

Ongoing Projects

1. Evaluation of Salix Species for Stream Corridors and Shoreline Erosion (NRCS, Manhattan Plant Materials Center, Manhattan, Kansas),

   Shrub-type willows of known origin and adaptability are not currently available for revegetation work along stream and river corridors in the Central Great Plains. Willows currently available to solve conservation problems must come from wild harvest or from commercial sources. Some commercially available sources are introduced species that have not been fully evaluated in the Central Plains. Increased interest in soil bioengineering systems have placed additional demand on native willow populations for source materials. Thirty-nine vegetative willow collections were assembled at the PMC. These collections will be evaluated for performance and adaptation for use in bank stabilization along rivers and streams, shoreline and beach stabilization on large reservoirs, and for improved wildlife habitat.

2. Revegetation of an Exposed Raw Shale Site in Jewell County, Kansas (Terry Conway, Plant Materials Specialist, NRCS, Salina, Kansas; Jewell County Soil and Water Conservation District, Mankato, Kansas; Kansas Department of Environment and Health, Topeka, Kansas).

   Past management and naturally occurring slumping have exposed large areas of raw shale. These areas are prone to erosion, resulting in offsite degradation to the downslope plant community. The quality of water flowing from these sites is very acidic which also has a negative effect on downstream resources. The objective of the study is to evaluate the adaptability, survival, and spread of common reed (*Phragmites australis*) on these sites and determine the effectiveness of the established plant cover in reducing offsite degradation.

3. Controlling Shoreline Erosion With Bioengineering Techniques at Cheney Reservoir State Park, Cheney, Kansas (Terry Conway, Plant Materials Specialist, NRCS, Salina, Kansas, USDI Bureau of Reclamation, Austin, Texas; Kansas Department of Wildlife and Parks, Cheney, Kansas)

   Shoreline erosion is a significant tissue at Cheney Reservoir particularly where existing facilities are being threatened. Structural measures have been used in the past, but installation cost, aesthetics, and safety concerns with these measures have agency supervisors looking for other options. The objective of this study is to evaluate various bio engineering techniques and plant materials for the purpose of the potential development of cost effective and aesthetic alternatives for addressing the shoreline erosion.

4. Sand Dune Stabilization (Terry Conway, Plant Materials Specialist, NRCS, Salina, Kansas; Morris Houck, Plant Center Manager, NRCS, Knox City, Texas; Wade Anderson, Range Conservationist, NRCS, Cheyenne, Oklahoma)

   Where vegetation has been damaged or destroyed on sandy rangeland sites, the area becomes prone to severe wind erosion resulting in blowouts. The blowout areas are troublesome because of their potential for migration onto adjacent rangeland, the potential for road and fence inundation, and the difficulty with revegetation. While the principles of dune revegetation are well know, cost effective methods that would have local application are needed. The objective of this study is to evaluate various plant materials and stabilization techniques that are cost effective and would have application at the local level for dune stabilization.

5. Plant Species and Soil Amendments for Revegetation of Saline Sites (Terry Conway, Plant Materials Specialist, NRCS, Salina, Kansas; USDA NRCS Field Offices of El Dorado, KS - Eureka, KS - Perry, OK - Okmulgee, OK)

   Small areas of pasture and rangeland have been damaged through the spillage of brine water associated with oil drilling activity. Natural saline seeps have formed in cropland fields due to cropping practices, geology soils, and drainage configuration. These areas while small in size (typically less than 5 acres) are extremely erosive and contribute heavy sediment loads (including contaminants) to adjacent water bodies. Because these sites are typically high in salts, poor in soil structure, and low in organic matter, revegetation is extremely difficult without considerable economic input. The objective of the study is to evaluate various plant species for use in revegetating saline areas and to evaluate the effect of various surface treatments on plant species establishment.

Montana/Wyoming

USDA-NRCS Plant Materials Center
Bridger, Montana

Bridger PMC
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Introduction

This report summarizes reclamation and restoration research being conducted by the USDA-NRCS Plant Materials Center near Bridger, Montana for 2003. The Bridger PMC collects, assembles, and evaluates plant materials to help solve conservation problems in Montana and Wyoming. The emphasis is on native plant materials for reclamation of drastically disturbed lands (including surface strip mines, acid/heavy metal affected sites, saline soils, highway roadsides), windbreaks and shelterbelts, wildlife habitat, livestock forage, native landscaping, threatened & endangered, and culturally significant plants. Cooperative agreements exist with the USDI--National Park Service (roadside restoration in Yellowstone and Glacier Parks) and Deer Lodge Valley Conservation District (development of acid/heavy metal tolerant plants with funding from EPA and Montana Natural Resources Damage Program).

Completed Research

1. Express Pipeline

At two locations (saline upland and sandy sagebrush flats) in the arid Bighorn Basin of north central Wyoming, plots were established on areas disturbed by the installation of the Express Pipeline. Four mixtures (Old-commercially available cultivars, New-new and pending releases, Sandy-new and old releases adapted to sandy soils, and Clayey- new and old releases adapted to clayey soils) were seeded with a double disk drill (with depth bands) at both sites. Old cultivars that exhibited good establishment and survival include 'Critana' thickspike wheatgrass (*Elymus lanceolatus*), 'Rosana' western wheatgrass (*Pascopyrum smithii*), 'Rimrock' Indian ricegrass (*Achnatherum hymenoides*), 'Pryor' slender wheatgrass (*Elymus trachycaulus*), and 'Wytana' 4-wing saltbush (*Atriplex* X *aptera*). New releases that performed well include Bad River germplasm blue grama (*Boutelous gracilis*), High Plains germplasm Sandberg bluegrass (*Poa secunda*), Open Range germplasm winterfat (*Krascheninnikovia lanata*), antelope germplasm slender white prairie

clover (*Dalea candida*), and a wildland collection of needle and thread (*Hesperostipa comata*).

2. Idaho Fescue Compartive Evalaution

In the late 1970's and early 1980's a total of 32 collections of Idaho fescue (*Festuca idahoensis*) were made in Montana and Wyoming. They were evaluated at a site provided by the Montana Tree Seedling Nursery in Missoula, Montana. The top five performing accessions were established in a replicated trial in comparison with 'Joseph' (U. of Idaho), an accession in advanced evaluation at the Pullman PMC, and one collection each from Glacier and Yellowstone National Parks. The five selected accessions continued to be the top performers and are now being increased for potential release. Three germplasm selections in increase include; the combination of two accessions from western Montana (Missoula Co. and Sanders Co.), the combination of two accessions from southeastern Montana (Big Horn Co. and Powder River Co.), and an accession collected in the Big Horn Mountains of north-central Wyoming. Initial seed increase plots were transplanted to the field in the spring of 2003.

Ongoing Research

1. Bluebunch Wheatgrass

Twenty collections of bluebunch wheatgrass (*Pseudoroegneria spicata*) were made along the eastern front of the Rocky Mountains in Montana. Three cycles of Recurrent Restricted Phenotypic Selection were utilized to develop a strain that is currently being compared to released cultivars of bluebunch wheatgrass. This is an attempt to develop a strain that is adapted to areas in Montana and Wyoming east of the Continental Divide. All three cycles are being compared to released material (Secar, Goldar, and Whitmar) in a 20 replication Randomized Complete Block Design.

2. Development of Acid/Heavy Metal Tolerant Plants

The Acid Tolerant Plant Materials Project, is handled by two Deer Lodge Valley Conservation District employees, with grant money from the EPA Mine Waste Technology Program and the Montana Resource Damages Program. Collections of native indigenous plant materials are being increased for release to commercial growers, while further testing of species adaptation and mixture compatibility are being tested utilizing plots of individual species (35 grasses and 16 forbs) and 4 different mixes at an upland lime amended site near Anaconda, Montana. Previous mixture trials at non-amended upland and lowland sites were unsuccessful. A trial comparing local and non-local sources of woody

species is underway on a lowland non-amended site. Plant material is being released to the commercial market via the Pre-Varietal release procedures as Source Identified, Selected, or Tested germplasm. To date Washoe germplasm of basin wildrye (*Leymus cinereus*), Prospectors germplasm of snowberry (*Symphoricarpos albus*), and Old Works germplasm of fuzzytongue penstemon (*Penstemon eriantherus*) have been released. Other potential releases include slender wheatgrass (*Elymus trachycaulus*), bluebunch wheatgrass (*Pseudoroegneria spicata*), Indian ricegrass (*Achnatherum hymenoides*), alpine bluegrass (*Poa alpina*), Pacific aster (*Symphotrichum chilense*), wooly cinquefoil (*Potentilla hippiana*), big bluegrass (*Poa ampla*), Woods rose (*Rosa woodsii*), horizontal juniper (*Juniperus horizontalis*), and silverleaf phacelia (*Phacelia hastata*).

3. Dryland grasses for Xeriscaping

Ten native and introduced grasses were established under dryland conditions at the Bridger PMC as a demonstration of various alternatives for low-maintenance landscaping. One half of each plot is mowed and the other half left non-mowed during the growing season. A vehicle is driven down the length of the plots with one tire track on the non-mowed portion and the other tire track on the mowed portion to document trampling resistance. All species were initially seeded at a rate of 500 seeds/ft^2. The species in the demonstration/trial include 'Roadcrest' crested wheatgrass (*Agropyron cristatum*), 'Ephraim' crested wheatgrass (*A. cristatum*), 'Bad River' blue grama (*Bouteloua gracilis*), 'Critana' thickspike wheatgrass (*Elymus lanceolatus*), 'Bismarck' buffalograss (*Buchloe dactyloides*), 'Sodar' streamback wheatgrass (*Elymus lanceolatus*), 'Covar' sheep fescue (*Festuca ovina*), 'Rosana' western wheatgrass (*Pascopyrum smithii*), 'Bozoisky-Select' Russian wildrye (*Psathyrostachys junceus*), and 'Foothills' Canada bluegrass (*Poa compressa*). Notes are taken on ground cover, impact of trampling, softness, color, green period, and cutting shear comparing mowed and non-mowed conditions. Western wheatgrass has the longest green period under drought conditions. Blue grama has developed the densest cover, while blue grama, buffalograss, and sheep fescue have the shortest stature under uncut conditions.

4. Foundation Seed Graduate Studies

Foundation seed produced at the Bridger PMC is given to the Foundation Seed Programs at Montana State University-Bozeman and the University of Wyoming-Laramie; they ,in turn, sell the seed to commercial growers. The money generated from the sale of Foundation seed is used to fund graduate studies at these universities. At the present time three Masters projects are underway. One study, through the University of Wyoming involves the evaluation seed production of prairie coneflower (*Ratibida*

columnifera) as influenced by between-row spacing and within-row spacing. A second study, through Montana State University, is evaluating the nitrogen-fixing capabilities of native legumes; white prairieclover (*Dalea candida*), purple prairieclover (*Dalea purpurea*), northern sweetvetch (*Hedysarum boreale*), American vetch (*Vicia americana*), silvery lupine (*Lupinus argenteus*), and Canadian milkvetch (*Astragalus canadensis*). A third study will look at the water use efficiency of both native and introduced low-maintenance grass species used in a turf situation. Species to be evaluated include blue grama (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), Canada bluegrass *Poa compressa*), western wheatgrass (*Pascopyrum smithii*), thickspike wheatgrass/streambank wheatgrass (*Elymus lanceolatus*), sheep fescue (*Festuca ovina*), crested wheatgrass (*Agropyron cristatum)*, and tall fescue (*Lolium arundinaceus).* Another just completed study, through Montana State University, attempted to develop baseline hormone, temperature and timing response curves for the asexual propagation of bur oak (*Quercus macrocarpa*). In addition, other novel approaches were explored. i.e., etiolation, banding, blanching, and hedging.

5. Mongolian legumes

The grasslands of Outer Mongolia are very similar to those of the northern Great Plains,having many of the same or similar forage species. The grasslands of Mongolia, however, have an abundance of native legumes and forbs, many more than found in the prairies of Montana, Wyoming and the Dakotas. One hundred thirteen legume collections from north central Mongolia, made in the fall of 1998, are being evaluated in a replicated study at the Bridger PMC. There may be some legume species that have potential for use in dryland pastures in the United States.

6. Sweetgrass Inter-Center Strain Trial

Sweetgrass (*Hierochloe odorata*) is a culturally significant plant to the Native American tribes of the northern tier of the United States. It is used extensively in religious and cultural ceremonies. Several Plant Materials Centers (PMCs) have been evaluating ecotypes native to their respective regions. In the spring of 2002 containerized plants of sweetgrass were exchanged for Inter-Center Strain Trials with all of the PMCs involved. Plots were established with transplants from Montana, Colorado, North Dakota, Michigan, Kansas, and the released cultivar 'Redora' from South Dakota State Univesity. They are being evaluated for survival, vigor, rate of spread, and strength of odor (vanilla).

7. Demonstration Plantings

Demonstration plantings are established throughout Montana and Wyoming to exhibit new plant releases and establishment techniques. Worth noting are two recently established field demonstration plantings in Montana; one near Circle in cooperation with the McCone County Conservation District and one near Molt (north of Laurel) on the David Coles farm. The McCone County planting included 66 individual entries (37 species) and 18 different mixtures of various warm, cool season grasses, forbs, and shrubs. The mixtures were seeded as complete mixtures and in alternate rows. Some mixtures have grasses and forbs/shrubs in alternate rows, while others had cool season and warm season grasses seeded in alternate rows. The alternate rows of cool season and warm season grasses exhibited significant improvement over the combined mix of cool and warm season grasses. Shrub establishment was also improved by using the alternate row planting technique.

The Coles planting included 14 individual species, 4 mixtures and 6 alternate row plantings. Four shrub and legume species were also cross seeded on portions of the individual species plots. The winterfat (*Krascheninnikovia lanata*) and 4-wing saltbush (*Atriplex X aptera*) had only fair establishment when included in both cool and warm season grass mixtures, but established excellent stands when planted in alternate rows with Critana thickspike wheatgrass (*Elymus* lanceolatus). Native legumes such as slender white prairieclover (*Dalea candida*) and Canada milkvetch (*Astragalus Canadensis* readily established when cross-seeded across all of the individual native grasses.

Planned or Potential Projects

1. Chemical Weed Control in Native Forbs

With increased emphasis on the development and release of additional native forbs, there is a need to test new herbicides for the control of broadleaf and grassy weeds in forb seed production fields. We will examine both pre-emergent and post-emergent treatments on prairie coneflower (*Ratibida columnifera),* blanketflower (*Gaillardia aristata*), dotted gayfeather (*Liatris punctata*), white prairieclover (*Dalea candida*), and common yarrow (*Achillea millefolia*).

2. Row Spacing/alternate row planting

A replicated wheel-design (rows, like spokes of a wheel, projecting outward from 4" spacing to 4' spacing) study will be established to document the response of dryland forage grasses to increasing row spacing and forage production as influenced by being planted in alternate rows with a legume. Introduced pasture species such as crested wheatgrass (*Agropyron cristatum*, intermediate wheatgrass (*Thinopyrum*

intermedium), Pubescent wheatgrass (*Thinopyrum intermedium*), and Russsian wildrye (*Psathyrostachys junceus*) will be planted in pure stands and with alternate rows of alfalfa (*Medicago sativa*).

3. Irrigated Hay/Pasture Trials

   A replicated study will be established in the spring of 2004 to compare 14 grass species in solid stands and in alternate rows with alfalfa. Two mixes will be tested, a simple two species mix and a more complicated five species mix. Species to be included are: orchardgrass (*Dactylis glomerata)*, meadow brome (*Bromus biebersteinii*), smooth brome (*Bromus inermis*), Altai wildrye (*Leymus angustus*), tall fescue (*Lolium arundinaceus*), tall wheatgrass (*Thinopyrum elongatum*), creeping foxtail (*Alopecurus arundinaceus*), intermediate wheatgrass (*Thinopyrum intermedium*), pubescent wheatgrass (*Thinopyrum intermedium*), western wheatgrass (*Pascopyrum smithii*), timothy (*Phleum pratense*) hybrid wheatgrass(*Elymus hoffmanii*), beardless wildrye (*Leymus triticoides*), and basin wildrye (*Leymus cinereus*).

