Revegetation and Stabilization of Deteriorated and Altered Lands

Annual Review of Activities by the Western Coordinating Committee-21
WCC-21

May 16-17, 2000
Albuquerque, New Mexico

FORWARD

This document contains the annual activity reports of the members of the Western Coordinating Committee 21 (WCC-21) for Revegetation and Stabilization of Deteriorated and Altered Lands, as of May 15, 2000.

The 2000 annual meeting was held in Albuquerque, NM, May 16-17 at the Rocky Mountain Research Station, 2205 Columbia Blvd. SE. The hosts for the meeting and field tours were Sam Loftin (Los Alamos National Laboratories) and Roy Jemison (Rocky Mountain Research Station).

Copies of this document can be viewed and downloaded from our website at: http://ars-boi.ars.pn.usbr.gov/wcc21/index.html. Please visit our site frequently for updates to the information contained in this document and other information about our committee and members.

Submitted to the WCC-21 Committee this 16th day of May, 2000.

Roy Jemison

Secretary, WCC-21

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ALASKA

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INTRODUCTION

This report summarizes the revegetation and bioremediation research projects at the Agricultural and Forestry Experiment Station (AFES) of the University of Alaska Fairbanks from April 1, 1999, to April 30, 2000. Current AFES revegetation research is focusing on continued evaluation of earlier studies and assisting state agencies with monitoring revegetation on abandoned coal mined lands. Most projects are in direct response to industry needs and work closely with private industry and state and federal agencies. Some funding has been provided by the Agricultural and Forestry Experiment Station in all cases. Additional funding sources are indicated at the end of each project description. Most projects are in the monitoring stage.

ONGOING PROJECTS

1. Reestablishment of woody browse species for mined land reclamation (D.J. Helm, AFES)

Revegetation trials to establish moose browse on topsoils (as opposed to floodplain deposits) was initiated in 1989 to address three main objectives: (1) to select woody plant species that would grow on selected soils to produce moose browse, (2) to identify plant species that regenerate naturally on these soils, and (3) to select grass cultivars suitable for these substrates and multiple, sometimes conflicting goals of revegetation. Seven woody species were tested in four different growth media, three soils and undisturbed glacial till (simulated overburden). Although year 10 (1998) was the last year of active measurements on these test plots, we continue to visually monitor these plots because of their significance documenting changes over time. The success of natural colonization and facilitation methods during revegetation strongly depended on the substrates, plant materials available, and environmental conditions. Using fresh A and some B horizon materials in relatively mild southcentral Alaska, natural colonization from seeds and rhizomes was substantial after about 3 to 7 yr, but was inadequate for ground cover in the short term (first 2 yr). Some natural colonizers (e.g. *Picea glauca*, *Betula papyrifera*) were more desirable for the project goals than some other species (*Calamagrostis canadensis*, *Epilobium angustifolium*, *Heracleum lanatum*), which were controlled by seeding competitive grasses. Diversities were generally not reduced by seeding grasses because some of the natural colonizers were so aggressive once they got started. Although woody colonization has been slower on plots with the aggressive grasses compared to some others, woody colonization is, nevertheless, occurring. Greenhouse-grown woody plant materials (rooted cuttings, seedlings) were transplanted to achieve the desired wildlife habitat goals in the desired time frame (10 yr) since natural colonization could not achieve that goal. On this site, natural processes needed to

be enhanced in the short term to provide adequate ground cover, and the successional trajectory needed to be altered in the intermediate term to meet project goals. (Primary initial funding by Idemitsu-Alaska, Inc. and Alaska Science and Technology Foundation, then by McIntire-Stennis Forestry Research Program as part of "Ecosystem management for establishment of woody plants on disturbed lands" project, Usibelli Coal Mine.)

2. Vegetation Studies at Usibelli Coal Mine (D.J. Helm, AFES)

Usibelli Coal Mine has funded several pre- and post-mining vegetation inventories and revegetation studies since 1985 to use the most recent knowledge and plant materials in a continuing effort to improve revegetation on their mined sites. Trials were initiated in 1991 to determine which grass species and growth media could provide the most ground cover on south-facing, windward slopes. Cover and vigor of most seeded grass species have declined since the last fertilization on both the sandstone and topsoil materials although the decline was slower on the topsoil. Norcoast Bering hairgrass (*Deschampsia beringensis*), a cultivar developed at the Agricultural and Forestry Experiment Station, has maintained better cover than most other species on the once-fertilized plots. We also evaluated the benefits of repeated fertilization on small plots on a proposed new mine site. One year of fertilization was inadequate and benefits were observed as long as the fertilization occurred in multiple years, including the first year. 1999 was the last year of formal measurements on these plots, and the site may be mined within the next couple years. (Primary funding by Usibelli Coal Mine, Inc.)

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

One objective of this study is to evaluate natural colonization, especially that of *Populus tremuloides* (aspen) for ruffed grouse habitat, on various treatments applied by the Alaska Department of Natural Resources (Division of Mining and Water Management, Division of Agriculture) when reclaiming abandoned coal mined sites in southcentral and interior Alaska. Most woody colonization is by *Populus balsamifera* (balsam poplar), which is locally more common than the *P. tremuloides*. Colonization has been slow on an unseeded site (6 stems/m^2) and increased with distance from trees. On another site that had been both fertilized and seeded, but the seed had been banded, early colonization appeared similar on both the seeded and unseeded portions, although it now appears greater on the unseeded portions. However, the seedlings appear larger here (not actually measured), probably a result of the fertilization. Some differences may be confounded with slope, aspect, and wind patterns. A new addition to this study by the Plant Material Center on a newly reclaimed area has included some non-mineral fertilizer treatments (Biosol, FertilFibers, Humazyme). During the first year, vascular plant cover was greater on the control (mineral fertilizer) and grubbed (some topsoil, woody debris) areas compared to the commercial products. Forb cover was significantly lower on Biosol and Humazyme treatments compared to the others. Other participating agencies include Alaska Department of Fish and Game. (Primary funding by Alaska Division of Mining and Water Management)

4. Constructed Wetlands for Waste Water Treatment in the Sub_Arctic (D.C. Maddux, Ph.D. Student, School of Agriculture and Land Resources Management, University of Alaska Fairbanks)

A constructed wetland complex has been built to treat sewage wastewater from the swine barn at the Agricultural and Forestry Experiment Station at the University of Alaska Fairbanks campus. Species include indigenous macrophytes *Typha latifolia*, *Scirpus validus*, *Menyanthes trifoliata*, *Carex rhyncophisa*, *Arctophila fulva*, and an unplanted control. Another successful year of testing was completed by the fall of 1999. Research shows that the wetland ecosystem is adjusting to the manmade environment, with microbial communities and plant communities filling in the niches available within the confines of the experiment. Water quality analysis shows that for the first two thirds of the treatment season, water quality discharge standards were met approximately 50% of the time, but the last 1/3 of the treatment the water quality was meeting the standards 95% of the time. This indicates that the wetland was responding to the input of senesced plant material from the previous fall for the first part of the treatment season and once the microbial community had established itself in the senesced material, treatment capabilities improved. These findings agree with previous constructed wetland data that show the typical "start up" time for a constructed wetland to reach its full treatment potential is three years.

PLANNED PROJECTS

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

We plan to compare ectomycorrhizal (EM) communities in early successional sites across a latitudinal gradient of Alaska to determine whether there are similarities in ectomycorrhizae (fungi and plants) and time frames so that developing a common inoculum or revegetation strategy may make sense, either at a regional or state level. We also want to see how many of these EM may persist until mid-succession or whether there is likely to be a complete replacement.

ARIZONA

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INTRODUCTION

This report summarizes revegetation and restoration research at the University of Arizona for 1999. Researchers at the University of Arizona investigate whole plant, population, community, and ecosystem processes and dynamics in arid and semi-arid environments. Assembled here are summaries of projects that have direct implications for revegetation and restoration of disturbed land in the western U.S.

COMPLETED RESEARCH

1. Biomass allocation, root system architecture, and transpiration in cottonwood and mesquite: plastic responses to experimental defoliation and irrigation**.** (Keirith A. Snyder. and David G. Williams. University of Arizona, Tucson, AZ 85721 USA)

We conducted a pot experiment with cottonwood (*Populus fremontii*) and mesquite (*Prosopis velutina*) to determine if biomass allocation to fine and coarse roots and rates of water absorption from hydraulically separated upper and lower soil compartments is altered by available moisture and defoliation. Bottoms of the pots were irrigated at regular intervals to maintain high ("wet") or low ("dry") moisture availability and half of the plants in each watering treatment were defoliated at regular intervals. Isotopically labeled water was supplied to the top soil compartment in pulses to determine the fraction of total transpiration derived from each soil compartment. Dry treatments reduced total plant biomass and root-mass ratio relative to wet treatments in cottonwood. Within the wet treatment, total biomass was higher and root-mass ratio was lower in cottonwood trees that were defoliated compared to non-defoliated controls. However, the ratio of fine roots to coarse roots in top and bottom soil compartments did not change with watering or defoliation treatments in this obligate riparian species. Watering treatments did not alter growth or biomass partitioning in mesquite.