3. Seed Moisture as an Indicator of Harvest Readiness

   A portable, hand-held seed moisture tester will be used to measure seed moisture as seed approached ripeness. Seed of the major grass, legume, and forb species being grown at the Bridger PMC will be tested for seed moisture content and subsequently tested for germination and seed viability at soft, firm, and hard dough stages to determine optimum time of harvest to maximize total seed production. The correlation of seed moisture and harvest readiness can be a useful tool for commercial seed growers, particularly those that are new and inexperienced at determining optimum harvest dates of native plant species.

New Releases

Hunter Selected Class germplasm pondersosa pine (*Pinus ponderosa)*
Open Range Tested Class germplasm winterfat (*Krascheninnikovia lanata)*
Washoe Selected Class germplasm basin wildrye (*Leymus cinereus)*
Prospectors Selected Class germplasm snowberry (*Symphoricarpos albus)*
Old Works Source Identified germplasm Fuzzytongue penstemon (*Penstemon eriantherus)*

Pending releases
2004
Great Northern Selected Class germplasm Western yarrow (*Achillea millefolium)*
Trapper Selected Class germplasm Snowberry (*Symphoricapros occidentalis)*
Stillwater Selected Class germplasm Prairie coneflower (*Ratibida columnifera)*

Spirit Selected Class germplasm Sweetgrass (*Hierochloa odorata)* (vegetative release)

Future Releases

Gardner saltbush (*Atriplex falcata)*
Bur Oak (*Quercus macrocarpa)*
Green Ash (*Fraxinus pennsylvanica)*
Blanketflower (*Gaillardia aristata*)
Dotted gayfeather (*Liatris punctata*)
Idaho fescue (*Festuca idahoensis*)
Silverleaf phacelia (*Phacelia hastata)*

Current Publications and Papers

Holzworth, L.K., H. Hunter, and D. Ogle. 2003. Disturbed Forestland Revegetation Effectiveness Monitoring--Results of 30 Years. Poster. USDA-NRCS.

Majerus, M.E. 2003. Production and Conditioning of Winterfat Seed (*Krascheninnikovia lanata*). Native Plant Journal. Vol. 4, No. 1. Pp 10-15.

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HortNote 2: Establishment Watering of New Plantings.
HortNote 3: Tree Injection as a Conservation Tool?
HortNote 4. Witches brooms: Stress Symptoms to Genetically Modified Organisms
HortNote 5. Salt Affected Soils: Their cause, Measure, and Classification
HortNote 6. Selecting Plant Species for Salt-Affected Soils.
HortNote 7. Iron (Fe) Chlorosis in Plants.
HortNote 8. Balled and Burlapped and Contanierized Trees for a Conservation Christmas. Bridger Plant Materials Center, Bridger, MT

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MONTANA

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INTRODUCTION

This report summarizes revegetation and restoration research conducted in 2003 by the Reclamation Research Unit and the Department of Land Resources and Environmental Sciences at Montana State University.

COMPLETED PROJECTS

1. Phytostabilization Permanence Within Montana's Clark Fork River Basin Superfund Sites: (Dennis Neuman, Frank Munshower, and Stuart Jennings, Reclamation Research Unit, Montana State University).

   The purpose of this investigation was to generate sufficient data and information from areas receiving phytostabilization treatments, varying in age from 6 to 19 years, so that the permanence and self-sufficiency of the established and reconstructed ecosystem(s) can be assessed. Six different field sites were selected that represent phytostabilization implementation in different landscape positions, using slightly different equipment, and at different times. The sites are similar in that each was degraded because of impacts from the metal mine/mill/smelter processes. Soils or tailings at the sites contain acid producing materials and are elevated in metal concentrations compared to adjacent, non-impacted landscapes. At each site, neutralizing amendments were added to raise the soil or waste pH to a target level of seven, and at some sites, other amendments were also added. Vegetation response variables observed or measured at the six sites included cover, species richness, evidence of reproduction, evidence of nutrient cycling, evidence of succession, and biomass. Soil response variables measured included pH, acid buffering capacity, and metal concentrations. Data indicated that *in situ* reclamation or phytostabilization of acid waste is a valuable reclamation technique. The calcium carbonate amendment applied as ground limestone or industrial waste can be calculated to produce a non-acid root zone that will last indefinitely. There were indications that once vegetation is established on the waste the root mass growing into amended and non-amended materials complexes the toxic ions and thereby renders the

materials less toxic. This permits further root proliferation into adjacent non-amended materials and the initiation of a cycle of growth/neutralization/growth that is self perpetuating. This eventually permits the establishment of less tolerant vegetation on the wastes and a plant successional cycle is underway. The establishment of Lodgepole pine on amended mine tailings was only one indication that later successional changes had occurred on these treated materials. The proliferation of Rubber rabbitbrush was further evidence of this phenomenon. The spread of stands of *Juncus* and *Salix* thickets in the riparian border of the Clark Fork River and the development of pure stands of Basin wildrye on upland soils were examples of rapid successional changes taking place on these *insitu* reclaimed materials. All of these species, Lodgepole pine to the Basin wildrye, were later successional stages of the ecosystem in which they were successfully developing

2. Butte Reclamation Evaluation System (Dennis Neuman, Pam Blicker, Stuart Jennings, Reclamation Research Unit, Montana State University).

   The Butte Reclamation Evaluation System (BRES) was developed as an evaluation tool designed to ensure that the integrity of all reclaimed land, including soil cover caps or other forms of engineered caps covering mine-waste left-in-place, are maintained at a level that provides for the long-term protection of human health and the environment in an urban-upland setting. Reclamation evaluation parameters include ground cover, erosion, condition of site edges, exposed waste material, bulk soil failure or land slumps, barren areas, and gullies. The US EPA will utilize the BRES over the long-term to assess the condition of response action sites, identify problem areas, specify corrective action, and determine long-term monitoring schedules. During the development of the BRES, stakeholder representatives (County, State, EPA, and the Potentially Responsible Party Group) worked together to establish overarching objectives, develop site assessment methodologies, provide guidance, and identify evaluation parameters.

3. Montana Department of Transportation Erosion Control Manual Development and Personnel Training (Stuart Jennings and Dennis Neuman, Reclamation Research Unit, Montana State University).

   Discharge of sediment-laden stormwater from construction sites is a critical environmental and regulatory consideration for State Departments of Transportation. During the road construction season many hundreds of acres of soil are denuded of vegetation. Multiple growing seasons may be required to reestablish stabilizing vegetation. Best Management Practices (BMPs) for erosion control are required. Coincidental with implementation

of EPA's Phase II stormwater discharge regulations the Montana Department of Transportation (MDT) sought to develop a new erosion control manual. The Reclamation Research Unit, in cooperation with Camp Dresser and McGee engineers, developed a new manual for minimization of stormwater discharges from construction sites and provided training at six locations across the State for MDT construction and maintenance personnel.

4. Joint Conference of the 9th Billings Land Reclamation Symposium and the 20th Annual Meeting of the Society of Mining and Reclamation (Dennis Neuman, Reclamation Research Unit, Montana State University).

The 9th Billings Land Reclamation Symposium (BLRS) and the 20th Annual Meeting of the American Society of Mining and Reclamation held during the week of June 3-6, 2003 drew approximately 450 people from around the world. Reclamation Research Unit staff served on the Conference's Organizing Committee and Dennis Neuman was the Conference Chairman and Conference co-convener. The scientific conference dealt with regional, national, and international land reclamation and restoration issues and scientists from Texas to Alaska and from California to New Jersey, as well as five foreign countries, participated and provided results from their land reclamation and restoration research studies.

The conference theme "Working Together for Innovative Reclamation" was highlighted by field tours to reclaimed coal mining areas in southeastern Montana and northern Wyoming, coal bed methane sites in the Powder River Basin, and a tour to the Clark Fork River Basin Superfund Sites in Western Montana. Nine workshops, over 130 technical research papers and two special sessions were conducted. A series of papers from EPA's Region VIII Hazardous Substances Research Center was presented. Industrial reclamation practitioners described unique reclamation problems and innovative solutions.

5. Revegetation Strategies to Minimize Weed Re-Colonization Following Herbicide Application (Lew Stringer, Cathy Zabinski, Land Resources and Environmental Sciences, Montana State University and Joyce Lapp, Glacier National Park).

Eradication of invasive species through herbicide application represents a major ecological disturbance to a plant community, providing space and resources for subsequent plant colonization. This project focuses on revegetation after herbicide application on spotted knapweed-infested sites in northwestern Montana grasslands. We measured the density and species composition of seeds stored in the soil of weed-infested sites, to

test the hypothesis that seed bank composition and density can be a good predictor of revegetation patterns after herbicide application. Additionally, we compared site preparation approaches in the field, including hand scarification of weed-treated sites, to determine whether the seed bank of native plant species, can be effectively manipulated to further management goals. This research is being done at 2 subalpine grassland sites: one within Glacier National Park and the other on Blackfeet tribal land, near the eastern border of the Park. We concluded that the high density of knapweed seed in soils suggests that efforts to manage the seed bank prior to revegetation efforts will reduce competition between native plants and knapweed seedlings emerging from the seed stored at the site.

ONGOING PROJECTS

1. M Reclamation Project (Stuart Jennings, Reclamation Research Unit, Montana State University).

   This community service project has been initiated to repair ecological damage caused to the University and Bozeman community icon-- a large rock "M" monument on the southern end of the Bridger Mountains. The "M" is a very popular destination for local hikers resulting in severe erosion and loss of native species. MSU has provided leadership on this project allowing for the formation of a community partnership to initiate multiple enhancements at the site. Hiking trails have been reconstructed, denuded areas have been revegetated, the rock monument has been stabilized, weed management has been initiated and the parking lot has been rebuilt. This work has been completed in cooperation with the U.S. Forest Service and U.S. Fish and Wildlife Service. Over 600 private contributions have been received ranging from $10 to $10,000 dollars. Total contributions have exceeded $100,000. Supplementary support has been provided through grant writing, volunteer labor and from the Forest Service. The project was initiated in 1996 and should be completed in 2004.

2. East Helena Smelter Superfund Site (Dennis Neuman, Reclamation Research Unit, Montana State University).

   Reclamation Research Unit scientists continue to advise the U.S. Environmental Protection Agency on issues dealing with land reclamation, agricultural land use, ecological risks, and urbanization at this Montana Superfund Site. A summer field tour of impacted lands surrounding the smelter is conducted. The RRU scientists have conducted research and acted as reclamation policy advisors to the EPA for nearly twenty years.

3. Ash Disposal Pond Revegetation (Frank Munshower and John Goering, Reclamation Research Unit, Montana State University).

   This is a long-term investigation of the potential to revegetate the surface of the coal ash disposal ponds near Colstrip, MT. Permanent reclamation of the ponds is the ultimate goal of this study. Initial objectives were to determine 1) how much soil is necessary over the ash to permit establishment of a permanent vegetation cover; 2) if a diffusion barrier is necessary to seal the ash from the soil and prevent movement of salts into the soil; 3) if topsoil is necessary over the soil layer to provide an adequate plant growth medium; and 4) to determine what plant species should be seeded on the site to insure survival of a permanent plant cover that can be grazed by wildlife and/or livestock. Replicated field plots were constructed of varying materials and depths, with and without barriers, with and without topsoil, and species selection trials were integrated into the experimental design. The hydrologic and vegetation response to the different treatments have been monitored throughout a thirteen-year period.

4. Ecological Restoration Website (Stuart Jennings, Reclamation Research Unit, Montana State University)

   A Web Site devoted to the restoration of disturbed lands has been developed. The Ecosystem Restoration Website (http://ecorestoration.montana.edu) has been developed to provide web-based access to technical resources for design and implementation of land restoration technologies. The website emphasizes mineland restoration issues and examples, but includes a technical toolbox applicable to a broader spectrum of land disturbing activities. Key attributes of the website include a Technology Guide and Case History Repository. The Technology Guide presents detailed descriptions of design, evaluation and construction techniques. The Case History Repository shows an image-laden record of completed projects with supporting narrative that describes where, why and how each project was completed. These sections deliver current examples of the "state-of-the-art" project work supplemented by the underlying design basis and scientific literature. The web address for this site is http://ecorestoration.montana.edu/

5. Clark Fork River, Montana Superfund Site (Dennis Neuman, Stuart Jennings, and Doug Dollhopf, Reclamation Research Unit, Montana State University)

   Members of the Reclamation Research Unit have participated in the preparation of the Remedial Investigation for one of the nation's longest

Superfund Sites. In addition, RRU scientists have assisted the U.S. Environmental Protection Agency in discussions with the Agency's National Remedy Review Board, acted as major reviewers on the Feasibility Study, and participated in U.S. EPA sponsored Phytostabilization Forums. Current activities include participating in the preparation of the Record of Decision and the Responsiveness Summary documents. In addition, a remedial design tool used to classify lands impacted by contamination is being developed and integrated with the Record of Decision document.

6. Long-term Water Quality Monitoring, Colstrip, Montana (Stuart Jennings and John Goering, Reclamation Research Unit, Montana State University)

Mining of near surface coal deposits in Montana and Wyoming is a significant commercial industry. The Rosebud Coal member of the Paleocene age Fort Union formation is mined at Colstrip Montana. A large portion of the coal mined is burned on-site for power generation. The large ecological disturbance caused by mining and power generation is a concern to nearby residents, particularly the ranching community downgradient from the mine disturbance. This research project provides twice yearly sample collection of ground, surface and spring water quality to ensure the non-degradation of water quality in ranch lands adjacent to the mine. Research is performed in conjunction with Battelle Pacific Northwest Labs from Richland, Washington.

7. Bond Release Vegetation Criteria (Dennis Neuman, Pam Blicker, and Frank Munshower, Reclamation Research Unit, Montana State University and Tad Weaver, Department of Ecology, Montana State University).

Since the passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977, vegetation data have been collected by mine operators to describe pre-mining vegetation and establish baseline data from which vegetation reference areas can be derived. These vegetation reference areas are intended to serve as a standard for comparisons to revegetated areas on reclaimed coal mines to evaluate the success of reclamation for bond release. To date, the reference area data and pre-mine data have not been synthesized in a manner to facilitate statistical equivalency, derivation of revegetation standards, or facilitate appropriate categorization of reference areas and data in relation to some revegetation and postmine land use requirements. Data quality objectives and a quality assurance/quality control system were designed to screen data for inclusion in the database. A relational database has been designed and tested with representative data sets. Multivariate statistics have been used to evaluate queried data. Future phases include Phase III - Plant Community Characterization; and Phase IV - Plant Community Categorization.

8. Phytostabilization Studies at the Keating Tailings Site (Dennis Neuman, Greg Vandeberg, John Goering, and Stuart Jennings, Reclamation Research Unit, Montana State University).

   The objective of conducting a phytostabilization study at the Keating Tailings Site is to provide BLM managers and decisions makers with site specific information and data relating to the implementation, costs, and effectiveness of this technology so that it may be applied to other similar acid metalliferous mine tailing sites administered by BLM. During the 2003 field season, the tailings were chemically and physically characterized, and replicated experimental plots were constructed using soil amendments designed to ameliorate the plant inhibiting chemical characteristics of the tailings. The plots were seeded with native plant species indigenous to the area. During the first growing season (2004) vegetation response variables (specifically establishment, seedling density, cover, and above ground biomass) will be measured and compared to results for plants seeded into tailings that are not amended, and performance of plants seeded in an adjacent off-site, but non-impacted area.

9. Anaconda Smelter Superfund Site (Dennis Neuman, Doug Dollhopf, Stuart Jennings, John Goering and Greg Vandeberg, Montana State University).

   Members of the Reclamation Research Unit are assisting the U.S. Environmental Protection Agency in evaluation remedial designs and assessing remedial actions being implemented at this large (> 300 square miles) Superfund Site. Land reclamation was selected by the US EPA as the main remedy for large tailings ponds (> 4000 acres), and landscapes contaminated by aerial emissions. Both land restoration research and matters of land management are integrated with EPA policy so that appropriate risk-based cleanup is achieved.

10. Evaluation of Reclaimed Areas on Land Administered by the Northern Regional Office of the US Forest Service (Stuart Jennings, Pam Blicker, and Dennis Neuman, Reclamation Research Unit, Montana State University).

    The objects of this new projects are as follows: 1]. develop a technical process for the evaluation of mine reclamation projects; 2]. review of all environmental documents and technical reports pertaining to the mitigation of the human health and environmental impacts associated with the historic metal mines presently reclaimed by the Forest Service; 3]. field assessments of reclaimed mine sites within the Northern Region of the Forest Service gathering various scientific and engineering data, measurements, and observations pertaining to mine

reclamation/mitigation; 4]. field evaluation of water and aquatic resources; 5]. develop a data and information archival protocol; and 6]. integration of an educational component relating to the other objectives.

11. Evaluation of Organic Matter Addition and Incorporation on Steep Cut Slopes (Stuart Jennings and John Goering, Reclamation Research Unit, Montana State University).

    Fundamental to successful revegetation of highway corridors following disturbance is the creation of a growth environment conducive to the establishment and early survival of the seeded plants. Steep cut slopes present a unique problem. The steepness of cut slopes prevents practical replacement of salvaged topsoil with conventional equipment. The current remedy is simply to broadcast seed and hydromulch the bare slope. These techniques all too often result in marginal plant establishment since germination and initial seedling survival is limited by nutrient poor, rocky substrates characteristic of cut slopes. The resulting poor vegetation establishment leads to increased erosion and sedimentation, occasional slope failure, increased noxious weed growth, and low aesthetic quality. All of these factors except the latter can be expected to substantially increase maintenance costs in the affected areas. The overall research objectives for the project are to: 1]. reduce sediment yield and erosion from steep highway cut slopes through amendment with compost; 2]. enhance vegetation establishment on steep highway cut slopes through amendment with compost; 3]. develop amendment rates, application protocols and techniques for compost addition and incorporation on steep highway cut slopes; 4]. implement, monitor and evaluate test plots on steep highway cut slopes; and 5]. communicate, report and provide technology transfer of the research findings. Several components have been completed including conducting a review of relevant scientific literature with respect to organic matter amendment addition to enhance plant growth media, and an assessment of their applicability to conditions in Montana, and investigation of methods for organic matter application and incorporation to steep slope areas (greater than 33 percent) through literature review and correspondence with equipment manufactures and contractors. During the 2003 field season test plots were construct on steep highway cut slopes with erosive and/or poorly vegetated parent material, and an evaluation of the equipment and protocols for application and incorporation of compost on steep cut slopes were conducted. Future plans include monitoring of vegetation response on and off the plots.

12. The Ecology of Plant-Fungal Symbioses in Extreme Environments (Rebecca Bunn and Catherine Zabinski, Land Resources and Environmental Sciences, Montana State University).

The study of plant growth and the mycorrhizal symbiosis in extreme environments is relevant to understanding the potential for vegetation establishment on industrially-impacted sites, builds on research done by Moynahan and Zabinski regarding AM adaptation to extreme sites, and addresses the question of whether mycorrhizae increase plant growth on extreme sites, and if that effect depends on the inoculum source. This research focuses on arbuscular mycorrhizae (AM) and plant growth on thermal soils Yellowstone National Park. These soils are characterized by acidic to basic chemistry, elevated rooting zone temperatures (up to 57^{o}C), low phosphorous levels, and potentially toxic concentrations of multiple elements. These sites are very old, and therefore the potential exists for plant and fungal adaptations to extreme environmental conditions. Our research goals are: 1) to measure the effects of mycorrhizae on plant growth in thermal soils with a pH range of 3.5 to 9.5; 2) to assess the mechanisms by which mycorrhizae affect plant growth; and 3) to determine whether mycorrhizal fungi occurring in thermal sites are specifically adapted to those sites. We are just harvesting a greenhouse experiment with 2 grass species and one forb native to thermal soils, grown at either ambient or elevated (45 °C), with AM fungi from thermal and non-thermal soils, or no AM fungi. We are measuring plant response and AM hyphae that extend into the soil, to test the following hypotheses: AM will affect plant response to elevated soil temperatures, but that response will vary between host species; and AM plants will have lower root growth in hotter soils and more AM hyphae, with AM fungi replacing root function. We are also completing analysis of a previous experiment varying pH of the soil in which plants are grown with AM fungi from soils of pH's that range from 4.5 to 9.0. These experiments will increase our understanding of AM across a pH and temperature range.

13. Native Versus Active Revegetation on Abandoned Mine Lands in High Elevation Wetlands (Lois J. Olsen, Helena National Forest and Catherine Zabinski, Land Resources and Environmental Sciences, Montana State University).

Wetlands and riparian areas, critical habitats for both species and landscape diversity, were often the sites of hard rock mining beginning in the late 19th century. Mining created heavy metal-contaminated wastes associated with ore bodies and mine tailings, and acid mine drainage. The Ontario Mine, in west central Montana was remediated in 2002 by removing bare tailings piles, which were replaced with clean soil and seeded and planted with native species. Tailings in the Ontario mine wetland that had naturally revegetated were left in place, and there was no treatment of adit water draining into the wetland. This study's main objectives are 1) to compare vegetation composition and plant and organic matter metal concentrations between the metal-contaminated

mine wetland and an uncontaminated reference wetland, and 2) to compare remediated area plant survival, and tissue metal concentrations of *Carex utriculata* and *Carex aquatilis* between the remediated, reference and unremediated mine site plants.

14. Recreation Impacts on High Elevation Soil Biota and Soil Processes (Brian Eckenrod and Catherine Zabinski, Land Resources and Environmental Sciences, Montana State University).

Mountainous regions are some of the most heavily utilized recreation areas, and this increased pressure from human use has resulted in major ecological changes, ranging from soil compaction and decreased water infiltration to loss of habitat and vegetation loss. Soil animals and soil microbial communities facilitate the decomposition of organic matter, making nutrients available for subsequent plant and microbe uptake and are essential to the productivity, successful establishment and sustainability of restored systems. Our research has three main objectives: 1) assessing the density of arbuscular mycorrhizal fungal propagules in soils; 2) measuring and quantifying decomposition rates and nitrogen mineralization on undisturbed, disturbed, and restored campsites; and 3) characterizing soil chemical and physical properties across both site types and locations. We began this research at disturbed sites in the Gallatin and Bitterroot Mountains in western Montana and the North Cascades in Washington. With this work we will generate a better understanding of disturbance and restoration effects on high-elevation soil structural and functional components. By expanding the number of sites we sample in the North Cascades, and comparing them to results from Rocky Mountain high elevation sites, we will determine whether there are general patterns of response to disturbance that can be incorporated into restoration plans for these sites.

15. Reclaiming Hard Rock Mines: An In Depth Look at Vegetation, Soil, and Water on the Bullion Mine Site, Basin, Montana (Catherine Zabinski, Brian Eckenrod and others, Land Resources and Environmental Sciences, Montana State University).

Seniors in Montana State University's Department of Land Resources and Environmental Sciences are required to take a capstone course. This year the topic was hard rock mine reclamation, and students worked at a site on the eastern slope of the Continental Divide, 9 miles north of Basin, Montana. The abandoned Bullion Mine contained an unstable hillslope with tailings piles, waste rock and acid mine drainage. The Bullion Mine site is approximately eight acres, and was reclaimed by the EPA and the USFS during 2001 and 2002. Students measured vegetation cover by species, soil metal and nutrient levels, and water chemistry of a stream that was affected by acid rock drainage, which was not addressed in the

reclamation. Vegetation cover was 27% the first year after reclamation, with 27% of that due to a rye cover crop. Invasive species were not a problem. While cover soil effectively reduced surface metal levels, there were areas of slope failure and rill formation, which are potential sources of metal exposure. Metal levels in the stream on the site and for 1 mile down stream exceed EPA standards. Students developed a monitoring plan for the site to track soil, water, and vegetation characteristics over the next years.

PLANNED OR POTENTIAL PROJECTS

1. Development of guidelines for the proposal of and assessment of revegetation technical standards for reclaimed lands disturbed by coal extraction.

2. Development of evaluation systems for the success of reclamation and restoration of abandoned mine in Montana.

3. Development of reclamation/restoration success criteria for Superfund Sites.

4. Phytotoxicity responses of metal and acid tolerant plant species used in reclamation of acid metalliferous mine and smelter tailings.

5, Investigations of cover soil material's suitability for plant establishment and growth.

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NEW MEXICO

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INTRODUCTION

The Rocky Mountain Research Station (RMRS) maintains three Research Work Units (RWUs) in New Mexico which are co-located with the Forest Service's Southwestern Region. Two of these RWUs conduct research which is directly or indirectly related to restoration of ecosystems.

- RWU 4351 - *Ecology, Recovery and Sustainability of Grassland and Riparian Ecosystems and Wildlife in the Southwest*, has for its "Mission," to develop new methods and knowledge needed to restore damaged ecosystems and recover sensitive and endangered species resulting from disturbances and degradation of southwestern and southern-plains grasslands and riparian areas.

- RWU 4652 – *Ecology, Diversity and Sustainability of Soil, Plant, animal and Human Resources of the Rio Grande Basin,* has for its "Mission," to provide new information on the Rio Grande Basin ecosystem, with primary focus on the central basin in New Mexico. Studies focus on the influence of watersheds and management activities on riparian systems, biological diversity or riparian areas, and socioeconomic and historic responses to changes in land use.

This report summarizes ongoing research undertaken by RMRS scientists and their collaborators in New Mexico during calendar year 2003. Additional information is available on their web site at www.fs.fed.us/rm/albuq/.

ONGOING PROJECTS

1. Middle Rio Grande Exotic Fuels Reduction Study. Deborah Finch (Project Leader and Research Wildlife Biologist), Roy Jemison (Research Hydrologist), and Alice Chung-MacCoubrey (Research Wildlife Biologist).

   Treatments to reduce excess fuel loads of exotic woody species are needed in southwestern riparian ecosystems to reduce the threat of wildfires to these ecosystems, wildlife and humans that live around them. The Middle Rio Grande (MRG) bosque (riparian woodland) in Sandoval, Bernalillo, Valencia,

and Socorro counties of New Mexico is a prime example of a system where fuel reduction is needed to prevent further spread of wildfire and fire damage for residents of Albuquerque, Socorro, Belen, Isleta, Sandia, Cochiti, and surrounding rural areas. Dead and downed wood and exotic woody plants make up the fuels which put the bosque at high fire risk. The fires are most often ignited by lightening and human error. Research was initiated in 2000 by project scientists and collaborators which will identify cost effective practices that will simultaneously preserve cottonwoods (*Populus fremontii*) and other native plants, reduce wild fire risk via fuels removal, control spread of exotic woody trees and shrubs including Saltcedar (*Tamarix*, spp.) and Russian olive (*Elaeagnus angustifolia*), and have positive or neutral impacts on wildlife species. Three treatments are being compared: 1) Mechanical removal of dead and down wood and exotic plants, 2) Mechanical removal of dead and down wood and exotics plants, followed by light prescribed fire, and 3) Mechanical removal of dead and downed wood and exotic plants, followed by revegetation with native plants. The project is using a Randomized Block design to test the effectiveness of the 3 treatments, plus a control, on an average size site of 20 ha each, at three different locations (blocks) in the bosque between Albuquerque and Socorro. On each of the 12 sites, the team monitored pretreatment conditions for 3 years and will monitor post treatment conditions for at least 5 years of bird presence and nesting, bat activity, herps, vegetation, hydrology, and soils.

Collaborators:

Middle Rio Grande Conservancy District, US Fish and Wildlife Service – Bosque Del Apache, Bureau of Land management – Socorro Field Office, City of Albuquerque – Open Space, New Mexico State Forestry, and NRCS – Los Lunas Plant Materials Center.

Publications and reports:

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2. Vegetation Response of a Semiarid Grassland Watershed to Prescribed Fire. Burton K. Pendleton and Rosemary L. Pendleton (Research Ecologists).

The Bernalillo Watershed Protection Project was begun in 1953. Prior to this, heavy runoff and erosion from monsoonal rains caused catastrophic damage to small communities below. Erosion control features constructed by the Soil Conservation Service and the U. S. Forest Service consisted of terracing, furrow plowing, pitting, check dams, and grass seeding. These measures resulted in the stabilization of the watershed and a gradual increase in perennial grass cover. Aerial photographs document the expansion of juniper (*Juniperus monosperma*) woodland into the Bernalillo watershed grassland over the last 50 years. In 1995, fire was re-introduced into the grassland as a means of maintaining perennial grass cover and preventing the expansion of the juniper woodland community. A second fire was conducted in January of 1998. Except for periods of drought, total vegetative cover at the site generally increased during the years from 1995 to 2000. Drought conditions in 1995 and 2000 resulted in a temporary reduction in both vegetative and grass cover of unburned plots. Vegetative cover and perennial grass cover of burned plots declined initially following both fires, but recovered fully within 2 to 3 years. The number of juniper per plot, censused in February of 2002, averaged 22.75 for control plots and 7.25 for burned plots. Average size of live juniper was greater on burned plots, indicating that fire was effective in reducing juniper recruitment. Burned plots also contained significantly fewer cholla (*Opuntia imbricata*) than did unburned plots. Burning did not reduce the number of *Opuntia phaeacantha* patches, but did significantly reduce their size. Cover of broom snakeweed (*Gutierrezia sarothrae*), the most common woody plant on the site, initially declined following both burns, but was equal to that of unburned plots within 2 years. Prescribed fire appears to be an effective means of reducing recruitment of woody perennials while maintaining perennial grass cover. Fire treatments and monitoring at this site are on-going.

In 2003, spring and fall vegetation and soils data were collected both at the Bernalillo watershed and at a comparable site on the West Mesa, west of Albuquerque. Data sets for the major grass species and broom snakeweed were summarized. Data for the major grass species on the West Mesa were presented at the annual meeting of the Society for Range Management, January 24-30, in Salt Lake City, UT. A paper using soils data from the Bernalillo site is now in press.

Collaborators:

Carleton S. White from the University of New Mexico, Albuquerque, NM; Samuel R. Loftin with Los Alamos National Laboratories, Los Alamos, NM; and The Cibola National Forest.

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White, C.S., D.I. Moore, and J.A. Craig. (In press). Relationship between regional-scale drought and potential soil fertility in semiarid grasslands. Biology and Fertility of Soils.

3. Using Fire as a Management Tool for Yellow Starthistle under New Mexico Conditions. Burton K. Pendleton and Rosemary L. Pendleton Research Ecologists).

The spread of yellow starthistle (*Centaurea solstitialis*) in the southwest poses an increasing problem to land managers. Once established, yellow starthistle quickly dominates the site, out-competing native vegetation and making pastureland and rangeland unusable. Occupying an estimated 22 million acres in California where it is now the state's most widely distributed weed, starthistle infestations have increased in Arizona and have moved into parts of New Mexico causing concern over the potential economic and environmental impacts this invasive species might have in the region. (It is also a major problem in the Pacific Northwest.) Control of yellow starthistle requires an integrated approach using combinations of herbicide use, reseeding, biocontrol, and fire. No single control method will work. Recently, significant reductions of starthistle populations in California have been achieved using repeated burning. Under conditions associated with the yellow starthistle populations in southern New Mexico, the possibility of having sufficient fuel to carry fire in two successive years is unlikely, however the role a single fire might play in the overall management strategy has not been investigated. Our study, done in cooperation with Larry Howrey and Willie Sommers (graduate student) at the University of Arizona, and a local starthistle steering committee at Gila, New Mexico, seeks to evaluate how fire might be used in the integrated management plan for control of yellow starthistle in New Mexico using different treatment combinations of fire, herbicide use, and reseeding with perennial grasses. The study was begun in the fall of 2001. Twenty study plots, each 25 x 9 m, were established in an infested pasture near Cliff/Gila, New Mexico. Pre-burn vegetation data and

soil samples were taken prior to burning. A fire was conducted in March, 2002 on an infested field in southwestern New Mexico using Forest Service, BLM and State Forestry personnel. Fire conditions were monitored and post-fire soil samples taken for examination of seed bank mortality. Four different grasses were seeded in July 2002 just prior to the monsoon season. Herbicide treatments are planned for late March or early April. Plots will be evaluated in the fall of 2003 and again in 2004 to determine the best combination of treatments for starthistle control. Additional studies in more of a rangeland situation are planned in cooperation with new faculty member Mark Renz at New Mexico State University (NMSU).