2. Effects of elevated CO2, water supply, and nitrogen nutrition on growth and photosynthesis in three C4 grasses**.** (Alessandra Fravolini and David G. Williams. University of Arizona, Tucson, AZ 85721 USA)

Photosynthesis and growth responses of semi-arid C_4 grasslands to rising atmospheric CO_2 will depend on soil water and nutrient availability. Furthermore, these responses may vary among biochemical subtypes (NADP-ME, NAD-ME, PCK) that have discernable differences in C4 bundle sheath leakiness (Φ) in response to drought and nitrogen supply. To address C4

subtype responses to soil resource gradients, we measured photosynthetic rates(*A*), stomatal conductance(*g*), the ratio of intercellular to ambient CO_2 concentration (ci/ca), leaf carbon isotope discrimination (Δ), and above ground biomass accumulation in *Eragrostis lehmanniana* (NAD-ME), *Aristida glabrata* (NADP-ME) and *Bouteloua curtipendula* (PCK), in a controlled environment chamber. These species have similar life history strategies and occupy the same habitats in semi-arid grasslands of southeastern Arizona. The three species were grown from seed under a complete, multi-factorial combination of present ambient (370 ppm) and elevated (690 ppm) CO_2 concentration and under high and low water and nitrogen supply. Leaf-level photosynthetic rate in *A. glabrata* was relatively unchanged by CO_2 treatments, likely due to its NADP-ME biochemistry. Photosynthetic rates under elevated CO_2 increased in *B. curtipendula* and *E. lehmanniana* across all treatments, although responses were greatest in *E. lehmanniana*. Above-ground biomass and *A* were reduced more in *B. curtipendula*, the PCK type, by deficits of nitrogen compared to the other two grasses. In contrast, biomass of *B. curtipendula* increased most in response to elevated CO_2 when nitrogen and water were not limiting. Carbon isotope discrimination and ci/ca values will be used to estimate Φ to help interpret changes *A* and biomass accumulation under favorable and stressful conditions. These results suggest that responses of semi-arid grasslands to rising atmospheric CO_2 will depend on the interaction between the composition of C_4 grasses as it relates to biochemical subtype, drought, and soil fertility.

3. Water source use of a riparian tallgrass, big sacaton (*Sporobolus wrightii*), along a gradient of depth to groundwater and rainfall regime in southeastern Arizona USA**.**

(Ronald L. Tiller[1], Keirith A. Snyder[2], David G. Williams[2] and Juliet C. Stromberg[1] ; 1Arizona State University, Tempe, AZ 85287 USA, 2University of Arizona, Tucson, AZ 85721 USA)

Riparian grasslands dominated by big sacaton, a warm season perennial bunchgrass, were abundant in the southwest before the turn of the century, occupying millions of acres of floodplain habitat. These grasslands played important ecological functions by controlling erosion, intercepting and retaining sediment, and promoting groundwater recharge. Today, these grasslands cover less than 5% of their historical extent. There is growing interest in the conservation and restoration of big sacaton, yet little is known about the ecology of this important grassland species. Effective conservation and management of big sacaton grasslands will depend on a strong base of ecological knowledge.

Recent studies by the authors have begun to elucidate how big sacaton interacts with its environment (i.e. plant-soil-hydrology relationships). An important and heretofore unstudied aspect of its ecology is the source(s) from which it derives moisture for maintenance and survivorship. This research attempts to answer the following questions: 1) Does big sacaton utilize shallow soil moisture from precipitation, moisture provided by groundwater, or both, and; 2) Is utilization of these water sources influenced by site conditions? Stable isotope technology is being used to determine the water source(s) utilized by big sacaton at five grassland sites with different groundwater conditions and rainfall regimes. Natural abundance ratios of isotopes of hydrogen (^1H and ^2H) and oxygen (^{16}O and ^{18}O) are being used to determine its source waters. At each grassland, tissue samples were collected from six big sacaton growing in an area of representative cover and density. Soil samples were collected from three cores at depths of 5, 10,

15, 30, 60 and 100 cm. Precipitation samples were collected from standard raingages containing a layer of mineral oil and groundwater samples were collected from local wells. Preliminary results of ^{18}O analysis indicate big sacaton derives water solely from precipitation at a site where depth to groundwater exceeds 10 meters. At a location where depth to groundwater averages approximately 4 meters, big sacaton appear to use rainfall derived soil moisture and groundwater. These early results suggest big sacaton may use rainwater and/or groundwater depending on site conditions.

4. Biogeography of red brome (*Bromus madritensis* subsp. *rubens*) in the Sonoran Desert**.** (Cindy Salo, Guy R. McPherson and David G. Williams. University of Arizona, Tucson, AZ 85721, USA)

Invasions by exotic plants can alter ecosystem structure and function, and biological invasions have caused the extinction of more species than any other human-caused aspect of global change. Red brome (Bromus madritensis subsp. rubens) is a Mediterranean winter annual grass that was introduced to California before 1880. Red brome was seeded in southern Arizona in the first decade of the 20th century and soon became common in this area. Through a search of herbarium collections in the western U. S. and original botanical sources, we trace the spread of red brome from California and recruitment foci in Arizona to describe the biogeography of this exotic species in the Sonoran Desert. Red brome has been able to invade relatively undisturbed areas in the Mojave Desert, the Great Basin, and the Sonoran Desert. This plant can become the most common species in the latter region during El Nino events, which result in high levels of winter precipitation.

ONGOING RESEARCH

1. Restoration of ponderosa pine savanna in the Black Hills (Guy R. McPherson and Carolyn Hull Sieg, School of Renewable Natural Resources, University of Arizona and USDA Forest Service Rocky Mountain Research Station)

We are investigating use of overstory removal and prescribed fire as tools to restore savanna structure to ponderosa pine forests in the Black Hills of South Dakota. A large-scale field experiment has been initiated with the following dependent variables: level of overstory removal (none, partial, complete) and prescribed fire (burned, unburned). We will evaluate response of soil moisture and population- and community-level response of plants for at least 5 years. A complementary study addresses the seedbank as a potential constraint to restoration of these systems.

2. Fire-based restoration of biodiversity in semidesert grasslands (Guy R. McPherson and Robert J. Steidl, School of Renewable Natural Resources, University of Arizona)

We are investigating use of prescribed fire as a tool to restore biological diversity in semidesert grasslands dominated by Lehman lovegrass (*Eragrostis lehmanniana*). Specifically, we are implementing a large-scale field experiment in southern Arizona. Independent variables include pre-treatment community structure, season of fire, and year of fire. We will evaluate population- and community-level response of plants, invertebrates, and vertebrates for at least 5

years. Complementary experiments focus on the role of soil nitrogen in establishment of native herbs.

3. Groundwater dependence of riparian vegetation: A synthetic dendrohydrology and isotope ecophysiology study (Bob Webb, USGS; Dave Williams, School of Renewable Natural Resources, University of Arizona; Dave Meko Laboratory of Tree Ring Research, University of Arizona)

The purpose of this study is to develop riparian dendrohydrology methods that can be used to assess the relationship between groundwater/surface water and physiological stress in riparian vegetation. We have three basic objectives for tree ecophysiology studies; 1) Examine of δ^2H and $\delta^{18}O$ variation in tree xylem water and its relation to tree water sources, 2) investigate the utility of leaf and tree ring $\delta^{13}C$ for understanding consequences of water source and climate variation for tree physiologic stress, and 3) evaluate the level of clonal resource integration among riparian trees.

CURRENT PUBLICATIONS AND PAPERS

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Goodrich, D.C., A. Chehbouni, B. Goff, B. MacNish, T. Maddock, S. Moran, W.J. Shuttleworth, D.G. Williams et al. Preface paper to the Semi-Arid Land-Surface-Atmosphere (SALSA) program special issue. *Agricultural and Forest Meterology*, In press.

Goodrich, D.C., R. Scott, J. Qi, B. Goff, C.L. Unkrich, M.S. Moran, D.G. Williams, S. Schaeffer, K. Snyder, R. MacNish, T. Maddock, D. Pool, A. Chehbouni, D.I. Cooper, W.E. Eichinger, W.J. Shuttleworth, Y. Kerr, R. Marsett, and W. Ni. Seasonal estimates of riparian evapotranspiration using remote and *in-situ* measurements. *Agricultural and Forest Meterology*, In press.

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Schaeffer, S.M., D.G. Williams, and D.C. Goodrich. Transpiration in cottonwood/willow forest patches estimated from sap flux. *Agricultural and Forest Meterology*, In press.

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Williams, D.G. and J. R. Ehleringer. Intra- and interspecific variation for summer precipitation use in pinyon-juniper woodlands. *Ecological Monographs*, In press.