During 2003, all treatments were completed, including grass seeding, mowing, grazing, and herbicide application. A paper regarding attitudes of different community groups to the yellow starthistle problem was presented at the annual meeting of the Society for Range Management, January 24-30, in Salt Lake City, UT. A new study with Mark Renz of NMSU is looking at the feasibility of using fire in conjunction with biological control agents for the control of yellow starthistle.

Collaborators:

William D. Sommers and Larry D. Howery of the University of Arizona, Mark Renz of New Mexico State University, and property owner, Joe Runyan.

Publications and presentations:

Sommers, William D., Larry D. Howery. 2004. The development of a community-based yellow starthistle management strategy in southwest New Mexico. Abstract #338, Abstracts, 57th Annual Meeting of the Society for Range Management, January 24-30, 2004, Salt Lake City, UT.

4. Long-term Experimental Fire Research in Shortgrass Steppe on the Kiowa National Grassland, in Northeastern New Mexico. Paulette Ford (Research Ecologist).

One of the major goals of National Forest System (NFS) land management is ecological sustainability. Fire research on the Kiowa National Grassland is part of a continuing effort to achieve ecological sustainability of NFS land by developing a scientific basis for management. Though there has been considerable descriptive research on the effects of wildfire on plant cover and productivity, the effects of prescribed burns on multiple components of the shortgrass ecosystem are not well known. Experimental research in the southern Great Plains on the Kiowa National Grassland in northeastern New Mexico is an example of the kind of research needed to address the effects of fire in shortgrass steppe. The Kiowa study uses an 18-year experimental

framework to examine the short- and long-term effects of fire frequency and seasonality on various ecosystem processes, including plant community composition, structure, diversity, and productivity; nutrient cycling dynamics; as well as the effects on microbiotic crusts, arthropods, and small mammals. Experimental fire treatments were applied to the site by the Cibola National Forest during the spring and summer of 1997, and will be applied periodically at intervals of 3, 6, and 9 years over 18 years. Research objectives for this ongoing project include the evaluation of the role of fire as 1) a tool for restoring ecological processes in shortgrass steppe; 2) a means of remediating adverse environmental effects of historical management practices; and 3) the role of fire as a component of ecosystem sustainability.

Collaborators: Cibola National Forest, Kiowa National Grassland.

Publications:

Ford, P.L. 2003. Steppe plant response to seasonal fire. Pages 1125-1131. In session: Rehabilitating Rangelands. Proceedings of the VIIth International Rangeland Congress. Editors: N. Allsopp, A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley, C.R. Hurt, and C.J. Brown. 26 July – 1 August, 2003, Durban, South Africa. Document Transformation Technologies.

5. Effects of Fire and Mowing on Expansion of Re-established Black-tailed Prairie Dog Colonies. Paulette Ford (Research Ecologist)

Black-tailed prairie dogs (*Cynomys ludovicianus*) once ranged from Canada to Mexico throughout the Great Plains and west to Arizona. During the last 100 years, public and private control programs, plague, and habitat loss have reduced the distribution of black-tailed prairie dog populations by 98%, causing localized extinctions. This species is now considered uncommon or extirpated in many areas of its former range. Black-tailed prairie dogs significantly alter grassland ecosystems and are considered a “keystone” species that require active conservation efforts (Kotliar et al. 1999). Conservation measures for this species, including reintroduction, are underway in a number of areas. Grass mowing to simulate the effects of grazing has been used to facilitate expansion of reintroduced prairie dog colonies, but large-scale mowing is generally not cost-effective. Another alternative to grazing and mowing is prescribed fire. Use of fire best simulates the system from which these species evolved and may provide a more cost-effective method to promote the expansion and vigor of reintroduced black-tailed prairie dog colonies.

Objectives are to 1) understand the use of fire as a tool for managing colony expansion of black-tailed prairie dogs in Chihuahuan Desert grasslands; 2) to

find a cost-efficient management tool for enhancing habitats for prairie dog reintroduction and 3) to use fire as a catalyst to help sustain a long-term dynamic between bison and prairie dogs. The study is on the Armendaris Land Grant located at the northern extent of the Chihuahuan Desert in southern New Mexico. The Armendaris Land Grant was purchased by Turner Enterprises, Inc., with the primary objective of producing bison (introduced in 1995), and promoting wildlife biodiversity. Efforts to restore black-tailed prairie dogs to previously occupied habitat on the ranch commenced in 1995.

Collaborators:

New Mexico State University, USDA/ARS Jornada Experimental Range, and The Turner Foundation.

6. Forest Road Reengineering to Restore Riparian Meadow Conditions in the Zuni Mountains of New Mexico. Roy Jemison (Research Hydrologist)

The Cibola National Forest in New Mexico began upgrading forest roads through the Zuni Mountains for safe all season passage in the mid 1990s. As opportunities present themselves Forest engineers try to correct some of the environmental damage that had been created by the old roads and associated structures. This is being achieved by re-engineering roads to function in concert with the environment. A specific example is the Agua Fria meadow road crossing. Prior to reconstruction, the road crossed the meadow on a solid earthen prism just above grade. A concrete bridge on one edge of the meadow allowed all the water from the upper watershed to be channeled under the roadway. An abandoned railway bed also crossed the meadow several hundred meters up stream of the roadway. It too had a single location where water was channeled under the railway. From an environmental and hydrological perspective the road and railway crossings functioned as barriers to the natural surface and subsurface flow processes of the meadow. Channelization of the meadow's runoff lead to entrenchment of Agua Fria creek, dewatering of the meadow, and loss of riparian and wet meadow habitat. Between 1995 and 1996, forest engineers redesigned and constructed the Agua Fria crossing to try and restore a significant number of wet meadow acres and improve road conditions. The specific objectives of the project were to: 1) upgrade the road that crossed Agua Fria meadow for safe all season passage and 2) restore wet meadow conditions to areas that had been impacted by roadway and railway crossings.

The restoration included a channel component and a road component. The channel present at the beginning of the project was buried. A new channel was dug down the center of the meadow, incorporating a sinuous flow pattern, typical of natural channels in the area. The road was elevated on an earthen prism which has multiple culverts through it, across total width of the

active floodplain. This design allows surface runoff to pass under the roadway without being channeled.

A monitoring program was established following construction to determine if wet meadow conditions are restored as a result of the improvements made to the road crossing and the newly constructed channel. Data are being collected on vegetation, stream flow, groundwater and channel morphology.

Seven years have elapsed since the project was completed. Runoff from spring snow melt which provides the water that causes channel changing processes in this ecosystem has been minimal due below average annual precipitation since completion of the project. Several isolated runoff events caused significant and costly damage to parts of the channel. These were related to minor design and construction errors that have been corrected. No increases in wet meadow species has been observed to date. The road is providing safe all year crossing of the meadow for residents with in-holdings in the area, recreationalists, and forest managers.

Collaborators:

Cibola National Forest, Cibola County, McKinley County, and the Federal Highway Administration.

Publications:

Jemison, R. (in press) Forest road reengineering to restore riparian meadow conditions in the Zuni Mountains of New Mexico. In: Proceedings of the International Conference on Transportation and the Environment, August 24-29, 2003, Lake Placid, NY.

7. Restoration of Riparian Conditions (Hydrology and Vegetation) and Associated Wildlife Species in Upper Bluewater Creek of the Zuni Mountains. Roy Jemison (Research Hydrologist).

   The vegetation in high elevation riparian areas plays a variety of important roles in creating and maintaining healthy watersheds. Such vegetation stabilizes the bank and channel structures of streams, slows the movement of water downstream and dissipates flow energy, and helps maintain good water quality. In addition, these riparian systems provide crucial habitat for native species of birds, fish, amphibians and small mammals. However, historically high levels of grazing and browsing are believed to have eliminated much of this habitat, and current ungulate grazing pressures may be keeping native vegetation from regenerating.

In the Cibola National Forest - Mt. Taylor Ranger District, a key area for restoration activities has been on Bluewater Creek, directly south and west of Bluewater Lake. Restoration work was conducted on a 2.4-km stretch of the creek in the mid to late 1980's, focusing on the re-planting of native species of willow (*Salix* spp.), restriction of motorized vehicle access, and the use of fencing to exclude livestock. Although recognized as a successful restoration project, there was never a program to establish baseline data on hydrology, vegetation, wildlife habitat, and wildlife use, nor to collect data for monitoring changes over time.

Collaborators: Cibola National Forest.

Publications:

Jemison, R. and C.L. Stropki. 2003. Restoration of riparian conditions and associated wildlife species in upper Bluewater Creek in the Zuni Mountains of New Mexico. (Published Abstract) In: Proceedings of the VIIth International Rangeland Congress. Editors: N. Allsopp, A. R. Palmer, S. J. Milton, K. P. Kirkman, G. I. H. Kerley,C. R. Hurt, C. J. Brown. 26 July – 1 August, 2003, Durban, South Africa.

NORTH DAKOTA

Bismarck Plant Materials Center

INTRODUCTION

This report summarizes 2003 project activities at the USDA, Natural Resources Conservation Service, Plant Materials Center located at Bismarck, North Dakota. Current projects are focused on native prairie and riparian restoration and development of native forbs, legumes and wetland species for conservation use. Work continues on woody species and foundation seed production.

COMPLETED PROJECTS

Prairie Restoration Partnership. (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota, and the North Dakota State Game and Fish Department).

The objective was to develop technology for restoring diverse native prairies. No-till seeding methods were used for renovating old introduced stands of grass. These field trials were evaluated and data collected on diverse native seedings. Project plans included the renovation of introduced species with a diverse mixture of native grass, forbs and shrubs. A technical brochure for prairie restoration in the Northern Great Plains is currently being developed.

ONGOING PROJECTS

Native Forbs/Legumes for Conservation (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota).

Three native forbs and legumes are currently being evaluated and increased at the Bismarck PMC. These are leadplant (Amorpha canescens), silky prairieclover, (Dalea villosa), and shell-leaf penstemon (Penstemon grandiflorus). These species appear to have release potential for many conservation uses.

Perennial Food Plot Study (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota, and the North Dakota State Game and Fish Department).

The goal of this project is to determine plant species and related plant technology for establishing and maintaining perennial food plots. Two perennial mixes; a

native mix and an introduced mix will be evaluated. Plant performance and general wildlife use will be observed and documented.

Native Grasses for Conservation (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota).

Evaluate new species and technology that have potential conservation use for the Northern Great Plains. Seed collections of prairie dropseed (Sporobolus heterolepis) from ND and MN are currently being evaluated for potential release by the Bismarck PMC. The release of this native warm-season species would provide additional diversity for native seedings.

Seed collections of prairie sandreed (Calamovilfa longifolia) from ND, SD and MN were initiated in the fall of 2003. Greenhouse propagation and the planting of a field evaluation block are scheduled for 2004. Initial screening will include leaf rust tolerance. The final objective will be to release plant material of prairie sandreed for conservation use in the higher rainfall areas in the Eastern Dakotas and MN.

Seed collections of sand bluestem (Andropogon hallii) were initiated in 2003. Collections will be evaluated for future release. This release would provide a northern seed origin of this warm season grass species that is not currently available.

Vegetative propagation of prairie cordgrass (Spartina pectinata). Propagation of prairie cordgrass by rhizomes continues to be evaluated. Harvest dates, planting date and planting methods are being tested. Planting success of spring and fall dug rhizome material will allow commercial producers production flexibility in offering this material for conservation use.

Evaluation of slough sedge (Carex atherodes). (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota).

Technology development and selection for future release of this common wetland species is progressing. Nineteen accessions from SD, ND, MN and Canada were selected for seed production in 2001. Seed production, however, has been poor. Currently the potential of using bare root rhizome material for wetland conservation is being evaluated.

Direct Seeding Woody Species into Riparian Zones (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota).

This study is being conducted on lands enrolled into the Emergency Watershed Program (EWP). Eight native trees and shrub species were directly seeded into soybean stubble. Basswood (Tilia americana), bur oak (Quercus macrocarpa), green ash (Fraxinus pennsylvanica), hackberry (Celtis occidentalis), birch (Betula papyrifera), chokecherry (Prunus virginiana), false indigo (Amorpha fruticosa), and ironwood (Ostrya virginiana) were planted from seed. Weed control methods, using both clipping and herbicide are being tested on the site. All species, except birch, basswood and ironwood, were observed in plots. Natural regeneration of boxelder (Acer negundo), and american elm (Ulmus americana), is also being monitored. Direct seeding methods are being evaluated as a potential option for renovation of riparian areas.

Evaluation of the Effectiveness of Various Grasses and Herbicides in Reducing Leafy Spurge. (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota, North Dakota State University, Fargo North Dakota).

This study will evaluate various grass mixes and their competitive association with leafy spurge. Sites have been selected and will be seeded in the spring of 2004. Data collected from this study will provide information about grass species performance in areas impacted by leafy spurge.

Native Shrubs for Conservation. (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota)

The main objective of this multi-species study is to evaluate and release additional trees and shrubs for use in conservation. Evaluations of native hawthorn (Crataegus chrysocarpa), sandbar willow (Salix interior), false indigo (Amorpha fruiticosa), select plum (Prunus sp.), chokeberry (Photinia melanocarpa) and 4-wing saltbush (Atriplex canesens) are ongoing. Selections of false indigo and sandbar willow will be released by the Bismarck PMC in the near future.

Tree and Shrub Field Evaluation Plantings. (USDA Natural Resources Conservation Service, Plant Materials Center (PMC), Bismarck, North Dakota, Bottineau Park Board, Bottineau, ND, South Dakota State University, North Dakota State University, University of Minnesota, U.S. Department Of Interior).

This is an ongoing evaluation of tree and shrub material at 7 sites in Minnesota, North Dakota and South Dakota. This long-term study evaluates numerous tree and shrub stock over a number of years for potential selection of suitable material for conservation use in the Northern Great Plains and Minnesota.

PLANNED OR POTENTIAL PROJECTS

Evaluation of meadow blazingstar (Liatris ligustylis) Evaluate and increase the accession collected in Central North Dakota.

Evaluation of indian breadroot (Psoralea esculenta) Evaluate and increase the accessions collected in ND, SD and MN.

PUBLICATIONS AND PAPERS

Bismarck Plant Materials Center. 2003. Prairie Restoration Final Report. USDA-NRCS-Bismarck Plant Materials Center, Bismarck, ND. May 2003. 45 pages.

Bismarck Plant Materials Center 2003. Five Keys to Successful Grass Seeding. USDA-NRCS, Plant Materials Center, Bismarck, ND. April 2003. 6p.

Bismarck Plant Materials Center. 2002. Red River Natural Germplasm Prairie Cordgrass. USDA-NRCS Bismarck Plant Materials Center, Bismarck, ND. September 2002. 6p.

OREGON / WASHINGTON / IDAHO

David A. Pyke and Cindy Salo

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INTRODUCTION

This report summarizes the revegetation and restoration research being conducted or contracted by the USGS, Forest & Rangeland Ecosystem Science Center (FRESC) for the period of January 1, 2003 to December 31, 2003. Research reported in this document was funded by USGS, the Bureau of Land Management, or by funds obtained through external granting agencies.

COMPLETED PROJECTS

None.

ONGOING PROJECTS

1. VegSpec. (Phil Smith, Natural Resources Conservation Service, Information Technology Center, Fort Collins, CO; John Patterson, NRCS, Lincoln, NE; James Henson, NRCS, Baton Rouge, LA; Steven Warren, Cntr. for Ecol. Mgmt. of Military Lands, Colo. State Univ., Ft. Collins, CO; David Pyke, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, OR)

   A prototype spatially explicit version of VegSpec has been developed and is being tested. This version will allow users to input Latitude and Longitude for a site and will extrapolate the necessary climate data from nearby climate stations using the PRISM climate model to adjust for elevation and distances from water bodies. This should prove be an improvement on this species selection tool for revegetation. The release of this modification has been delayed until 2004.

2. Interactions of Cattle Grazing and Climate Change on Semi-arid Ecosystem Function (David Clausnitzer, David A. Pyke, Jayne Belnap, Tim Graham, USGS, Forest & Rangeland Ecosystem Science Center, and Robert Sanford, Denver University).

   Analysis of this project has begun. We are using two approaches, a hierarchical regression analysis and a structural equation modeling. The initial analyses are showing changes in physical soil parameters associated with livestock grazing intensity as measured by distance from water. We began testing the Century model using our data from the Great Basin and Colorado Plateau shrub grasslands. Modifications to the model are being conducted to allow it to operate correctly in these ecosystems.

3. Coordinated Intermountain Restoration Project (David A. Pyke and Cindy Salo, USGS, Forest & Rangeland Ecosystem Science Center, and Mike Pellant, Bureau of Land Management, Idaho State Office, Boise ID).

   One component was completed and a MS thesis was published on aboveground litter decomposition and microbial diversity. Four studies are in various stages of progress. Two projects began last year to examine mechanisms for controlling cheatgrass competition and are nearing completion. One is a defoliation study to determine the phenologic period when grazing might be effective as a tool to control cheatgrass. The second is an herbicide study to investigate the effect of Plateau, an herbicide that may be effective in controlling cheatgrass, on seedling establishment of native species. This herbicide study is being repeated in a second location this year. A third project is investigating BLM's success rate in establishing Wyoming big sagebrush and mountain big sagebrush on wildfire rehabilitation projects. Lastly, we have initiated a study to determine the threshold amount of cheatgrass or perennial plants in a community that cause managers to revegetate or allow natural recovery of plant communities after wildfires.

4. BLM's Emergency Fire Rehabilitation (EFR) Monitoring in the Intermountain West (David A. Pyke, USGS, Forest & Rangeland Ecosystem Science Center, and Ted O. McArthur, Oregon State University).

   Fieldwork is completed, but data analysis and final report submission is still pending. Major findings indicate species establishment, regardless of origin (native vs. introduced), was directly associated with knowledge of a species ability to grow on the sites. Native plants appeared to establish equal cover to that provided by introduced species. The lack of unseeded areas in rehabilitation projects made it impossible to determine if rehabilitation was necessary or effective.

5. Integrated Restoration Strategies towards Weed Control on Western Rangelands (Robert Nowak, Department of Environmental and Resource Science, University of Nevada – Reno and 11 other investigators including David A. Pyke, USGS, Forest & Rangeland Ecosystem Science Center).

   Two study sites were located in each of the four states and the appropriate Environmental Assessments for conducting studies. In Autumn 2003, 21 accessions of native grasses were seeded with and without cheatgrass to determine establishment and survival success throughout the Great Basin. In addition, a set of competition and nutrient studies are looking at nutrient reductions, native plant mixtures and competition with cheatgrass. We are also investigating soil microbes and nitrogen fluxes with carbohydrates (sucrose) are added to soils.

6. Prioritizing Regions for Restoration of Wyoming and Basin Big Sagebrush Habitats in the Great Basin (Steven Knick, USGS, Forest & Rangeland Ecosystem Science Center).

   We have developed a preliminary model of priority regions for restoring big sagebrush landscapes and have presented it at the Sagebrush Restoration Conference in Elko, NV, June 2002. This management tool is based on spatial modeling of landscape variables important for restoration success and identifies general areas in which restoration success is most likely.

7. The Human Footprint in the West: A Large-Scale Analysis of Human Impacts (Matthias Leu, Steve Hanser, and Steven Knick, USGS, Forest & Rangeland Ecosystem Science Center).

   We have developed a preliminary model of the effects of land use and development and have mapped the human footprint in the western United States. We are now testing the model and its implications to better understand human impacts on shrubland ecosystems in the western United States. This includes the effects of humans on: 1) predators, 2) species of conservation concern, 3) population dynamics of wildlife, 4) regional migratory bird populations, and 5) spread of invasive plants.

PLANNED OR POTENTIAL PROJECTS

1. Fire and fire surrogate treatments on sagebrush ecosystems (J. McIver, USFS PNW Res. Stn. and multiple investigators including USGS)

This project will investigate the impacts of fire and fire surrogate treatments on ecosystem processes in mountain big sagebrush and Wyoming big sagebrush communities in the Great Basin.

CURRENT PUBLICATIONS AND PAPERS

Spaeth, K.E., F.B. Pierson, J.E. Herrick, P.L. Shaver, **D.A. Pyke**, M. Pellant, D. Thompson & B. Dayton. 2003. New proposed national resources inventory protocols on nonfederal rangelands. Journal of Soil and Water Conservation 58:18-21

Kaye, T.N. & **D.A. Pyke**. 2003. The effect of stochastic technique on estimates of population viability from transition matrix models. Ecology 84:1464-1477

Wirth, T.A. & **D.A. Pyke**. 2003. Restoring forbs for sage grouse habitat: fire, microsite and establishment methods. Restoration Ecology 11:370-377

Clausnitzer, D., M. Huso, **D. Pyke**, J. Belnap, T. Graham, R.L. Sanford & S. Phillips. 2003. Interactions of cattle grazing and climate change: hierarchical data analysis Pp 1062-1064 *IN*: Allsopp N., A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley & C.R. Hurt (eds) Proceedings of the VIIth International Rangelands Congress, 26th July-1st August 2003, Durban, South Africa. Document Transformation Technologies, Irene, South Africa

Karl, M.G.S., **D.A. Pyke**, P.T. Tueller, W. Ypsilantis, G.E. Schuman, and S.J. Borchard. 2003. Indicators for soil and water conservation on rangelands. Pp 713-716 *IN*: Allsopp N., A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley & C.R. Hurt (eds) Proceedings of the VIIth International Rangelands Congress, 26th July-1st August 2003, Durban, South Africa. Document Transformation Technologies, Irene, South Africa

Pyke, D.A., J.E. Herrick, P.L. Shaver & M. Pellant. 2003. What is the standard for rangeland health assessments? Pp 764-766 *IN*: Allsopp N., A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley & C.R. Hurt (eds) Proceedings of the VIIth International Rangelands Congress, 26th July-1st August 2003, Durban, South Africa. Document Transformation Technologies, Irene, South Africa

Pyke, D.A. & S.T. Knick. 2003. Plant invaders, global change, and landscape restoration. Pp 278-288 *IN*: Allsopp N., A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley & C.R. Hurt (eds) Proceedings of the VIIth International Rangelands Congress, 26th July-1st August 2003, Durban, South Africa. Document Transformation Technologies, Irene South Africa

Pyke, D.A., T.O. McArthur, K.S. Harrison & M. Pellant. 2003. Coordinated intermountain restoration project – fire, decomposition and restoration. Pp 1116-1124 *IN*: Allsopp N., A.R. Palmer, S.J. Milton, K.P. Kirkman, G.I.H. Kerley & C.R. Hurt (eds) Proceedings of the VIIth International Rangelands Congress, 26th July-1st August 2003, Durban, South Africa. Document Transformation Technologies, Irene, South Africa

Karl, M.G., **D.A. Pyke,** P.T. Tueller, G.E. Schuman, M.R. Vinson, J.L. Fogg, R.W. Shafer, S.J. Borchard, W.G. Ypsilantis, and R.H. Barrett, Jr. 2003. Indicators for soil and water conservation on rangelands. Chapter II *IN:* Bartlett, E.T. & J.E. Mitchell (eds) 2003 Sustainable rangelands roundtable first approximation report. Sustainable Rangelands Roundtable http://sustainablerangelands.cnr.colostate.edu/2003Report/Chapter%202%20edited.doc 18 January 2004

Leu, M., S. Hanser & S. Knick. 2003. The Human Footprint in the West: A Large-Scale Analysis of Human Impacts. USGS Fact Sheet FS-127-03. U.S. Department of the Interior, U.S. Geological Survey. 4 pp.

UTAH

BRIGHAM YOUNG UNIVERSITY and U. S. FOREST SERVICE SHRUB SCIENCES LABORATORY

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INTRODUCTION

This report summarizes revegetation and restoration-related research conducted by faculty and scientists of Brigham Young University, the U.S. Forest Service Shrub Sciences Laboratory, and their cooperators for the year of 2003. Projects range from basic studies of physiology, ecology, and genetics to applied revegetation trials and weed control procedures.

ONGOING PROJECTS

Restoration of a Mojave Desert Site (E.Durant McArthur, Stewart Sanderson, U.S. Forest Service Shrub Lab, Provo, UT 84401, and Bob Douglas, Dixie Field Office, Bureau of Land Management, St. George, UT).

This study is to restore native vegetation to a Mojave Desert site physically disturbed by recreational activities. Favorable precipitation has enhanced establishment of native grasses and forbs drill seeded in the fall of 1992, as well as natural recruitment of non-seeded species. Monitoring is continuing to determine if and when annual plant dominance will shift perennial dominance. Fourwing saltbush and Indian ricegrass have especially established well. Annual species occurrence varies from year to year.

Ecology and Restoration of Cheatgrass Dominated Sites (Nancy Shaw, U.S. Forest Service Rocky Mountain Station, 316 E. Myrtle, Boise, Idaho 83702 and Scott Jensen, U.S. Forest Service Shrub Lab, Provo, UT 84401, Mike Pellant, Bureau of Land Management, Boise, Idaho 83706, and Nancy Shaw, U.S. Forest Service, Boise, Idaho 83702).

This project involves a number of studies designed to protect or restore sagebrush rangelands in southern Idaho and central Utah threatened by cheatgrass invasion or dominance. To encourage use of native grasses in revegetation, studies are progressing on rearing techniques to increase efficiency of native seed production. Large- scale seed production is being developed for forbs which hold promise for revegetation in the Great Basin.

Secondary Succession of Montane and Subalpine Vegetation on the Wasatch Plateau (Richard Gill, Washington State University and Stephen B. Monsen, retired, U.S. Forest Service Shrub Lab, Provo, UT 84401).

Vegetation inside and outside exclosures established by Sampson and Ellison on the Wasatch Mountains east of Ephraim, Utah is being remeasured to determine effects of site degradation and time on seral stage composition. Also, establishment requirements and constraints of native forbs is being studied. Many of these species germinate under snow and are subject to fungal attack associated with saturated soil conditions.

Regeneration Biology of Shadscale (Susan Meyer and David Nelson, U.S. Forest Service Shrub Lab, Provo, UT 84401).

This project is to determine the seedbank dynamics and establishment phenology of shadscale, to develop techniques for direct seeding establishment. Field experiments are underway to determine the effects of damping-off organisms and their control by fungicides on seedling mortality. Additional seedling disease studies are underway. A thermal time model has been successful in predicting changes in the chill response of afterripened seed.

Regeneration Biology of Blackbrush (Susan Meyer and Burton Pendleton, U.S. Forest Service Shrub Lab, Provo, UT 84401).

This project is determining the reproductive output, seedbank dynamics, and field seedling recruitment of this mast fruiting shrub. Heteromyid rodent population dynamics are currently being studied in relation to masting and seed dispersal of blackbrush. Data on home ranges and caching behavior are being collected.

Modeling Dormancy Loss and Germination in the Field of Annual and Perennial Grasses (Susan Meyer, U.S. Forest Service Shrub Lab, Provo, UT 84401, and Phil Allen, Brigham Young University, Provo, UT 84602).

Laboratory germination data are being used to predict dormancy loss and germination in the field for cheatgrass and squirreltail grass using a hydrothermal time model. The model has been extended to include effects of dynamic temperatures in order to predict germination under field conditions. Both cheatgrass and squirreltail seeds increase their rates of afterripening with increasing temperature when soil water potential is > -150 MPa, but decrease their rate of afterripening below that water potential until afterripening stops at about - 400 MPa.

Ecological genetics of the cheatgrass head smut pathosystem. (Susan Meyer and David Nelson, U.S. Forest Service Shrub Lab, Provo, UT 84401).

This project is determining the potential of using head smut for biocontrol of cheatgrass. The smut infects seedlings, which subsequently do not produce seeds. Basic smut genetics are being investigated in order to eventually determine the limitations of environmental conditions or frequency-dependent selection on infection rates. Molecular markers for cheatgrass genotypes are consistent with phenotypic characteristics. After testing hundreds of cheatgrass collections, 40-50 different genotypes have been found. Smut more effectively infects fall than winter-germinated cheatgrass. Future studies will examine use of a bunt disease and a soil-borne fungus that attacks cheatgrass seeds in the soil during the winter.

Germination and propagation of native forbs. (Susan Meyer, U.S. Forest Service Shrub Lab, Provo, UT 84401).

Requirements for germination are currently being tested for ecotypes of high elevation forbs including species of *Solidago, Eriogonum, Potentilla, Castilleja,* and *Geranium.* The goal of the research is to provide guidelines for increasing native seed production. A propagation manual for Intermountain native plants is being prepared.

Increasing Diversity of Mountain Big Sagebrush Stands (E.Durant McArthur, Stewart Sanderson, U.S. Forest Service Shrub Lab, Provo, UT 84401, Bruce Webb, Brigham Young University, Provo, UT 84602**,** Barbara Wachocki, and Mohammed Sandossi, Weber State University, Ogden, UT).

Effects of tebuthiuron rates and season of application are being determined on herbicide persistence, soil microbes, and shrub and herbaceous plant composition of mountain big sagebrush stands. Rates up to 0.7 kg/ha have not negatively impacted soil microbes and in some cases enhanced their growth, possibly through increased availability of resources. Rates of 0.2-0.3 kg/ha have effectively thinned sagebrush. Herbaceous perennials initially increased, but have varied on both control and treated plots.

Herbicide and Grazing Effects on Increasing Diversity of Aspen Parkland (Val Jo Anderson, Brigham Young University, Provo, UT 84602, and Scott Walker, Utah Division of Wildlife Resources, Ephraim, UT 84627).

The effects of cattle and elk grazing, as well as herbicide applications are being measured on tarweed, mule's ear, and thistle dominance and on plant community composition of aspen parklands.

Natural Resource Monitoring, Analysis, and Reclamation Activities at Dugway Proving Ground (Val Jo Anderson, Brigham Young University, Provo, UT 84602).

Effects of disturbance and revegetation for cold-desert communities at Dugway are being studied under the objectives of a cooperative agreement between BYU and the Department of the Army. The following studies are in progress: 1) effects of a sweep broom attachment to clear cheatgrass litter on establishment of drill-seeded perennials (wheatgrasses, flax, and four-wing saltbush); 2) effectiveness of 6 species for greenstrip-fire control (kochia, yarrow, burnet, and wheatgrasses); 3) effects of >Plateau= and >Oust= herbicides and mechanical treatments on cheatgrass control and revegetation success; 4) establishment of kochia after fire and soil disturbances; 5) small mammal presence and diversity in relation to vegetation treatments and dominance; 6) cheatgrass invasion into salt desert shrublands; 7) use of wheatgrasses to capture sites from cheatgrass as a precursor to revegetation with native species; and 8) factors that constrain Utah juniper recruitment. Although various theses and manuscripts are in various stages of preparation or completion, long-term data are still being collected on most of these experiments.

Restoring Native Diversity of Mountain Meadows (Val Jo Anderson, Brigham Young University, Provo, UT 84602).

Herbicide (Roundup) and mechanical treatments (tillage) are being applied alone and in combination prior to seeding native grasses to convert meadows dominated by smooth brome and intermediate wheatgrass back to native species in Ephraim Canyon, Utah.

Control of Squarrose Knapweed (Scott Walker, Utah Division of Wildlife Resources, Ephraim, UT 84627).

Phenology and reproductive biology and ecology of knapweed are being studied to better understand its ability to invade or be replaced by desirable species. The environmental controls of this species= ability to remain in the rosette until released by disturbance is a key to its control. Revegetation as a follow up to fire and herbicidal control is being studied, as well.

Operational Scale Fire Rehabilitation with Native and Exotic Seed Mixes. (Tyler Thompson and Bruce Roundy, Brigham Young University, Provo, UT 84602**,** E.Durant McArthur, U.S. Forest Service Shrub Lab, Provo, UT 84601, Pat Fosse, Bureau of Land Management, Philmore, UT Jim Davis, Utah Division of Wildlife Resources, Provo, UT 84601, and Jerry Chatterton, USDA, Agricultural Research Service, Logan, UT 84322-6300).

A multiagency cooperative study was installed fall 1999 in Tintic Valley, Utah on land burned by the Railroad Fire during midsummer 1999. Four seed

mixes were drilled on five blocks in a burned Wyoming big sagebrush area and were aerial broadcast and covered by 1-way chaining on five blocks in a burned Utah juniper area. Seed mixes included two native mixes, one with a higher number of species and total seeding rate than the other. Also seeded was a mix of selected exotic and native plant materials supplied by the Agricultural Research Service, and the standard Bureau of Land Management fire rehabilitation mix, composed mainly of exotic and some native species. After 3 years, perennial grass establishment from all mixes was high and similar on 3 of the 5 drill blocks, except for the native low rate mix which had limited establishment. Seeding failure on 2 drill blocks was probably due to excessive seed burial on sandy soils. On the broadcast and chain sites all mixes established but produced less cover than on the drill sites. Monitoring will continue over the next 10 years.