Williams, D.G. and J. R. Ehleringer. 2000. Carbon isotope discrimination and water relations in oak hybrid populations in southwestern Utah. *Western North American Naturalist*

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CALIFORNIA

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INTRODUCTION

This report summarizes restoration research in the Department of Botany and Plant Sciences, University of California, Riverside. The research is funded by the Metropolitan Water District of California, The National Science, and the U.S.D.A. Forest/Range/Crop/Aquatic Ecosystems Research Program. Experiments are being carried out on a newly constructed reservoir dam, rangeland, and experimental plots in University and other reserves. The rangelands include *Artemisia tridentata* rangelands and *Artemisia californica* shrublands. The later are still grazed in some locations, but are subject to urbanization in California. Because coastal sage shrubland is being lost to urbanization and contains many threatened, endangered, and sensitive plant and animal species, it is the subject of many restoration and mitigation studies.

COMPLETED PROJECTS

The effects of nitrogen deposition on *Artemisia* shrublands. (Edith B. Allen; Andrzej Bytnerowicz, USDA Forest Fire Lab, Riverside; Richard A. Minnich, Department of Earth Sciences, University of California, Riverside; and Michael F. Allen, Center for Conservation Biology, UC Riverside)

The coastal sage scrub (CSS) vegetation of southern California has been declining in land area and in shrub density over the past 60 years or more, and is being replaced by Mediterranean annual grasses in many areas. We are examining nitrogen deposition as a cause of CSS decline, as up to 45 kg/ha/yr are deposited in the Los Angeles Air Basin. Field nitrogen fertilization plots have yielded convincing evidence after five years that high soil N may be a cause of shrub decline. Fertilization began in sites burned in the fall 1993 wildfires, and has caused an increase in exotic grass growth relative to native shrub growth. By contrast, in the unburned plots there has been no change in relative grass and shrub cover during 5 years. Competition studies indicated there was no change in the relative competitive ability of the shrubs or grasses after fertilization. However, we detected negative effects of high soil N on the growth and survival of the shrubs. Greenhouse grown *Artemisia californica* began to senesce at 6-9 months when fertilized with 50 ug N/g soil. This soil N concentration corresponds to extractable N levels in polluted sites, which had up to 80 ug/g soil extractable N, while levels are typically less than 10 ug/g in unpolluted sites.

Additional observations show that the diversity and density of spores of mycorrhizal fungi declines along a N pollution gradient, and that root infection of mycorrhizal fungi

decreases with high N. These changes have feedbacks on the plant response, with fungi from high soil N causing a reduced, or "lazy" mycorrhizal response. In addition, we have determined that sites high in soil N have a high bacterial/fungal biomass ratio that may be related to more nitrification and higher inorganic forms of nitrogen.

An experiment was initiated in the fall of 1997 to determine whether soils that have the dual problems of high nitrogen and exotic grasses can be restored. The worst cases are near urban areas, where the annual grasses are also subject to frequent fire. Controlling the grasses, which burn on a yearly cycle, and replacing them with native shrubs, which burn every 30-60 years, is the goal of this experiment. The treatments included bark mulch to immobilize N and reduce grass seed germination, hand cultivation, and herbicides to remove grass. The bark mulch was largely ineffective in controlling the weed seed bank, and did not have high enough C/N to immobilize high amounts of N. We relied on the use of mulch generated by the local urban yard refuse program, but other sources would need to be used if N immobilization is the goal. The two grass removal treatments both produced healthy stands of native shrubs. An early season fire burned through the surrounding grassland, saving only the shrub plots but consuming untreated grass-dominated plots. Thus this method will work to reduce fire frequency, and at the same time will increase the conservation value by restoring native shrubland. The planted shrub stands must likely be maintained by periodic grass control, and fire breaks plus controlled burns must be maintained to reduce the threat of large-scale wildfire. This approach is labor intensive and may be relevant for the urban wildland interface where the threat of fire is great.

Another project that was begun in spring 1998 was to determine the effects of different seeding methods on establishment of native shrubs and forbs in CSS. We compared drilling, imprinting, and hydroseeding, each with three soil ripping levels (shallow, deep, and none). The first year results of this experiment indicate that the small-seeded plants perform better with hydroseeding and imprinting, while the large-seeded plants had denser establishment with drill seeding. The results of this project have allowed us to recommend a seeding density to the Metropolitan Water District for a large reservoir in southern California. The results are of especial interest because the seeds will be hand collected locally and thus are very expensive.

ONGOING PROJECTS

Seed Certification Program for Restoration in Southern California (Arlee Montalvo, Department of Botany and Plant Sciences, University of California Riverside).

We are working on a native seed certification program for the state of California. The program is in conjunction with the MWD Diamond Valley Lake Reservoir landscaping and restoration project to assure quality control of seed collection, plant growth in the nurseries, propagation of native mycorrhizal fungi, seed planting in untopsoiled spoil materials, and measurements of restoration success.

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, E. Konno, M.F. Allen, UC Riverside, Allison Anderson, San Diego Zoo).

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 have grazed in 1 ha plots for 24-48 hours in spring 1999 and 2000 using moveable electric fence. The herbicide Fusilade has been applied to 1 ha plots during both spring seasons. Dethatching was done during October-November 1999 prior to the winter rainy and spring growing season. In the first spring (1999) the height of grass litter from the prior growing season was too great to be effective for herbicide contact with vegetation, and we had only a 25% reduction in exotic grass cover. At the same time, we had about a 25% increase in exotic Erodium spp. Thus the native vegetation does not respond as rapidly to the exotic grass removal as do the exotic forbs. This spring conditions are better for both herbicide application and sheep grazing, as we expect a more positive response. 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.

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COLORADO

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INTRODUCTION

This report summarizes reclamation and restoration research projects at Colorado State University for the period October 1999 through June 2000. Reclamation research has been conducted by the Rangeland Ecosystem Science and Soil and Crop Science Departments with funding from the Colorado Agricultural Experiment Station, USDA, EPA, U.S. Army, and the Colorado Department of Public Health and Environment.

COMPLETED RESEARCH

1. Restoration Methods at the Rocky Mountain Arsenal National Wildlife Refuge (Edward Redente, Rangeland Ecosystem Science Department)

   This project began in the summer of 1995 and the objective was to use nitrogen gradients, irrigation, and seeding techniques to develop methodology for restoring exotic grassland sites to native prairie.

2. Restoration of Techniques on Abandoned Roads in Grand Teton National Park (Edward F. Redente, Rangeland Ecosystem Science Department)

   This project was a follow up to a project that was initiated in 1988 and completed in 1991. Funding from the National Park Service provided for additional data collection on test plots that were established for ten years and to document longer-term successional trends.

ONGOING RESEARCH

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. 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 is to determine appropriate organic matter and nutrient inputs from biosolids to facilitate post-burn ecosystem recovery in a forested system southwest of Denver.

3. Recovery of Rangeland and Abandoned Croplands Following Removal of N Stress (Edward Redente, Mark Paschke, and Donald Klein, Rangeland Ecosystem Science and Microbiology Departments)

This project began in the summer of 1997 and will extend for a three-year period. The primary objective of this research is to determine if N-stress related changes in plant community structure and function have long-term consequences following removal of the N-related stress. This project is being conducted in the shortgrass steppe of Colorado.

4. 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.

5. Integrated Control and Assessment of Knapweed and Cheatgrass on Department of Defense Installations (Mark Paschke, Edward Redente, and Donald Klein, Rangeland Ecosystem Science Department and Microbiology Departments; 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.

PLANNED OR POTENTIAL PROJECTS

1. Develop methods for improving woody plant establishment on coal mined lands in northwest Colorado.

2. Evaluate a reclaimed site treated with annual inorganic N applications, initial inorganic N applications, initial inorganic N and wood waste applications, and sewage sludge and wood waste applications. The study was initiated in 1977 and data collection is proposed for 2000 and will focus on plant community composition and N pools in vegetation and soils.

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COLORADO

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INTRODUCTION

This report summarizes the reclamation-related research conducted by Dr. Terrence Toy during the period April 1, 1990 to March 31, 2000. During this time, I was on sabbatical as a visiting researcher at the Federal University of Viçosa, in Minas Gerais, Brazil and engaged in a hillslope erosion project with Dr. George Foster and The National Sedimentation Laboratory in Oxford Mississippi. The products of these activities are described below. Only the new publications are listed.

COMPLETED RESEARCH

The sabbatical consisted of two principal parts. The first part (September to December, 1999) was an invited three-month residency at the Federal University of Viçosa, Minas Gerais, Brazil. During that time, the focus was an examination of surface-mine reclamation practices in Brazil. The second part (January to March, 2000) was hillslope-erosion research in co-operation with the U.S. Department of Agriculture, Agricultural Research Service. Each part and the resulting products are discussed in subsequent sections of this report.

A. Professional Activities

Following an invitation from the Department of Forestry Engineering at the Federal University of Viçosa, and funding by *Conselho Nacional de Desenvolvimento Cientifico e Technologico* (CNPq, the Brazilian equivalent of the National Science Foundation), I served as "pesquisador visitante" (visiting researcher) from September to December, 1999. This department has been involved in mineland reclamation research for more than 18 years. The principal collaborators in the department were Dr. James Jackson Griffith and Dr. Carlos A. Ribeiro.

During that time, the research centered on changing surface-mine reclamation practices in Brazil. A previous study (Barth, 1987) served as a basis of comparison. Whereas Barth's study was based solely on mine visits and inspections of the reclamation work, this project included mine visits with inspections and interviews of reclamation specialists, as well as interviews with State of Minas Gerais regulatory authorities and private consultants engaged in reclamation

contract work, in order to gain a more comprehensive view of contemporary reclamation. As one might guess, there are some differences in perspectives.

The mines examined included those producing iron ore, bauxite, and kaolin clay. The iron ore mines are some of the largest in the world, operated by both native Brazilian companies and multi-national corporations. Brazil is one of the largest exporters of iron ore in the world and revenues from these exports constitute a significant proportion of the national economy. Overall, the reclamation is quite good, especially at the large, multi-nationally owned, iron ore mines. New and innovative reclamation techniques were observed that have no counterpart in the United States. With fairly modest effort, great success is realized in revegetating disturbed surfaces.

A number of students in the Department of Forestry Engineering at Viçosa have been and are engaged in reclamation research. I visited several field sites and offered suggestions concerning research design and data analyses. The department also has a weekly reclamation seminar; I attended a number of these seminars and participated (through translation, of course) in discussions with the students. Various other students visited in my office seeking advice regarding their research during my time in Brazil. This was all a part of an interesting cultural experience.

With colleagues at Viçosa and elsewhere in Brazil, I examined the use of the Revised Universal Soil Loss Equation under Brazilian environmental conditions. From this a list of essential research questions were compiled that may provide research directions for various earth scientists in Brazil during the months to come. I designed erosion plots to determine the erodibility of soil and plant-growth medium under Brazilian conditions

The second part of the sabbatical involved the hillslope-erosion research project from the Agricultural Research Service. Due to the late arrival of the funding in relation to the completion of the sabbatical period and the reduced funding amount, the project was re-defined and is now considered Phase I of a three-phase project. This project is entitled “Three-Dimensional hillslope Morphology and Soil-Loss Predictions“ and involves collaboration with Dr. George Foster, research hydraulic engineer, considered to be one of the foremost erosion scientists in the world. A part of the project was conducted at the University of Denver and another part was conducted at the Agricultural Research Service offices in College Station, Texas. The final report for this project will be transmitted to the Agricultural Research Service by mid-May.

B. Presentations

Three papers were presented in evening seminars for the faculty and students at the Federal University of Viçosa. The titles and dates are as follows:

“Erosion rates as indicators of reclamation success,” November 3, 1999

“The Linear Erosion measuring instrument: better than erosion pins,” November 16, 1999

“Changes in soil properties due to mining and reclamation,” November 24, 1999

Also while in Viçosa, two training workshops were conducted concerning the use of the Revised Universal Soil Loss Equation (RUSLE), one for students and one for faculty and reclamation specialists from the mines in Minas Gerais. Each workshop was one full day in length and used computer laboratories on the campus. The participants were given the RUSLE software at the end of the workshop.

At the invitation of the International Erosion Control Association, a colleague and myself conducted a workshop entitled "How to Evaluate and Select 'Best Management Practices' for Construction Sites" at the national meeting of that organization in Palm Springs, CA on February 22, 2000.

C. Publications

It is expected that this sabbatical will result in three journal articles. The three journal articles and their status are listed below.

1. Changing Surface-mining Reclamation Practices in Minas Gerais, Brazil, by Terrence Toy and James Griffith.

   The purpose of this article is to compare reclamation practices in 1987, based upon the Barth report, with recently collected information at mines in Minas Gerais, Brazil. There has been considerable progress in the design and implementation of reclamation strategies. Topographic reconstruction to provide stable foundations for reclamation practices is more common. Revegetation uses a greater variety of plant species in the past. However, there remains little long-term planning concerning the post-mining use of the land. Based on field visits to the mines, some common successful reclamation practices are identified.

   Status: Manuscript is complete and submitted to the International Journal of Surface Mining, Reclamation and Environment

2. Long-term Planning for Brazilian Mine Reclamation, by Terrence Toy, Carlos Ribeiro, and James Griffith.

   The purpose of this article is to advocate long-term planning for surface-mine reclamation in Brazil. There have been many improvements in surface-mine reclamation since 1987 but there is still little long-term planning concerning the future and eventual use of the land following the closing of the mine. The steps for complete reclamation are discussed with a focus on long-term planning. The need for rapid vegetation cover, using the two-phase model, is encouraged in order to control erosion and sedimentation processes. An example of a long-term land-use plan based on agricultural production is presented.

Status: This manuscript is complete except for the addition of two pictures. It will be published in a referred Brazilian journal. Carlos Ribeiro is responsible for completion of the publication process.

3. Linkages Between Social and Physical Systems in the Reclamation of Disturbed Lands, by James Griffith and Terrence Toy.

The purpose of this article is to demonstrate the linkages between social and physical systems in the successful reclamation of disturbed lands. The relationship between force and resistance in both social and physical systems provides a basis for systems analysis. The likelihood of successful reclamation can be evaluated on the basis of systems analysis. An example of successful reclamation is discussed.

Status: About one-third of the manuscript remains to be written. My part is complete. The finished manuscript will be submitted to the Journal of Environmental Management. James Griffith is responsible for completion of the publication process.

ON-GOING RESEARCH

Investigation continues concerning the use of computer-assisted design technologies for the reconstruction of topographies on severely disturbed lands. Currently, AutoCAD and extensions, such as SurvCAD, are often used to design post-reclamation landscapes. The ultimate purpose of this research is to determine the feasibility of incorporating geomorphic principles into engineering designs.

Research continues concerning the effect of three-dimensional hillslope morphology on soil-loss rates.

Writing continues on the university-level textbook concerning erosion processes, measurement and control, co-authored with George Foster and Ken Renard. The book is now under contact with John Wiley and Sons, Inc.

PLANNED OR POTENTIAL PROJECTS

Phase II of the research concerning hillslope morphology and soil-loss rates may be funded by the Agricultural Research Service during the coming year.

Most of the writing for the erosion book will be completed in the next year

CURRENT PUBLICATION AND PAPERS

T. J. Toy, and W.R. Osterkamp. 1999. The stability of rock-veneered hillslopes. International Journal of Sediment Research. 14(3): 63-73.

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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 the period of April 1, 1999 through May 1, 2000. The focus of the NWRC revegetation/disturbed land program is to characterize establishment requirements of native grass and shrub species and to optimize restoration strategies for disturbed rangeland in the Great Basin region of the western United States.

ONGOING RESEARCH

1. Carbon Application for Annual Weed Control

Annual weeds that proliferate following wildfires dominate millions of hectares of rangeland in the western United States. Revegetation with native perennial plants is not feasible in these areas without some form of weed control. Carbon application in the form of sucrose has been shown to suppress annual weeds by temporary immobilization of nitrogen in the soil profile. NWRC scientist Stuart Hardegree and USFS-RMRS scientist Nancy Shaw initiated a 3-year study in July, 1997 to assess the efficacy of sucrose for annual weed suppression under a wide range of treatment applications in multiple years. The study is being conducted on an area in the Snake River Birds of Prey National Conservation Area that burned in 1997. Sucrose was applied in either early December or in both December and February at 0, 200, 400, 600, 800, 1000, 1200, 1600, or 2000 total kgC ha^{-1}. In the first 2 years of this 3_year study, the maximum carbon treatment resulted in a >75% reduction in biomass production of the 2 main weed species, cheatgrass (*Bromus tectorum*) and tumble mustard *(Sisymbrium altissimum*). For the same total amount of sucrose, a single application in December was more effective than the December/February application. Application rates necessary for adequate weed control are probably not economical for broad_scale application after wildfire. Use of sucrose as a carbon source may still be feasible for some high_intensity, small_area applications and in areas where herbicide use is not acceptable. This ongoing study will be completed in June, 2000.

2. Species-Level Response of Bottlebrush Squirreltail to Seed Priming

Seeds of bottlebrush squirreltail [*Elymus elymoides* (Raf.) Swezey = *Sitanion hystrix* (Nutt.) J.G. Smith], collected from 12 locations in Idaho, Nevada, Colorado, Montana, California and Washington used to evaluate species-level response to seed priming. Seeds from these

collections were primed and germinated at a range of constant temperatures between 3 and 360°C. Thermal-germination coefficients were determined to predict potential seedlot response to alternative field-temperature regimes. There was relatively high variability among seedlots in thermal response of both primed and non-primed seeds. Priming can result in significant germination advancement of this species under cold temperature conditions but the magnitude of the effect is highly seedlot dependant.