Changing fire regimes, increased fuel loads, and invasive species: effects on sagebrush steppe and pinyon-juniper ecosystems. (Jeanne Chambers, Durant McArthur, Susan Meyer, USFS Rocky Mountain Research Station, Bruce Roundy, Brigham Young University, and 10 other cooperators and investigators).

This project is comparing historical and current fuel load characteristics and determining the effects of residue perennial vegetation on resource availability and invasibility of weedy species.

Native Plant Community Resistance to Weed Invasion. (Phil S. Allen and Bruce A. Roundy, Brigham Young University, Provo, UT 84602; and Susan Meyer, U.S. Forest Service Shrub Sciences Lab, Provo, UT 84601).

Low and high densities of 2 native grasses, 2 native shrubs, and 4 native forbs have been established in various combinations. These plots were seeded either to no weeds, or cereal rye, jointed goatgrass, or cheatgrass in fall 2002 to determine resistance to weed invasion. Plots with shrubs (big sagebrush and rabbitbrush) had less weed seed production than those with just grasses and forbs in 2003. Cereal rye dried out the upper 50 cm of the soil profile about a week earlier than the other weed species. The most complex plant community with grasses, shrubs, and forbs reduced phosphorus and iron in the upper 3 cm of soil, but neither weeds nor plant community composition had much affect on other major nutrients. The restored communities are still developing and will continue to be monitored for weed resistance.

Establishment of Reserve Pastures for Camelids on the Bolivian Altiplano. (Val Jo Anderson and Bruce A. Roundy, Benson Institute and Brigham Young University, Provo, UT 84602).

A variety of introduced grasses and shrubs have been seeded or transplanted at 3 sites in the Altiplano. Cool-season grasses have established

well and show promise. Additional studies will compare native grasses and also investigate forage plants for saline soils.

Renovation of Big Sagebrush Steppe. (Bruce A. Roundy and Danny Summers, Brigham Young University, Provo, UT 84602; Scott Walker and Jim Davis, Utah Division of Wildlife Resources, Provo, UT 84601).

A variety of mechanical methods including chaining, aeration, and harrowing prior to seeding grasses and forbs are being compared as a way to diversify decadent stands of big sagebrush in northeastern Utah. Greater disturbance by disking- imprinting and 2-way harrowing resulted in 70- 90% mortality of sagebrush, but produced greater establishment of seeded species. Sagebrush mortality from other treatments was < 54 %. By the second year of monitoring, total grass cover was highest on most disturbed plots due to greater revegetation success, but residual grass cover had also increased on less-disturbed plots.

Effects of cheatgrass and browsing on big sagebrush growth and seed production. (Jim Davis, Utah Division of Wildlife Resources, Daniel Eddington, and Bruce A. Roundy, Brigham Young University, 401 WIDB, Brigham Young University, Provo, UT 84602)

The effects of Plateau herbicide on reduction of cheatgrass on 7 big sagebrush communities are being studied. Big sagebrush leader growth and seed production is being measured on adjacent sprayed and unsprayed plots, and on caged and uncaged shrubs.

Native seed production. (Val Jo Anderson, Bruce A. Roundy, and various other cooperators at Brigham Young University, Provo, UT 84602, in cooperation with Scott Jensen, U.S. Forest Service Shrub Sciences Lab, Provo, UT 84601, and Scott Walker, Utah Division of Wildlife Resources, Ephraim, UT 84627).

Effects of rearing practices on production of native forbs, grasses, and shrubs are being investigated at the Brigham Young University Farm, Spanish Fork, UT. This should be an ongoing project for the next 5 to 10 years. In addition to funded rearing research, foundation seed for source-identified plant materials will be developed. BYU undergraduate mentoring grants and a research joint venture with the U.S. Forest Service Shrub Sciences Laboratory currently fund the research.

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UTAH

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INTRODUCTION

This report summarizes my research activities related to revegetation and stabilization of deteriorated and altered lands at Utah State University for the calendar year 2003. Primary funding for these activities has been provided by USDA CSREES National Research Initiative Competitive Grants Program and USDA CSREES IFAFS. Supplemental support has been provided by the Utah Agricultural Experiment Station.

In addition to my research program, Chris Call of the Department of Forest, Range, & Wildlife Sciences has maintained an active program in revegetation based on cattle dispersing seeds, creating disturbances for new plant establishment, and burying seeds with hoof activity.

COMPLETED PROJECTS

1. Nitrogen Immobilization for Restoration of Cheatgrass-Infested Range (Eugene W. Schupp, Utah State University).

   Nitrogen immobilization has been speculated to benefit restoration of annual weed-dominated systems by disproportionately harming the success of the weeds, therefore reducing competition on desirable perennials. To investigate this over-all issue, and to tease apart nitrogen effects on seedling emergence versus effects on per individual competitive relationships, I addressed two specific objectives:

   1) Experimentally evaluate whether nitrogen manipulation alters per individual competitive relationships between cheatgrass and bottlebrush squirreltail during seedling establishment and early growth.

   2) Experimentally evaluate whether seedling emergence of cheatgrass and other annual weeds is more sensitive to nitrogen manipulation than is emergence of the early-seral perennial bottlebrush squirreltail and a suite of longer-lived native perennial grasses that have shown promise as restoration species.

We addressed each objective with a combination of greenhouse and field experiments. Competition studies used cheatgrass (*Bromus tectorum*) as the annual grass weed and big squirreltail (*Elymus multisetus*) as the perennial grass. Complete additive designs were employed where each of 5 density levels of *Bromus* was crossed factorially with the same 5 density levels of *Elymus*. Response curve analyses yield intraspecific and interspecific competition coefficients for each species. Greenhouse experiments compared competition responses in N-immobilized, nitrate-fertilized, and ammonium-fertilized treatments. Field experiments compared competition in N-immobilized, control, and N-fertilized treatments. Seedling emergence was addressed in a controlled germination cabinet using 6 annual weed species and 6 native perennial species on a gradient of Nitrate concentrations (7 levels from 0.0–4.0 mM). The field component investigated emergence and initial establishment from artificial seed communities composed of 3 annual weed species and 7 native perennial species; treatments were N-immobilized, control, and ammonium-fertilized.

Results of competition experiments were compatible in both greenhouse and field settings. As expected, N-immobilization reduced biomass, height, and tiller production of the weed *Bromus tectorum* much more so than of the native perennial *Elymus multisetus*. Such a result suggests that N-immobilization can potentially benefit perennials during establishment and may contribute to a restoration strategy. Competition analyses, however, were less clear cut. Competition from *Bromus* invariably strongly reduced performance of itself (intraspecific competition) and of *Elymus* (interspecific competition), while *Elymus* had only occasional weak intraspecific and interspecific competitive effects. Comparisons of competition coefficients across nitrogen manipulation treatments showed a slight effect of nitrogen treatment on per individual competitive relationships between the species, and that the interaction between *Bromus* and *Elymus* densities was significant and biologically important. Thus, N-immobilization increased the competitive ability of *Elymus* relative to *Bromus*, as desired, but only at low to moderate densities of *Bromus*. At high *Bromus* densities, nothing helps. The slight benefit of N-immobilization was correlated with greater water availability in this treatment, probably because of the reduced cheatgrass biomass. Studies of germination in controlled conditions and seedling establishment in the field showed that N-immobilization does not benefit perennial establishment by reducing emergence of weeds. Perennials as a group had less and slower germination than annual weeds as a group, but neither perennial nor annual germination was affected by nitrogen quantity. Development of artificial communities composed of 3 annual weed and 7 desirable perennial species showed that N-immobilization did not affect the number of weeds or desirables, but did reduce the size of weeds. Overall results suggest that N-immobilization may be a useful part

of a viable overall restoration strategy. If *Bromus* seed banks are first reduced, N-immobilization can further increase the success of perennial establishment by slightly altering competitive relationships favorably.

ONGOING PROJECTS

1. Integrated Restoration Strategies Towards Weed Control on Western Rangelands (**Robert Nowak {overall project PI}** & Hudson Glimp, University of Nevada, Reno; Paul Doescher & John Tanaka, Oregon State University; **Eugene W. Schupp {Utah State University PI**} & Chris Call, Utah State University; Jeanne Chambers & Robin Tausch, USFS Rocky Mountain Research Laboratory; Dave Pyke, USGS Forest & Rangeland Ecosystem Science Center; Bob Blank & Tom Jones, USDA ARS; Mike Pellant, USDI BLM Idaho State Office; and Dan Ogle and Loren St. John, USDA Natural Resources Conservation Service)

   Our overall goal is to provide a scientific foundation for developing management strategies for control of cheatgrass and other weeds in the Great Basin and for restoration of infested lands to productive native rangelands.

   This study is based on three experiments:

   Experiment 1) Screen 25 accessions of restoration material for competitiveness against cheatgrass.

   Objective: Identify suitable material for a transition stage in restoration from cheatgrass-infested range to diverse native range, and to evaluate generality of results across the Basin.

   Experiment 2) Investigate whether competitive interactions between cheatgrass and native perennials vary with nitrogen availability, perennial diversity, and with presence or absence of secondary weeds.

   Objectives: Determine the role of nitrogen availability in competition between cheatgrass and perennials; determine if a carefully selected set of perennial species is more competitive than individual species; determine if responses change with varying densities of perennials and cheatgrass (not in Utah); determine if the presence of secondary perennial weeds alter the interactions between cheatgrass and perennials.

Experiment 3) Investigate a series of potential restoration strategies at a larger scale, including prescribed fire, selected species mixtures, etc. This experiment will also be used for economic analyses, environmental education, and extension.

Objectives: Determine the effectiveness and the economic viability of a variety of potential restoration techniques; provide environmental education opportunities for the general public to help them understand rangelands, the threats they face, and restoration potential; provide outreach to public landowners and State and Federal land managers on restoration strategies.

Experiment 1 and 2 are being conducted at two sites in each of four States (Utah, Nevada, Idaho, and Oregon), one relatively drier and one relatively wetter. This will allow cross-Basin comparisons. Experiment 3, because of its size, will only be conducted in one site, likely in Nevada near Reno.

Experiment 1 involves sowing at all eight sites the same 21 available accessions of potential restoration materials, mostly grasses simply because that is what is primarily available. The remaining 4 accessions varies slightly among sites, depending on local interest. The trials are done with and without cheatgrass competition. This experiment was drill-seeded in Fall 2003 and results will be monitored until the end of the study. No results are available yet.

Experiment 2 involves at all eight sites the core factorial experiment of: 9 perennial treatments (6 species of native perennials as monocultures, the 6 natives as a mixture, crested wheatgrass as monoculture, and no perennials) x 2 nitrogen treatments (with or without mobilization) x 2 cheatgrass treatments (with or without cheatgrass). One of the Utah sites also includes 2 secondary weed treatments (with or without squarrose knapweed, a weed already present at that site) crossed with the treatment combinations in the perennial mixture treatment. The first year of this experiment was sown in Fall 2003 and results will be monitored until the end of the study. No results are available yet.

Experiment 3 is still slightly in flux. This experiment will be initiated in summer/fall 2004. Clearly, no results are available yet.

PLANNED OR POTENTIAL PROJECTS

1. I am involved in the development of a large collaborative project proposal involving Universities and Federal Agencies in the Great Basin to investigate restoration of the sagebrush ecosystem. The specific focus is on the threats of invasion by piñon-juniper woodlands at higher elevations and invasion by cheatgrass at lower elevations. The primary goal will be to identify thresholds beyond which the sagebrush ecosystem can not recover on its own and will require active restoration. Treatments will involve fire and fire surrogates, including mechanical treatments and herbicides. We are also including economic and social science components. Research will take place in Utah, Nevada, Idaho, and Oregon and will require close collaboration between researchers and land managers. The targeted funding source is the Joint Fire Sciences Program.

2. I am developing a project funded by the Utah Agricultural Experiment Station investigating community-level responses to massive piñon mortality (with apparently minor juniper mortality) from bark beetle attack linked to the combination of extreme drought and record high temperatures. This research will take place on the Colorado Plateau and will likely involve at least some collaboration with researchers from Northern Arizona University.

3. My students/research associates and I are developing projects involving: (1) the role of mychorrizae in restoration of sagebrush ecosystems on the Colorado Plateau (Dusty Carpenter), (2) the effects of perennial grasses on germination and establishment of cheatgrass (Larua Blonski), (3) the interactive effects of nitrogen and phosphorous on the competitive relationships among cheatgrass, squarrose knapweed, and bluebunch wheatgrass (Jeff Burnham), and (4) the role of rodent and ant seed predators in restoration (Steve Ostoja).

CURRENT PUBLICATIONS AND PAPERS

Since this is the first report, I have included some older publications to represent what we have been doing.

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Myklebust, M. 2003. Nitrogen influence on germination and establishment of some common annual and perennial rangeland species. M.S. Thesis, Utah State University, Logan, UT.

WASHINGTON

WASHINGTON STATE UNIVERSITY

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INTRODUCTION

This report summarizes land rehabilitation and related research at Washington State University from January 2003 through December 2003. Research is conducted through the Department of Natural Resource Sciences, the Washington Water Research Center, and the USDA NRCS Plant Materials Center.

NEW PROJECTS

1. Implementing Weed Control through Multi-Species Grazing (J. Dobrowolski and Don Nelson, NATRS and Animal Sciences, Washington State University.

   Design and implement collaborative producer-driven field trials to test and compare the effectiveness, economic viability and sustainability of multi-species grazing by cattle, sheep, goats, biological control and herbicides for managment of weeds impacting wildlife and range resources.

2. Negative influence of herbivory or plant manipulations on endangered or economic and ecologically valuable plants and wildlife (L. Shipley and R. Sayler, NATRS, Washington State University.

   A field project examining how cattle grazing influences the habitat quality and populations of endangered pygmy rabbits in the shrub-steppe of Washington. During the course of this project, pygmy rabbit populations continued to plummet. Our work has provided critical information for state and federal biologists to secure Federal Endangered Species listing and protection and to remove cattle grazing on the last area in Washington in which pygmy rabbits are known to reside, which is on State Fish and Wildlife property. In fact, this project launched subsequent contracts from WDFW to develop a captive breeding facility and program at WSU, and to develop techniques for reintroduction into native habitats. The pygmy rabbit project has received much public attention over the last year, and I have been asked to speak on National Public Radio and have conducted

numerous interviews for newspapers and magazines. With the captive pygmy rabbits, we will also begin studying the role of sagebrush and other native forages in the nutrition of these animals.

3. Role of nutrition in population declines of mule deer in Washington (L. Shipley, R. Wielgus and C. Robbins, NATRS, Washington State University, and W. Myers, Washington Department of Fish and Wildlife.

   Mule deer, popular for both consumptive and nonconsumptive uses, have been declining in the western U.S. for the last few decades. A grant from Bonneville Power Administration was received to study the declines in mule deer populations in Washington. Wielgus is examining the role of cougar predation, and Shipley is looking at the role of nutrition on reproduction in mule deer. For this work, Shipley has been supported by WSU's College of Agriculture with a partial R.A. and new deer facilities at Steffan Center, WSU. Management of habitat, disease, and predators of mule deer will be influenced by the results of this study.

4. A Study of Agricultural Drainage in the Puget Sound Lowlands to Determine Practices which Minimize Detrimental Effects on Salmonids (C. Feise, Center for Sustaining Agriculture and Natural Resources, WSU; S. Chen, Biological Systems Engineering and Washington Water Research Center, WSU and UW; D. Saul, Center for Environmental Education, WSU; B. Goalach, WSU Cooperative Extension; J. Dobrowolski, NATRS and Washington Water Research Center, WSU and UW; M. Barber, Washington Water Research Center.