3. Vegetation Classification with Remote Sensing for Invasive Weed Assessment

NWRC scientist Patrick Clark has used Landsat 5 Thematic Mapper (TM) imagery to create prototype vegetation cover maps of the Snake River Birds of Prey National Conservation Area (SRBOP). Initial accuracy assessments of these prototype maps are encouraging. Refinements to these mapping techniques should provide an effective and efficient tool for determining the spatial distribution and extent of different vegetation cover types, particularly for invasive weeds such as cheatgrass, medusahead, and rush skeletonweed. This spatial information will be useful for many range management applications including weed invasion risk assessment, fuel condition and fire hazard evaluation, and rangeland restoration on extensive rangeland areas. NWRC is currently classifying Landsat 5 TM imagery acquired in 1986, 1991, and 1999 to evaluate changes in vegetation cover (primarily conversion of shrub steppe to annual grassland) on the western Snake River Plain during this 13 year time period.

COMPLETED RESEARCH

1. NEXRAD Meteorology for Distributing Precipitation Estimates

NWRC has developed new algorithm-coefficients for stratiform rain that were adopted by the National Weather Service for NEXRAD winter-precipitation estimates in the Pacific Northwest. NWRC scientists, David Levinson and Clayton Hanson obtained Level 1 radar reflectivity data for storm events within the Boise radar domain and compared precipitation estimates with rain gauge data from the Reynolds Creek Experimental Watershed and Snake River Birds of Prey National Conservation Area. Sensitivity analysis of algorithm coefficients for threshold reflectivity and reflectivity/rainfall ratios yielded improved estimates of rainfall in the test areas. NWRC continues to investigate technology that will make NEXRAD rainfall estimates of use to land managers and revegetation specialists.

2. Germplasm Screening for Thermal Germination Response

Seed priming may enhance establishment success of cool-season range grasses which must compete with annual weeds for early spring moisture. Previous priming studies have confirmed germination rate enhancement for these species but relative treatment effects under field-temperature conditions have not been assessed. NWRC scientist, Stuart Hardegree primed seeds of thickspike wheatgrass [*Elymus lanceolatus* (Scribn. and J.G. Smith) Gould], bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh) Löve], Sandberg bluegrass (*Poa sandbergii* Vasey.) and bottlebrush squirreltail [*Elymus elymoides* (Raf.) Swezey] and evaluated their relative emergence rate in three soil types as a function of spring-planting date. Germination response was simultaneously evaluated in germinators that were programmed to simulate the

field-temperature regime at planting depth. Seed priming enhanced both germination and emergence rate with the greatest effect occurring during the earlier, cooler planting dates. Total emergence and emergence rate in the field was lower than equivalent germination response in the laboratory. Thermal-germination response was modeled and predictions developed for evaluating potential germination under late winter/early spring soil-temperature regimes. Modeling results predicted that greater germination enhancement would have been possible at earlier planting dates than were measured in the field experiment.

3. Seedbed Microclimate Modeling

NWRC scientists, Gerald Flerchinger and Stuart Hardegree tested and calibrated the Simultaneous Heat and Water Model (SHAW) for estimating seedbed temperature and water content as a function of soil type and meteorological conditions of precipitation, temperature, relative humidity, solar radiation and wind speed. Simulation results using initial parameter estimates, calibrated parameters and moisture release curve parameters obtained from pressure plate measurements were compared to determine the impact of uncertainty in model parameters on potential hydrothermal germination response of both revegetation and weedy plant species. Near-surface soil temperatures were accurately estimated regardless of parameter estimation technique. Estimates of soil water content and potential were more sensitive to the accuracy of model input parameters. Calibrated model output is currently being used to evaluation annual variability in predicted germination response of both native and weedy plant species as it is affected by planting date.

4. Species-Level Response of Bottlebrush Squirreltail to Seed Priming

Seeds of bottlebrush squirreltail [*Elymus elymoides* (Raf.) Swezey = *Sitanion hystrix* (Nutt.) J.G. Smith], collected from 12 locations in Idaho, Nevada, Colorado, Montana, California and Washington used to evaluate species-level response to seed priming. Seeds from these collections were primed and germinated at a range of constant temperatures between 3 and 360^{o}C. Thermal-germination coefficients were determined to predict potential seedlot response to alternative field-temperature regimes. There was relatively high variability among seedlots in thermal response of both primed and non-primed seeds. Priming can result in significant germination advancement of this species under cold temperature conditions but the magnitude of the effect is highly seedlot dependant.

PLANNED OR POTENTIAL PROJECTS

1. Development of laboratory procedures to evaluate alternative carbon sources for nitrogen immobilization in the soil. These procedures may identify more cost effective immobilization strategies and will provide data for development of models for predicting the impact of soil temperature and moisture on soil carbon utilization by micro-organisms.

2. Field-scale evaluation of carbon application, it's effect on seedbed water relations and release of weed-suppressed perennial species.

3. Non-linear model development for optimizing hydrothermal germination response models for predicting field establishment response.

4. Population-level emergence model development in the laboratory and field testing of emergence models at the Orchard Field Test Site.

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Flerchinger, G.N. and S.P. Hardegree. 2000. Modeling near-surface soil temperature and moisture for seedling germination response. In: Abstracts of the 53rd Annual Meeting, Society for Range Management, Boise, ID, Feb. 13-18, 2000.

Hardegree, S.P., N. Shaw and J. Mowbray. 2000. Sucrose application for suppression of annual weeds. In: Abstracts of the 53rd Annual Meeting, Society for Range Management, Boise, ID, Feb 13-18, 2000.

Hardegree, S.P. and S.S. Van Vactor. 1999. Predicting germination response of four cool-season range grasses to field-variable temperature regimes. Environmental and Experimental Botany 41:209-217.

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NEVADA

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INTRODUCTION

This report summarizes reclamation/restoration projects in progress during 2000 by the Ecology, Paleoecology and Restoration of Great Basin Watersheds Research Work Unit and the Great Basin Ecosystem Management Project for Maintaining and Restoring Riparian Ecosystem Intergrity, two USDA Forest Service, Rocky Mountain Research Station projects, located in Reno, Nevada. Cooperators in these research projects include the Humboldt-Toiyabe National Forest; Agricultural Research Service, Reno, NV; Environmental Protection Agency, Ada, OK; University of Nevada, Reno, Reno, NV; Western Carolina University, Cullowhee, WC; Lafayette University, Easton, PA; and Utah State University, Logan, UT.

ONGOING PROJECTS

1. Great Basin Interdisciplinary Research and Management Project: Maintaining and Restoring Riparian Ecosystem Integrity (Jeanne C. Chambers, Team Leader, RMRS)

This USDA Forest Service, ecosystem management project was initiated in 1994 and has been approved to continue through 2003. The project has been a collaborative effort between the Rocky Mountain Research Station and the Humboldt-Toiyabe National Forest (H-T). The overall objective is to increase our understanding of the structure and functioning of central Nevada watersheds and riparian ecosystems and to develop management guidelines for maintaining or restoring riparian ecosystem integrity. Our specific objectives have evolved to include the following: (1) Determine the effects of longer-term climate change processes and shorter-term natural and anthropogenic disturbance on central Nevada watersheds, riparian corridors, and riparian ecosystems or stream reaches; (2) Determine the successional trajectories and recovery potentials of key riparian ecosystems exhibiting different disturbance regimes and varying levels of degradation; (3) Develop criteria for evaluating the effects of changes in management or restoration activities on watersheds and riparian ecosystems; (4) Evaluate the use of high resolution, low-altitude video imagery for rapidly assessing riparian ecosystem functioning; and (5) Evaluate specific management techniques for restoring or maintaining watershed and riparian ecosystem integrity. Research collaborators include the Agricultural Research Service, Environmental Protection Agency, University of Nevada, Reno, Western Carolina University, Lafayette University, and Utah State University.

2. Importance of Understanding Long- and Short-Term Changes in Vegetation and Geomorphology for Riparian Restoration (Jerry Miller, Indiana University, Purdue

University at Indianapolis; Jeanne Chambers, RMRS; Robin Tausch, RMRS; and Dru Germanoski, Lafayette University)

This interdisciplinary research is reconstructing the effects of climate change processes and disturbance on central Nevada watersheds by examining the vegetational and geomorphic histories of key drainage basins. It is focusing on both the Holocene (last 11,500 years) and the period of record (last 50 to 100 years). The examination of the Holocene record is based on the analysis of woodrat midden data to track vegetation dynamics and the examination of the stratigraphic record to determine changes in watershed processes. The recent record is being evaluated by investigating relationships among stream depositional surfaces, the dendrochronologic record, and hydrographic record. Initial results indicate that climate change processes and their influences on vegetation and geomorphic processes that occurred 2,000 years ago are still influencing stream dynamics. Recent stream incision in these systems began at the end of the Little Ice Age, after about 290 YBP. The tendency for these systems to downcut still exists and the rate of downcutting is being exacerbated by human activities. Currently, stream morphology and riparian ecosystem dynamics are being controlled by episodic flood events. The streams and riparian ecosystems are currently functioning as non-equilibrium systems and restoration to conditions that existed prior to the last 150 to 200 yrs of stream incision is unrealistic. Realistic management objectives include maintaining the integrity of stable reaches and riparian ecosystems, and increasing the stability of systems currently incising or at risk of future incision. This work will continue into the future with the goals of understanding differences in basin sensitivity to both climate change processes and natural and human disturbance.

3. Basin Big Sagebrush Dominated Riparian Corridors - Dry Meadows as Alternative Stable States? (Jeanne Chambers, RMRS; Michael Wright, UNR; Pam Mebine, UNR; and Bob Blank, ARS)

The study uses the dry meadow and basin big sagebrush/giant wild rye ecosystem types as models for examining the potential restoration of or, if a threshold has been crossed, conversion of sagebrush dominated riparian ecosystems to an alternative stable state, i.e., dry meadows. A restoration experiment is being used in which sites in three separate drainages are restored by burning and seeding with native grasses characteristic of the dry meadow ecosystem type. Ecosystem response is being evaluated for restored and paired not restored plots. Because of the importance of water table and microsite conditions (interspace and under shrub), both factors have been included in the study design. Several response variables are being measured including (1) the recovery of the pre-fire vegetation, (2) the role of the soil seed bank in species establishment, (3) the soil system response including changes in soil chemistry, temperature and water, and (4) the establishment response of the seeded species. Information from these studies can be used to prescribe restoration methods for dry meadow ecosystems. This research was funded by a CSRS Rangelands grant and was initiated in the 1996.

4. Instream Flow Requirements for Restoring and Maintaining Riparian Ecosystems Jeanne Chambers, RMRS; Jerry Miller, Indiana University, Purdue University at Indianapolis; and Dave Jewett, EPA

This study was initiated in 1997 to increase our understanding of the relationships between instream flows and the structure and function of riparian ecosystems. It is examining the relationships among geomorphic position, the surface and subsurface flow systems and riparian ecosystems for gaged stream systems in central Nevada. Because alluvial fans control stream form and function in many central Nevada drainages, the study is examining the effects of alluvial fans on channel form and depth of entrenchment. It focuses on depositional areas, usually characterized by meadow ecosystems, that occur immediately upstream of these fans and erosional areas, usually characterized by willow ecosystems, that occur further upstream of the fans. Within these different geomorphic settings, the stream morphology is being characterized, the surface and shallow groundwater systems examined, and the riparian vegetation and soils quantified. These data will be synthesized in order to determine the effects of geomorphic position and instream flows on ground water hydrology and riparian ecosystems. This administrative study is being conducted in cooperation with and partially supported by the USDA Forest Service, Stream Systems Technology Center.

CURRENT PUBLICATIONS AND PAPERS

Chambers, J.C., S.B. Vander Wall, and E.W. Schupp. 1999. Seed and seedling ecology of pinyon and juniper species in the pygmy woodlands of western North America. Botanical Reviews 65(1):1-38.

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Chambers, J.C. 2,000. Using threshold and alternative state concepts to restore degraded or disturbed ecosystems. In: J. Todd compiler. Fourteenth High Altitude Revegetation Workshop. Colorado State University and the High Altitude Revegetation Committee. Fort Collins, CO, In press.

Chambers, J.C. Great Basin Ecosystem Management Project: restoring and maintaining riparian ecosystem integrity. In: H.Y. Smith, ed. Proceedings: The Bitterroot Ecosystem Management Project--what we have learned, May 18-20, 1999. Missoula, MT, In press.

Castelli, R.M., J. Chambers, and R. Tausch. 2,000. Soil-plant relations along a soil water gradient in Great Basin riparian meadows. Wetlands. 20(2), In press.

Miller, J., D. Germanoski, K. Waltman, R. Tausch, and J. Chambers. Influence of late

Holocene processes and landforms on modern channel dynamics in upland watersheds of central Nevada. Geomorphology, In press**.**

Urbanska, K.M. and J.C. Chambers. High-elevation ecosystems. In: M.R. Perrow, and A.J. Davy, eds. Handbook of Restoration Ecology – Volume 2. Cambridge University Press, Cambridge, UK, In press.

NEW MEXICO

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INTRODUCTION

The Rocky Mountain Research Station, Albuquerque Lab, is home to an Ecology Research Work Unit (RWU) and an Ecosystem Research Work Unit. The titles, missions and summarized descriptions of these units are presented below.

Research Work Unit RMRS-4351 "Ecology, Recovery, and Sustainability of Grassland and Riparian Ecosystems in the Southwest."

Mission: Develop, synthesize, and apply new methods and knowledge on processes, interactions, and human uses of desert, prairie, and riparian ecosystems to restore damaged lands, recover sensitive species, and sustain intact, productive, and diverse plant and wildlife communities and associated abiotic systems in the Southwest.

Problem 1. Nonsustainable management of grazing, fire, woody and alien species, and wildlife has led to widespread disturbance and degradation of southwestern and southern-plains grasslands and associated ecosystems. The development of new methods and knowledge are needed to restore damaged systems and recover sensitive and endangered species.

In order to specifically define the research approach needed to solve Problem 1, its components have been separated into four elements.

Element 1. Evaluate the influence of fire as an agent of natural disturbance that regulates ecological processes in southwestern and national grasslands and assess its value as a means for restoring grassland ecosystems, including the maintenance of native diversity and control of noxious weeds and undesirable woody plants.

Element 2. Determine the efficacy of mechanical and chemical woody plant removal as ecological restoration techniques for grassland ecosystems that require alteration of composition and structure before they can be burned.

Element 3. Assess the habitat ecology and roost site selection of sensitive bat species and identify natural and anthropogenic factors that disturb bat populations.

Element 4. Assess whether grazing schedules can be altered to improve habitats for endangered, threatened and sensitive bird species in grassland ecosystems.

Problem 2. Disturbances such as grazing, roads, stream channel realignments, and exotic plant invasion have altered hydrological, biological, and ecological dynamics of riparian habitats, endangering terrestrial native plant and nongame bird species. New methods and knowledge are required to recover terrestrial riparian systems and associated sensitive species.

To specifically define the research approach needed to solve Problem 2, its components have been separated into the following three elements.

Element 1. Determine how roads and stream channel realignments influence the hydrological and vegetation dynamics of riparian systems and evaluate road engineering techniques designed to repair damaged systems.

Element 2. Determine how the increasing presence of exotic woody plants affects the abundance, migration, and stopover habitat use of Neotropical migratory birds in riparian systems.

Element 3. Investigate the factors that affect and inhibit reproduction, migration, and abundance of the endangered southwestern willow flycatcher, and develop methods to recover its populations.

Research Work Unit RMRS-4652 "Ecology, Diversity and Sustainability of Soil, Plant, Animal and Human Resources of the Rio Grande Basin."

Mission: Develop, synthesize, and apply new knowledge on processes, interactions, and sociocultural uses of upland and riparian ecological systems for sustaining diverse, productive, and healthy plant, animal, and human populations and associated natural resources in the Rio Grande Basin.

Ecological Disturbance and Restoration Research

Watershed and biological studies were initiated in FY94 and FY95 in the middle Rio Grande Basin, defined as the reach between Cochiti Dam and Elephant Butte Reservoir, New Mexico. Current studies are assessing responses of soil nutrients, water, belowground flora and fauna, herbaceous and woody plants, and fish and wildlife populations to 1) disturbances by drought, fire and its suppression, grazing, and past human activities, and 2) restoration treatments to mitigate or reverse disturbance effects.

Drought, overgrazing, and fire exclusion are three of the major factors, interacting in concert, hat have resulted in degraded upland and river ecosystems in the middle Basin. Several cooperative studies were implemented to evaluate effects of drought, grazing exclusion, fire suppression, and historic human influence. These studies have involved the use of tree-ring

dating, landscape analysis, experiments with cobble rocks, excluding cattle from streams and current and historic inventory data and photo records at Research Natural Areas (RNA). Ecological assessments have detected widespread shifts in grassland/shrubland/woodland boundaries; influences of early Puebloan cobble mulch gardens on current ecosystem functioning; effects of grazing and hydrology on nutrient composition and retention in streams, and influence of RNA protection on ecosystem health as indexed by plant age and densities, nutrient cycling, and extent of cryptogram crusts.

Diverse agency and interagency teams of biologist, ecologists, hydrologists and others are working together to address our research missions. A sample of the publications that have been produced from our research are listed below. Detailed presentations of our programs, collaborators and accomplishments are posted on our website at: http://www.fs.fed.us/rm/albuq/.

PUBLICATIONS AND PAPERS

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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 April 1, 1999 to April 30, 2000. The projects reported below are mostly part of the Vegetation Diversity Project (VDP). The goal of VDP is to develop new information and technology for restoration and maintenance of native plant diversity on semiarid rangelands of the Great Basin and Columbia/Snake River Plateau. As a result of recent changes in funding within USGS, the VDP has been discontinued and the projects under this overall program are coming to completion. The USGS and the U. S. Fish and Wildlife Service of the U. S. Department of the Interior fund the research reported in this document.