   The project is to provide consistent and comprehensive information base on the natural habitat quality, the extent of salmonid use of King County's floodplain habitats and how to avoid, minimize, or mitigate agriculture-related impacts on listed salmonids and their habitat. Additionally, the information garnered from this study will enable King County officials, working in conjunction with technical staff, to make decisions relating to allocation of resources as well as to establish work priorities in the county's agricultural areas. Furthermore, the study findings can be shared with other government partners in the region in order to facilitate the development and implement of programs that address salmonid use of floodplain habitats. The project will provide the county with a solid base of scientific research that enables the county to be better prepared to make decisions on a holistic scale in its rural areas. This project requires multi-disciplinary expertise, including fish biology, physical sciences, engineering, and riparian and ecological sciences in addition to a working knowledge of the County's agricultural industry and community.

5. Forested Riparian Buffers: Function, Management and Economic Implications for Agriculture (J. Johnson, Puyallup Research and Extension center, Washington State University; J. Dobrowolski, NATRS and

Washington Water Research Center, WSU and UW; and Carolyn Henri, Resource Consulting, Arlington, Washington).

Declining populations of native salmon species in the Pacific Northwest led to the listing in 1999 of several Puget Sound salmon species as threatened or endangered under the federal Endangered Species Act (ESA). Recovery of these populations is a complex and time intensive task that will require efforts in many sectors. One of the critical elements in improving water quality and restoring salmon is the restoration of riparian habitat in agricultural areas where salmon populations exist. Toward this end, Skagit County, located in western Washington, has implemented a new critical areas ordinance requiring agricultural landowners to establish forested buffers along agricultural watercourses. The purpose of this project is to examine the environmental and economic implications of establishing forested riparian buffers, a sustainable agricultural practice, on land that is in current agricultural production in Skagit County.Funded by USDA SARE, Rural Technology Initiative, Safe Food Initiative.

6. Palouse Prairie restoration (R. Sayler and L.H. Hardesty, NATRS, Washington State University).

   In 2003, we continue to develop a restoration plot at Washington State University devoted to a variety of native plants characterizing the highly endangered Palouse Prairie ecosystem. We have propagated a variety of native plants in greenhouses and used them in restoration efforts on a small watershed on the edge of campus. Information we developed from this restoration effort has been used to support teaching, other research, and public outreach efforts. In 2003, we completed work to develop a series of print and web publications on *Camassia* and *Chalocortus spp*. as part of the funding received from an endowment by the Mariposa Foundation.

7. Habitat restoration, and adaptive management of Sharp-tailed Grouse on lands of the Colville Confederated Tribes (R. Sayler and R.B. Wielgus, NATRS, Washington State University).

   This project will conduct a population viability analysis which, in turn, will aid in the development of an adaptive management plan to restore critical shrub-steppe habitat for sharp-tailed grouse in the Intermountain West.

ONGOING PROJECTS

1. Integration of upland, riparian and stream condition monitoring for intermediately sized watersheds on rangelands (G.A. Rasmussen, Department of Rangeland Resources, Utah State University and J.P. Dobrowolski, NATRS, Washington State University).

During the final year of this three-year study we will develop and test a monitoring protocol that will assess the hydrologic stability of rangeland watersheds and link upland and riparian conditions with downslope or down stream condition within intermediate-sized watersheds (<1000 km2). This assessment, with implications for restoration, will allow the interpretation of the overall condition of watersheds and evaluate the individual contribution of each sub-component (upland, riparian or stream. The major product of the research is a watershed based monitoring protocol that will help managers monitor and understand the cause of erosion- and sediment-related environmental changes in a watershed. The protocol uses GIS technology and conceptual and mathematical models for its implementation.

2. Plant materials for western riparian areas (Mark Stannard, USDA NRCS Washington State University).

   Increasing emphasis on improvement of degraded wetlands and riparian areas in the western United States has necessitated development of appropriate plant materials and planting technology. Treatment of damaged wetlands requires restoration of proper hydrologic functioning (e.g., Barker Ranch WRP on the Yakima River) and reestablishment of native vegetation. USDA NRCS Plant Material Centers in the western U.S. are developing source-identified material of common wetland species adapted to specific geographic areas. They are also developing new revegetation equipment and formulating planting guidelines.

3. Identification of grasses for possible use in upland restoration on eastern Washington and Oregon rangelands (Mark Stannard, USDA NRCS Washington State University).

   The objective of this project is to provide plant identification assistance to restorationists for the purpose of restoring upland and riparian plantings.

4. Habitat restoration of grizzly bear populations (Robert B. Wielgus, NATRS, Washington State University.

   This study evaluates grizzly bear populations to test three hypotheses on the effects of adult male mortality on female reproduction. There are three hypotheses, “no effect” (reproduction should be higher in the population with superior overall diet quality), “increased reproduction” (higher in the hunted population because of lowered numbers of competitive or cannibalistic males), and “decreased reproduction” (reproduction should be lower in the hunted population because of increased immigration by potentially infanticidal, nonsire males, and/or increased sexual segregation resulting in reduced production of cubs.

5. Two stage sampling to determine vegetation status on reclamation sites B.A. Zamora, NATRS, Washington State University).

Two-stage sampling is tested as a means of measuring the revegetation status of reclaimed pasture, forest or rangeland sites for comparison to vegetation success standards. Study sites are located on reclamation areas in eastern and western Washington. Results of this two stage sampling study are compared to single line transect sampling of the same area. Initial results show two stage sampling producing more consistent measures of variation, is more efficient in application, and is considered more reliable for accurate relocation of macroplots for repeat measurements and monitoring.

6. Effects of shade and defoliation on reed canarygrass *(Phalaris arundinacea* L.) biomass production: A greenhouse study (D.J. Forman, L.H. Hardesty and R.D. Sayler; NATRS, Washington State University).

   Many wetlands in the Pacific Northwest have become dense monotypic stands of reed canarygrass, reducing biodiversity. Control methods are not well developed. The literature is inconclusive on the effectiveness of defoliation and shade in controlling reed canarygrass. We investigated the effect of combining defoliation and shading on reed canarygrass productivity.

CURRENT PUBLICATIONS AND PAPERS

Bassman, J.H., J.D. Johnson, L. Fins, and **J.P. Dobrowolski**. 2003. Rocky Mountain ecosystems: Diversity, complexity and interactions. Tree Physiology 23:1081-1089.

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Bassman, J.H., J.D. Johnson, L. Fins, and **J.P. Dobrowolski**. 2003. Wherefore Rocky Mountain Ecosystems. In: Bassman, J.H., J.D. Johnson, L. Fins, and **J.P. Dobrowolski**, eds., Rocky Mountain Ecosystems: Diversity, Complexity and Interactions: Proc. 17th North American Forest Biology Workshop, July 15-18, 2002, Pullman, Washington. Washington State University Cooperative Extension, Pullman, Washington, U.S.A.

Dobrowolski, J.P. 2003. Asotin Creek Model Watershed: Local efforts in stream channel and riparian vegetation restoration and water quality improvement. 5 pages.

Dobrowolski, J.P. 2003. Washington State Research Progress Report for WCC-21. This report summarizes land rehabilitation and related research at Washington State University from July 2002 through December. Research is

conducted through the Department of Natural Resource Sciences, the Washington Water Research Center, and the USDA NRCS Plant Materials Center. 5 pages.

Dobrowolski, J.P. 2003. Book review: Agricultural extension and rural development. J. Range Manage. 56(1):102-103. Technically reviewed book review.

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Dobrowolski, J. 2003. Monitoring the vegetation resources in riparian areas. Three hour presentation to the Annual Fall Meeting of the Society for Range Management, Pacific Northwest Section, Ritzville, WA October 24, 75 attendees. 15 CD's of my powerpoint were requested by and sent to interested attendees.

Dobrowolski, J.P. 2003. Water conservation versus technology-supported lifestyles: Extension's role in water quantitiy education. 2003 Public Issues and Leadership Development (PILD) Conference, Washington, DC. 35 attendees. Led to appointment as shared faculty with USDA CSREES.

Dobrowolski, J.P. 2003. Watershed issues in rangeland management: Are juniper dominated rangelands self-destructive? Rangeland Graduate Seminar, University of Idaho, Moscow. Feb 17, 2003, 60 minutes, 45 attendees.

Dobrowolski, J.P. 2003. Some Hydrologic and Related Management Concerns in Juniper Dominated Watersheds. Invited talk to the Water Research Center and Jornada Long-term Experimental Research Program, Las Cruces, NM. March 21, 2003.

Dobrowolski, J.P. 2003. A new study to investigate riparian buffers: Their function, management,and economic implications for western Washington

agriculture. Annual Western Washington Horticultural Association Convention, Jan. 7-8, Seattle, WA. 35 attendees.

Dobrowolski, J.P. 2003. Wind Simulation To Evaluate Surface Soil Differences. Fact sheet to the Center for the Environmental Maintenance of Military Lands (CEMML). 4 pages.

Dobrowolski, J.P. 2003. Water Conservation Versus Technology-Supported Lifestyles: Extension's Role in Water Quantity Education. Presented to the Public Issues Leadership Development Conference, Washington DC, May 6 to National Program Leaders of CSREES and others.

Dobrowolski, J. 2003. Using soil biological crusts in rangeland repair. Repairing Pacific Northwest Rangelands, 32nd Annual Pacific Northwest Range Management Shortcourse, April 1-2, 2003, Spokane.

Henri, C., J.D. Johnson and **J.P. Dobrowolski**. 2003. Commercial management options for hybrid poplar buffers in western Washington. In, Proceedings of the 8th North American Agroforestry Conference, Corvallis, OR. June 22-25, 2003.

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Stannard, M. and **J. Dobrowolski**. 2004. Himalayan blackberry in the Pacific Northwest: Attack of the canes! Forest Stewardship Notes 13(1):11-12.

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WYOMING

UNIVERSITY OF WYOMING
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INTRODUCTION

This report summarizes revegetation and stabilization of disturbed land research activities conducted during 2003 and emphasizes activities of the newly formed Wyoming Reclamation Ecology Center and Department of Renewable Resource's personnel at the University of Wyoming. Federal, state and private industry, including the Abandoned Coal Mine Land Research Program (ACMLRP) and Agricultural Experiment Station Competitive Grant Program at the University of Wyoming, funded the projects listed below. The Abandoned Mine Land Division of the Wyoming Department of Environmental Quality administers the ACMLRP support from funds returned to Wyoming from the Office of Surface Mining of the U.S. Department of the Interior.

COMPLETED PROJECTS

1. Relationship Between Soil Organic Matter Content and Sustainable Nutrient Cycling in Reclaimed Soils. (P.D. Stahl and L.J. Ingram, Department of Renewable Resources, University of Wyoming; G.E. Schuman, USDA-ARS, High Plains Grasslands Research Station, Cheyenne, WY; L.K. Spackman, Wyoming Department of Environmental Quality-Land Quality Division)

   An important aim of mine site reclamation is to ensure that wherever possible, the "reconstructed" ecosystem is self-sustaining, requiring minimal and preferably no additional inputs. It is therefore critical that soils used in mine reclamation are able to provide sufficient quantities of nutrients for plant uptake. Many of the nutrients required for plant uptake, in particular N and P are found in soil organic matter (SOM). Equally important is the large mass of C found in SOM, which provides the chemical energy to sustain microbial populations. Microbial decomposition of this SOM makes nutrients available for plant uptake. The aim of this project is to determine the minimum amount of SOM in replaced topsoil

required to sustain nutrient cycling (i.e. N-mineralization) in reclaimed ecosystems. Also evaluated is the use of a new method to assess soil quality with surface mine land reclamation. If successful, this methodology may be of use as a relatively fast, economical and reliable “indicator” of a soil's potential to sustain nutrient cycling.

An important component of this study was to be able to estimate, on the basis of organic C and from our estimates of potential lab N-mineralization, the minimum concentration of SOM required to supply a sufficient amount of N to the plant community. Whereas a significant amount of N-immobilization was observed in soils sampled in 2000, N-mineralization was predominant in the samples collected during 2001, possibly reflecting the more normal precipitation patterns that year. However, our calculations indicate the amount of organic C required to maintain nutrient cycling is lower than what we have observed and expected. Subsequently, we have sampled a site which contains very low concentrations of organic C. Whereas biomass and N concentration of aboveground plant biomass varied considerably, but as a general rule across all three mines, both were much greater on the reclaimed sites than on the native, undisturbed sites. At all sites, however, estimates of potential N-mineralization indicated all soils would have been able to provide sufficient quantities of N for plant growth.

2. The Effects of Varying Topsoil Replacement Depth on Various Plant Parameters Within Reclaimed Areas. (B.K. Schladweiler, BKS Environmental Associates, Inc., P.O. Box 3467, Gillette, WY 82717; L.C. Munn and G.F. Vance, Department of Renewable Resources (Soil Science), University of Wyoming, Laramie, WY 82071; R. Haroian and S. Belden, Powder River Coal Company, NA/RC Complex, Gillette, WY 82717)

   This project tasks include: 1) review existing vegetation/soil information and WDEQ approval, 2) construct a study site at the Rochelle Coal Mine and 3) develop reference areas and field sampling. Samples were collected at maximum 15cm increments to the interface between topsoil and backfill. At that point, an additional 15cm of backfill was collected. All soils were analyzed for pH and EC. Approximately 25% of these samples were then randomly selected for analysis of SAR on the same extract. Significant differences were found between native and reclaimed areas. This point exemplifies the difficulty in selecting native areas as a revegetation success standard for reclaimed areas. Inherent differences resulting from the mining process, i.e., homogenous, replaced soil material make it difficult to compare native areas that have well defined profiles with horizons. After three years of sampling, total vegetation cover and total cover percentages were higher in the native areas due to the relatively young age of the reclaimed area and relatively low precipitation

throughout the 2000, 2001and 2002 growing seasons. The least amount of vegetative cover was noted during the 2002 sampling. Typically, the total cover percentages are higher in a reclaimed environment as litter accumulates with time. Average species and total species were also higher in the native areas. Although, this is a new reclaimed area, the problem of comparing diversity with native areas exists for older reclaimed areas, as well. Production was somewhat higher in the reclaimed areas. Typically, one would expect reclaimed production to be much higher than native areas but, again, the drought over the last three years has had a marked effect.

3. Impacts of Wildlife Utilization on Big Sagebrush Survival on Reclaimed Mined Lands. (K.A. Strait and R. A. Olson, Department of Renewable Resources, University of Wyoming; G.E. Schuman, High Plains Grasslands Research Station, USDA-ARS, Cheyenne, WY)

The project's objectives were to evaluate the historical progression of big sagebrush density from initial seeding to the present, determine community composition, similarity, and diversity, evaluate utilization levels of big sagebrush by wildlife, and to evaluate browsing impacts on big sagebrush survival. Big sagebrush density increases the first 2 years (1993 and 1994) following seeding (1992), but then declined during subsequent years across grass seeding rate and mulch treatment. Although there were no significant differences, mean big sagebrush density was generally highest across historical sampling years in the 0 kg PLS/ha grass seeding rate. Within the permanent belt transects, mean big sagebrush density was highest in the 32 kg PLS/ha grass seeding rate inside the exclosure. Big sagebrush densities outside the exclosure decreased more rapidly than those inside. Mean percent cover of grasses and total vegetation were significantly different between grass seeding rates inside the exclosure but not outside. Mean percent cover of grasses and total vegetation declined with increasing grass seeding rate both inside and outside the exclosure in both years. There was significantly more grass and total vegetation cover inside and outside the exclosure in 2001 compared to 2002. Mean percent cover of shrubs (primarily big sagebrush) increased with higher grass seeding rates inside the exclosure in 2001and 2002. Increased mean percent cover of shrubs at higher grass seeding rates indicates that big sagebrush benefits from competitive interaction with grass species, at least inside the exclosure. Sorenson's similarity index of species between grass seeding rates was greater in 2001 compared to 2002 values. Differences in diversity and similarity values between 2001 and 2002 are due to lower precipitation amounts in 2002 and related differences in community composition. The mean percent of browsed big sagebrush plants decreased inside the exclosure during the project period, but were consistently heavily browsed outside the exclosure. In all grass seeding rates rabbits were the primary browser

of sagebrush rather than big game. Mean number of big game pellet groups and presence or absence of rabbit pellets were recorded and cleared from the permanent belt transects during the September 2001 sampling period. In April and September 2002, pellet group analysis indicated presence of rabbit in all transects outside the exclosure. Big sagebrush plants inside the exclosure continue to respond to the protection from browsing.