COMPLETED PROJECTS

1. The effect of fire and herbicides on microphytic crust dynamics in high desert ecosystems. (Berta Youtie, Dan Salzer, and Jeanne Ponzetti, The Nature Conservancy of Oregon, Portland, OR)

Species richness was reduced the first year after the fire, but by the third year was not different from controls. For most of the crust variables, we found significant quadratic trends in cover over time, relative to controls. We observed reductions in cover for the first year after fire, followed by gradual increases in cover in subsequent years. However, most variables have not returned to pre-burn levels, including total crust cover, total lichens, and total bryophytes. Three years after the fire, bare soil is still higher in the burned plots relative to controls. Community composition of the burned plots remains significantly different from the controls ($p < 0.01$, Multi-Response Permutation Procedure). The dominant moss *Tortula ruralis* has been dramatically reduced by the fire, and is recovering more slowly than the other crust variables. Lichens appear to be recovering from the fire more rapidly than bryophytes, in large part because of the fire sensitivity of *T. ruralis*.

Microbiotic Crust Cover. Three years after the prescribed fire, terricolous lichen and bryophyte cover is showing signs of recovery, but has not returned to pre-burn levels. Many of the crust variables exhibit significant quadratic trends in burned plots relative to controls. For example, total crust cover, total lichens, and total bryophytes were initially reduced by the fire, and have increased gradually since 1997 ($p < 0.01$ for treatment x time interaction and treatment effect on quadratic trend, Repeated Measures ANOVA). Bare ground increased in the burned

plots in 1997, and has decreased since then ($p < 0.01$ for treatment x time interaction and treatment effect on quadratic trend, Repeated Measures ANOVA).

Quadratic trends are also evident with the ocular microbiotic crust species data, but they take on a slightly different form. With this data set, fire-charred crusts were included in the species totals, resulting in higher total cover values for some variables relative to the point-intercept data set. Analysis of variance results are similar to that of the point-intercept data, demonstrating quadratic trends, but these ocular variables continued to decline in the second monitoring season after the fire (1998), and didn't show recovery until the third year (1999).

Microbiotic Crust Species Richness. The prescribed fire had a statistically significant effect on trend in crust species richness ($p < 0.02$, Repeated Measures ANOVA, $p < 0.03$, treatment effect on quadratic trend). From 1996 to 1997, species richness was reduced by 4.2 (2.7) species in the burned plots relative to controls. From 1997 to 1999, richness in the burned plots increased by an average difference of 2.8 (2.3) species relative to controls. As of 1999, richness in the burned plots actually exceeded richness in the controls by an average of one species. Species richness analyses are based on the ocular microbiotic crust species data.

Microbiotic Crust Community Composition. Crust communities have not recovered from the prescribed fire. There was no difference in pre-fire (1996) crust communities between treatment and control groups ($p = 0.69$, MRPP), but there were strong differences between post-fire treatment and control communities ($p = 0.04$ for 1997, 1998, and 1999, MRPP). Control crust communities did not differ over the four years ($p = 0.58$, MRPP), but the burned communities did have significant compositional differences over time ($p = 0.002$, MRPP).

Post-fire Microbiotic Crust Community Dynamics. We used gradient analysis on the ocular microbiotic crust species data to explore compositional patterns in the five burned plots over all four years. With NMS, we found three axes to be the best solution, explaining more than 95% of the variation in the data ($r^2 = 0.953$). The majority of the variation is explained with Axis 2 ($r^2 = 0.53$), followed by Axis 1 ($r^2 = 0.33$), and Axis 3 ($r^2 = 0.09$). Graphical representations of this ordination, other associated variables, and distribution patterns of some of the crust species are displayed in Figures. The following describes the strongest variable correlations with the three axes. *Axis 2*. We found total bryophytes ($r = 0.89$), total crust ($r = 0.84$), total soil crust ($r = 0.79$), and short mosses ($r = 0.69$) to be most strongly associated with Axis 2. Variables with strong negative associations with Axis 2 include bare ground ($r = -0.60$), and year ($r = -0.62$). Crust species with strong positive correlations with Axis 2 include *Cladonia* spp. ($r = 0.75$), *Tortula ruralis* ($r = 0.73$), *Ceratadon purpureus* ($r = 0.65$), and *Leptogium* spp. ($r = 0.60$). There were no strong negative crust species correlations with this axis. *Axis 1*. Bare ground was negatively associated with this axis ($r = -0.51$), as well as Axis 2. Positively associated variables include total lichens ($r = 0.75$), "other lichens" ($r = 0.62$), *Poa secunda* ($r = 0.61$), black lichens ($r = 0.55$), annual forbs ($r = 0.53$), and crust on bunchgrass crowns ($r = 0.43$). Crust species negatively associated with this axis include *Tortula ruralis* ($r = -0.60$), *Bryum argenteum* ($r = -0.42$), and *Bryum* spp. ($r = -0.42$). Species with positive associations include *Encalypta rhaptocarpa* ($r = 0.58$), *Aspicilia* spp. ($r = 0.51$), *Diploschistes muscorum* ($r = 0.50$), and *Cladonia* spp. ($r = 0.45$). *Axis 3*. The diversity measure evenness was negatively associated with this axis ($r = -0.65$), along with the Shannon diversity index (H') ($r = -$

0.49) and gravel (r = -0.47). *Pseudoroegneria spicata* (r = 0.58), total soil crust (r = 0.45), *Cladonia* spp. (r = 0.72), and *Pterogoneuron ovatum* (r = .43) were all positively associated with Axis 3.

Invasive Exotic Annuals. The annual grasses *Bromus tectorum* and *Taeniatherum caput-medusae* both increased slightly over time, but the effect did not differ between treatment and control groups. Aerial cover of *Bromus tectorum* peaked in 1998 at 12.4% cover in the burned plots and 12.8% cover in the control plots. Cover in both groups declined in 1999. *Bunchgrass Mortality*. The first year after the fire, mortality of *Festuca idahoensis* was 11% (12/107 tagged plants). In 1998, two years after the fire, mortality increased to 15% (16/107). This mortality is significantly higher than that of the unburned plants, which had no deaths out of 138 tagged plants ($p < 0.0001$, one-tailed Fisher exact test). Mortality of *Pseudoroegneria spicata* increased from 1 plant in 1997 to 2 out of 20 tagged plants in 1998. This level of mortality did not differ statistically from the unburned tagged plants ($p = 0.21$, one-tailed Fisher exact test). There is no evidence that the condition of the surviving burned plants differs from the unburned plants ($p = 0.25$ for *F. idahoensis* and 0.67 for *P. spicata*, Repeated Measures ANOVA).

MANAGEMENT IMPLICATIONS: Three years after the fire, cover and community composition of the biotic crusts have not recovered. However, species richness has virtually recovered, and most crust species have increased in cover. These results suggest that a patchy, "cool-season" prescribed fire is more conducive to rapid crust recovery than hot fires. We found that partially burned crusts did not persist beyond the first year after the fire. They are important for site recovery because they function as a ground cover immediately after fire, when soils are particularly vulnerable to erosion. Managers should recognize that even lightly burned crusts are likely to break down rapidly, and must be replaced with living crust or plant cover for soil protection. At this site, the moss *Tortula ruralis* is more fire-sensitive than many other crust species, and recovers more slowly. If this holds true in other locations, we can expect that sites with a high proportion of *T. ruralis* will recover slowly from fire, including cooler prescribed fires. Two years after the fire, there was a 15% mortality of *Festuca idahoensis*, despite the "cool-season" fire prescription. While the surviving fescue plants are doing well, there may be a compositional shift in favor of *Pseudoroegneria spicata*, which was not significantly impacted by the fire. Further monitoring is needed to determine if invasive annual grasses will be favored by the fire. We recommend that the point-intercept method be used with morphological groups for monitoring biotic crust cover trends over time. If sample sizes are adequate, and the morphological groups are well-defined for the location in question, consistent percent cover estimates can be obtained and used for assessing management needs. However, if monitoring goals include compositional or biodiversity questions, properly designed ocular quadrat methods are best. Other methods that were not tested here may also prove to be useful, depending on site-specific management goals.