4. Effects of Variable Topsoil Replacement Depth on Plant Community Development and Soil Ecosystem Development After 24 Years. (C.K. Bowen, G.E. Schuman, R.A. Olson and L.J. Ingram, Department of Renewable Resources, University of Wyoming and High Plains Grasslands Research Station, USDA - ARS, Cheyenne, WY)

Using a study established in the early 1980s, long-term (24 years) effects of variable topsoil replacement on vegetative community development and soil physical and chemical attributes were examined. Baseline data from the initial 4 years of the study are available for comparison. Topsoil (a mixture A and B horizon material) was originally spread in a wedge, ranging from 0 - 600 mm in depth, over a regraded spoil dump. In August 2001 three of the five replications of each mulch x fertilizer treatments were randomly selected and sampled at each topsoil replacement depth. Samples were taken to a depth of 750 mm and divided into four increments (0-50, 50-200, 200-400, and 400-750 mm). The 600 mm topsoil depth core was divided the same as the other three replacement depths except for the final increment. This sample was divided at the topsoil/spoil interface resulting in a core increment of approximately 600-750 mm instead of 400-750 mm. Samples were analyzed for total N, organic C, clay content, and soluble salts. Topsoil depth had significant effects on the amount of organic C, total N, and clay content of the soil profile. Percent total N followed the same pattern of significance as organic C. The 200 and 600 mm depths were highest in 0-50 mm increments with the 400 and 600 mm depths having the highest overall amounts. The 200 mm depth showed the same inconsistent response as seen with organic C. Increased topsoil depths have higher levels of C and N because topsoil contains more of these elements than does spoil. Higher biomass production and water infiltration are also believed to be largely responsible for these trends due to the increased water storage in these profiles. These factors largely impact nutrient cycling, which in turn have a strong effect on C and N levels. Water infiltration measurements showed a near 100% increase in the 400 and 600 mm depths over the 0 and 200 mm depths, combined total average infiltration of 125 mm to 67 mm over a two hour period, respectively.

5. Grass competition and sagebrush seeding rates: Influence on sagebrush seedling establishment. (G.E. Schuman, High Plains Grasslands Research Station, USDA - ARS, Cheyenne, WY; M.I. Williams and A.L. Hild, Department of Renewable Resources, University of Wyoming; L.E. Vicklund, RAG, Coal West, Inc., Belle Ayr Coal Mine, Gillette, WY)

   This study was initiated to investigate the relationship between Wyoming big sagebrush and a mixture of cool-season grasses seeded concurrently. The study site is located at the Belle Ayr Coal Mine, RAG Coal West, Inc. mine near Gillette, WY. Sagebrush seedling density data exhibited statistically significant differences for the June and September density counts as affected by grass seeding rate. Sagebrush seedling densities were significantly lower for the 14 kg PLS/ha seeding rate compared to the 0 PLS/ha grass seeding rates in June and September 2002. Sagebrush seeding rate exhibited a significant effect on sagebrush seedling density. The 4 kg PLS/ha sagebrush seeding rate continues to produce a significantly greater density of seedlings than either the 2 or 1 kg PLS/ha sagebrush seeding rate. This data and other research continue to support the need for sagebrush seeding rates of >2 kg PLS/ha.
   To further assess the effects of grass seeding rate (competition) on sagebrush seedlings the volume of the sagebrush seedlings was measured and found that all grass seeding rates significantly affected the average sagebrush seedling volume. In 2001, grass seeding rates >4 kg PLS/ha resulted in significantly smaller sagebrush seedling size compared to grass seeding rates <4 kg PLS/ha. Sagebrush seedling size was not different for grass seeding rates of 2-14 kg PLS/ha in 2002. The data indicate that with the drought conditions present at the mine any grass competition stressed the sagebrush equally. This is further supported by the fact that the average sagebrush seedling size increased nearly 300% from 2001 to 2002 where no grass competition existed and by only 50-90% where grass competition existed. Grass seeding rates (competition) continue to have a limited effect on sagebrush seedling density and under drought conditions grass seeding rates have had a limited effect on sagebrush seedling volume.

6. Phytoremediation of Petroleum Contaminated Soil on the BP Amoco Tank Farm. (Peter D. Stahl, K.J. Reddy, J. Dan Rodgers, Drew W. Johnson, Marjorie E. Bedessem, Joshua H. Johnson, J.D. Hamerlinck, and Barry L. Perryman; Departments of Renewable Resources and Civil and Architectural Engineering, and Wyoming GIS Center, University of Wyoming)

   Phytoremediation is defined as the use of plants to remove, contain, or neutralize environmental contaminants. This definition applies to all plant-

influenced biotic, chemical, and physical processes that aid in remediation of contaminated substrates. Microorganisms play a critical role in the removal of organic contaminants from a site in that they can transform or degrade many compounds that may not be affected by plant growth. Abundant evidence exists demonstrating the effectiveness of plant-microbe based remediation of soil contaminated with organic pollutants. As initial steps in a longer term phytoremediation research project on the BP-Amoco refinery Old Tank Farm (unit # 9) site, we are conducting a project involving site characterization work, bioassessment and bioavailability studies, laboratory and greenhouse tests of phytoremediation potential for the contaminated soil and finally, field plot studies of the phytoremediation process. Products will include: 1) construction of a GIS database and multilayer maps of the site for future reference in monitoring remediation, 2) a final research report detailing methods and results of the studies mentioned above as well as recommendations for implementation of a full scale phytoremedation system on the Tank Farm site.

ONGOING PROJECTS

1. Development of a Wyoming Reclamation Ecology Center. (G.F. Vance, G.E. Schuman, P.D. Stahl, R.A. Olson, A.L. Hild, Renewable Resources, University of Wyoming and USDA-ARS, High Plains Grasslands Research Station, Cheyenne, WY)

   The Wyoming Reclamation Ecology Center (WREC or Center) consists of multi-disciplinary Reclamation and Restoration Ecology (R&RE) research, teaching and outreach programs that focus on the identification, assessment and rehabilitation of disturbed ecosystems. The Center coordinates efforts involving research and educational undertakings into a unified endeavor that provide a more efficient use of university resources, centralize cooperative research funding in the area of land reclamation and restoration, attract quality students and grant support through enhanced national and international visibility, market UW's expertise in reclamation and restoration ecology, and provide services to the agricultural, mineral, and energy economic base of Wyoming through enhanced science and technology in the field of reclamation and restoration ecology. Our mission is to pursue and disseminate impartial, scientifically-based research information related to the reclamation, rehabilitation and restoration of disturbed ecosystems, to educate students so that they will be able to analyze, synthesize and integrate findings, results and related research for use in protecting and improving Wyoming and western U.S. ecosystems and to serve as a resource for Wyoming citizens and communities, state and federal agencies, and private industries requiring assistance in reclamation science and ecological restoration endeavors. The primary goal of the WREC is to achieve

prominent recognition as a state-of-the-art resource center for investigating research problems and developing solutions to issues and challenges confronting Wyoming citizens, communities, agencies and private industries. Additional goals include distinction in educational undergraduate and graduate programs that prepare student and off-campus individuals with up-to-date instruction in R&RE and to provide outreach activities for clientele needing refresher and current information in subject matters related to rehabilitation and improvements of disturbed ecosystems.

2. Controls of Carbon Sequestration on Northern Rocky Mountain Rangelands. (G.F. Vance, P.D. Stahl and L.J. Ingram; Department of Renewable Resources, University of Wyoming; J.M. Welker, Natural Resource Ecology Laboratory, Colorado State University; G.E. Schuman and J.A. Morgan, USDA-ARS, High Plains Grasslands Research Station, Cheyenne, WY)

We are addressing processes associated with net CO_2 exchange and long-term soil C storage as influenced by grazing effects on microbial biomass production, N mineralization, soil organic matter (SOM) traits (labile vs. recalcitrant soil C) and annual budgets of net CO_2 exchange by comparing C and N processes in grazed and ungrazed, fenced exclosures (ungrazed by domestic livestock for 60 years) in a mixed-grass prairie. The 3 different grazing treatments studied include continuous light grazing (CLG), continuous heavy grazing (CHG) and exclosures (EXC). Rates of mineralization, net ecosystem exchange (NEE) of CO_2, ecosystem respiration (ER), gross ecosystem photosynthesis (GEP) and recorded air and soil temperatures, irradiance and collected vegetation for leaf N, leaf ^{15}N, leaf C isotope discrimination, total C and total biomass were also determined. Across grazing treatments, trends for soil NO_3, NH_4, and inorganic N (N_i = NO_3 + NH_4) production, as well as rates of N mineralization, were all identical. Mean concentrations of soil NO_3, NH_4 and N_i were in the order of CLG > EXC > CHG. Over the growing season, the rate of N mineralization in the EXC was generally greater than the other treatments. Despite comparable amounts of rainfall preceding each sampling period (with the exception of the first sampling period in early May when there was no preceding rainfall), there was considerable seasonal variation in NO_3 and N_i production. In addition, mineralization was highly variable, but N mineralization consistently occurred to a much greater extent than did N-immobilization. Diurnal changes were measuring that included CO_2 flux (i.e., NEE, GEP and ER). Grazing had no measurable affect on NEE or GEP, whereas CHG sites had higher ER rates. Throughout the growing season, these systems were all CO_2 sources to the atmosphere. Our findings suggest that precipitation is an overriding factor controlling CO_2 exchange and that possibly only during

favorable moisture years are there detectable differences in CO_2 exchange between pastures with different grazing histories.

Preliminary results indicate that rates of N-mineralization were sufficient for plant N requirements despite low soil water contents and that grazing treatments have a considerable impact on the amount of N available for plant uptake. However, grazing history had no measurable affect on NEE or GEP, but heavy continuously grazed pastures had ER rates about 10% higher than the other treatments. While ER values are within the ranges of those found for other grassland systems, when compared to values during wet years such as 1999 or 1998, they are ~ 50% lower. We also found that throughout the growing season, on a daily basis, that these systems were all sources of CO_2 production.

3. Influence of Reclamation Management Practices on Carbon Accumulation and Soil Fertility on Coal Mine Lands in Wyoming. (P.D. Stahl, G.F. Vance, L.J. Ingram, Department of Renewable Resources, University of Wyoming, S.V. Huzurbazar, Department of Statistics, University of Wyoming and C.J. Bilbrough, Wyoming Department of Environmental Quality)

The overall goal of this research project is to examine the influence of a number of surface coal mine reclamation management practices on C accumulation, organic nutrient pools and soil fertility in reclaimed soils. To accomplish this goal, we are examining the influence of commonly used management practices (i.e., grazing, mulching, direct haul/stockpiled topsoiling, and shrub mosaic seeding) on organic C and nutrient concentrations in soil, determine the mechanisms by which organic matter and nutrients accumulate in these soils and evaluating the potential for enhancing C and organic nutrient storage in reclaimed surface mine lands. Soil sampling was initiated in September, 2002. During September and October, three areas were sampled on the Dave Johnson Mine; one for a comparison of ungrazed and grazed reclamation, one for a comparison of shrub mosaic site vs. a non-shrub mosaic site, and an undisturbed, native prairie control site. Also sampled this fall were a site reclaimed with stockpiled topsoil and another reclaimed with direct hauled topsoil at the Jim Bridger Mine. Finally, we also sampled three areas at the Medicine Bow Mine for a comparison of the influence of stubble mulching and native hay mulching as well as an undisturbed control site. At all of these sites, soils were sampled at three depths; 0-5 cm, 5-15 cm, and 15-30 cm along transects established in each of the areas sampled. Laboratory analyses of organic C content, total N, soil pH, electrical conductivity and microbial biomass C for soil samples collected this fall are currently under way. As a result of the drought that was prevalent over much of Wyoming this past year, growth and biomass production of native vegetation was extremely

low to non-existent. It was therefore necessary to grow plant material in a Greenhouse for a litter decomposition study.

4. Potential Impacts and Alternatives to Land Application of Coalbed Methane Product Water. (G.F. Vance, Department of Renewable Resources, University of Wyoming)

   The Powder River Basin (PRB) in Wyoming and Montana has seen extensive coalbed methane (CBM) development over the past 10 years, with thousands of CBM wells in production and more than 50,000 total active wells projected within the next 10 years. During CBM production, large amounts of water are produced as coal seams are de-pressurized; most of this water is surface discharged to local streams and/or impoundments. Due to the quality of the product water, particularly its salinity and sodicity, CBM producers are required to obtain National Pollution Discharge Elimination System permits to surface discharge CBM waters into Tongue, Powder and Little Powder River Basins. Limitations on discharge permits has generated significant interest in alternative water disposal techniques. Land application of CBM product waters has been proposed as a method for water disposal; however, some of these waters have salinity and sodicity characteristics that may impact plant growth and/or soil chemical and physical properties. With the estimated production life of a CBM well at 8 - 10 years, there is great potential for CBM product water to cause salinization, sodicity, sedimentation, and erosion in affected lands and stream channels and tributaries. In addition, altered vegetative communities and wildlife habitats will result from the excess water, causing uncertainty in the sustainability of these ecosystems. The focus of this research is on potential impacts CBM discharge water has on soil properties and vegetation, with alternative application methods currently being tested in the PRB, e.g., sprinkler systems, water cannons or atomizer units.

5. Updating the Handbook of Western Reclamation Techniques. (Laurel E. Vicklund, Philip C. Dinsmoor, McVehil-Monnett Associates, Inc.)

   In 1996 the Handbook of Western Reclamation Techniques was written by more than two dozen authors on topics ranging from hydrologic design to revegetation techniques. The chapters represented the accumulated knowledge of one or more experts on techniques that have proved successful in the reclamation of coal mined land in the western United States. Since its initial publication, the Handbook has undergone numerous printings and has now been published on CD ROM. According to the Office of Technology Transfer within the Office of Surface Mining Reclamation and Enforcement, this Handbook has been the most

requested product in the federal ACMLRP library. It is being used as a field reference, classroom text, and guidance document throughout the world. In November of 2000, the Wyoming ACMLRP Steering Committee suggested updating the handbook. It was believed that the first edition technologies have evolved, new technologies have been developed, and new reclamation issues have come to the forefront to be addressed. The Steering Committee was also interested in having a second edition that was user friendly to a wider range of disciplines. Initial work was focused on project organization, contacting authors, and identifying which materials needed to be updated and what new information would be added. The general consensus of the Handbook committee is that revisions are warranted in the topic areas of reforestation, grazing, topsoil, vegetation, land use, seed, and wildlife. New work is desired in the areas of wetlands mitigation and creation, coal and oil/gas interaction, sagebrush establishment, GIS, hydrology, and soil amendments. In addition, it has been suggested that revegetation equipment be addressed.

PLANNED OR POTENTIAL PROJECTS

Projects will be conducted that are either associated with current funding or submitted grants that are accepted.

1. Recovery of Belowground Ecosystem Components Under Different Plant Communities on Coal Mine Land Reclamation Sites (submitted Proposal). (Peter D. Stahl, Lachlan J. Ingram, Dept. Of Renewable Resources, University of Wyoming, Carol Bilbrough, Wyoming Dept. of Environmental Quality, Land Quality Division, and Snehalata V. Huzubazar, Dept. of Statistics, University of Wyoming.

   The ultimate goal of mineland reclamation is reestablishment of a productive, healthy, and sustainable ecosystem suitable for postmining land use. All ecosystems are composed of a producer component and a decomposer component and these subsystems are obligately dependent upon one another. Any approach to better understanding or better evaluation of ecosystem functioning, especially nutrient cycling, requires serious consideration of both aboveground and belowground ecosystem components. Although a combined aboveground–belowground approach is crucial to an understanding of ecosystem-level processes, most ecological work has been traditionally conducted without much explicit consideration of the belowground component . This is also true of our understanding of reclaimed ecosystems on coal mine lands. We propose to examine recovery of belowground ecosystem components (nutrient cycling, microbial community structure, and soil structure) under different plant communities found on reclaimed coal mine lands. Our study will

include plant communities considered to be of good quality and of lower quality as well as communities having already been bond released. This approach has been chosen to ascertain whether there are differences in recovery of belowground ecosystem structure and function under these disparate communities. Examination of statistical relationships between plant community characteristics and belowground ecosystem components to will be conducted to determine if the plant community characteristics accurately reflect recovery of belowground structure and function.

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