2. Emergence, survival and reproduction of three species of forbs important in sage grouse nutrition using two establishment methods (Troy Wirth, Department of Rangeland Resources, Oregon State University and David A. Pyke, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, OR)

The following provides an overview of the findings of this project. During 1997, we chose eight study sites at Hart Mountain National Antelope Refuge. Hart Mountain National Antelope Refuge is located in southeastern Oregon and is within the current range of the western subspecies of sage grouse. In June of 1997, we collected plant species composition at each site for comparing among pre- and post-treatment years and between burned and unburned sites. In late June and early July, we collected seeds from the target Crepis and Astragalus species. In late September, the United States Fish and Wildlife Service did prescription burns of sagebrush grasslands at four of the sites. Each fire had slightly different fire attributes (intensity and heat per unit area) and preburn conditions (moisture content of vegetation, temperature, wind speed and direction and relative humidity), but all were head fires. After burning, one experimental plot was randomly located within each burned and unburned site. At each experimental plot, 250 seeds of each species were sown along 10, randomly located transects. The order of the three species along each transect was randomized to avoid positional bias within a transect. Seeds along each transect were planted alternately within the two microsites (shrub mound and interspace). In 1998, seeds were censused for emergence and survival throughout the spring and summer. In addition, tubelings of each species were transplanted into 50 mound and 50 interspace microsites at each of the eight sites in April of 1998. Species composition measurements were also taken at each site in July, 1998. Of the seeds planted in 1997, Astragalus purshii had the lowest emergence (8%) of all three species. Both Crepis species had similar overall emergence (38%). We found both fire and microsite location affected emergence of Crepis seedlings ($P=0.01$). Significantly more Crepis seedlings emerged from shrub mounds in unburned areas (50 %) than in any other fire by microsite treatment (33 to 36%). A. purshii was also affected by both fire and microsite ($P=0.02$). Significantly more A. purshii emerged in the burned interspace compared to the burned mounds. Nearly twice as many emerging Crepis seedlings survived in the burned areas as opposed to unburned areas ($P<0.01$). This increased survival in the burned treatments was accompanied by greater mortality in the unburned areas for Crepis. This resulted in more plant establishment in the burned mounds despite higher emergence in the unburned mounds. Microsite also significantly affected survival of Crepis seedlings ($P<0.01$). Approximately 10% more Crepis seedlings survived in the mounds compared to interspaces. A. purshii seedlings also survived better in burned areas ($P=0.06$), but had no differential response to microsite. Fire enhanced survival of both Crepis and Astragalus transplants ($P=0.08$ and $P=0.001$). Transplanting did not significantly enhance plant establishment over seeding. Therefore, we conclude that revegetation of sage grouse habitat with Crepis species is a viable option given its high germinability, favorable response to fire and wide distribution.

3. Influence of grazing on biotic crusts in a central Washington landscape. (B. McCune, and J. Ponzetti, Oregon State University and D.A. Pyke, Forest and Rangeland Ecosystem Science Center).

We studied biotic crust communities before the resumption of grazing in a large allotment in which the biotic soil crusts are largely intact. We used a two-level field study, including (1) permanent plots and (2) non-permanent, stratified landscape sampling. The permanent plots were designed as paired grazed/ungrazed comparisons at exclosures. These provide strong experimental controls, using a replicated before/after/treatment/control (BATC) design. The landscape-level study employed extensive sampling with non-permanent plots

stratified by topographic position. These provide a context for interpreting the results from the permanent plots. We've used these data to describe variation in the development of the biotic crust in relation to topographic position, disturbances, soil characteristics and vascular vegetation. We found that biotic crust communities are not uniformly distributed with regard to topographic position. Warm and cool draws were the most disturbed and had lower average species richness of all the topographic strata we examined. Crust integrity was inversely related to cover of *Bromus tectorum*. We found that pre-treatment biotic crust communities differed slightly inside versus outside of the exclosures, and we've documented those differences. In addition, we've presented our estimates of repeat-sampling error, provided baseline levels, and established criteria for evaluating future impacts to the biotic crusts.

4. Integrated weed management for perennial pepperweed at Malheur National Wildlife Refuge. (Fred Paveglio and Kevin Kilbride, Fish and Wildlife Service, Vancouver Field Station, Margaret Laws, Fish and Wildlife Service, Malheur National Wildlife Refuge and Department of Rangeland Resources, Oregon State University, and David A. Pyke, NBS, Forest & Rangeland Ecosystem Science Center).

The final report of the project appears in the form of a thesis by Margaret Laws. The abstract is as follows: *Lepidium latifolium* L. (perennial pepperweed, LEPLA) is an exotic invader throughout western North America. At Malheur National Wildlife Refuge (MNWR) in southeast Oregon, it has invaded about 10% of meadow habitats that are important for wildlife. The objective of this was to determine the most effective and least environmentally harmful treatment to control this weed and restore native vegetation using integrated pest management techniques. During summer 1995, nine 0.24-ha plots in three meadows infested with *L. latifolium* at MNWR were randomly assigned to a treatment with metsulfuron methyl herbicide, chlorsulfuron herbicide, disking, burning, herbicide (metsulfuron methyl or chlorsulfuron) then disking, herbicide (metsulfuron methyl or chlorsulfuron) then burning, or untreated. Changes in *L. latifolium* ramet densities and basal cover of vegetation, litter, and bare soil were evaluated in 1996 and 1997. Sheep grazing was evaluated as a treatment for reduction in flower production along roadsides and levees during summer 1997. Revegetation treatments of seeding, transplanting or natural (untreated) revegetation were attempted at plots treated with chlorsulfuron, disking, chlorsulfuron then disking, and at untreated plots from October 1996 through September 1997. Chlorsulfuron was the most effective control treatment with greater than 97% reduction in *L. latifolium* ramet densities two years after treatment. Metsulfuron methyl was an effective control (greater than 93% reduction) for one year. Disking was ineffective. Burning was ineffective at the one site where sufficient fine fuels existed to carry fire. Herbicide treatments were associated with increased grass and reduced forb cover. Disking was associated with reduced grass and litter cover. Disking combined with either herbicide treatment was associated with reductions in all plant cover (49 to 100%), increased bare ground, and invasion by other weedy species such as *Cirsium arvense* (L.) Scop. (Canada thistle, CIRAR) and *Bromus tectorum* L. (cheatgrass, BROTE). Ungrazed *L. latifolium* averaged 4513 flowers per ramet. Sheep grazing reduced *L. latifolium* flower production by at least 98%. Revegetation treatments were unnecessary in sites treated with chlorsulfuron and were ineffective at all treatment sites.

5. Evaluating Native Grass Accessions for Restoring Deteriorated Rangelands: Are Traditional Evaluation Techniques Adequate? (Eric Limbach, Department of Rangeland Resources, Oregon State University, Corvallis, OR)

Annual cheatgrass, *Bromus tectorum* has invaded much of the native sagebrush steppe of the northern Great Basin and Columbia Plateau region. Restoration of degraded communities in this region will require perennial plant materials that can establish and reproduce in a competitive background of cheatgrass. During 1997 and 1998, 18 native grass accessions in three species, and an introduced grass, crested wheatgrass, *Agropyron desertorum* cv. Nordan (1997) and cv. Hycrest (1998), were evaluated. We examined seedling emergence, transplant success, survival, and productivity with and without cheatgrass competition using a randomized block, 4-way analysis of variance experimental design. Native species included 1) four subspecies of bottlebrush squirreltail, Elymus elymoides, formerly Sitanion hystrix; 2) Sandberg's bluegrass, Poa sandbergii, and 3) Thurber's needlegrass, Achnatherum thurberiana, formerly Stipa thurberiana. Field plots were located on cheatgrass-dominated *Artemisia tridentata* ssp. *wyomingensis* sites at Brim Well, near Christmas Valley, OR and Boise, ID. Accessions were seeded in the fall of 1996 or 1997 and glasshouse-grown seedlings were transplanted in the spring of 1997 or 1998. Emergence both years was significantly greater ($P<0.001$) at Brim than at Boise. Survival in 1997 was significantly greater ($P<0.0001$) at Brim than at Boise but not in 1998 ($P<0.0834$). Emergence ($P < 0.0001$) and survival ($P < 0.0001$) were significantly reduced by competition from cheatgrass. Species trends for emergence and survival were highest in squirreltail, intermediate for thurber needlegrass, less for sandberg bluegrass, and least for crested wheatgrass. Among accessions, there were insignificant changes in ranked emergence compared to ranked survival in either year. Two accessions of squirreltail (Central Ferry, WA and Emmet, ID), both *jubatum* subspecies, had the highest seedling emergence and seedling survival, both years, irrespective of competitive background. Mortality of transplants was greater than 90%, irrespective of year, location, competition or accession number.

ONGOING PROJECTS

1. Changes in plant community dynamics caused by elevated CO_2 and altered precipitation. (Richard F. Miller, William E. Winner, Larry L. Larson, Gary L. Kiemnec, Oregon State University, and Tony Svejcar, Agricultural Research Service.

All shelter treatments tended to have greater ground cover than the Ambient treatment. Herbaceous biomass production and reproductive effort have been reduced under a Spring moisture pattern compared to other treatments. Bareground has been greater in Ambient and Spring treatments than in consistently lower in Spring treatment compared to the other treatments in all years. The phenology of all the species monitored was affected by the different precipitation treatments. The most dramatic effects occurred with herbaceous species where phenology was delayed or arrested by the Spring treatment (all years) when compared to the other treatments. Sagebrush phenology has been delayed in the Spring treatment through the time of floral shoot development. However, by the ephemeral leaf drop stage there have been few differences in sagebrush phenology among the treatments. Results suggest that summer moisture is an important factor in the reproductive effort of sagebrush and that winter/early spring

moisture is important to the reproductive effort of the herbaceous component. In all treatments root activity appears to be correlated to soil moisture conditions particularly in the upper (10-20cm) soil profile. During periods of higher moisture availability root activity increases. Although there has been a lack of any consistent treatment effects with rooting activity it does appear that the Spring treatment may be allocating more resources to below ground structures.

2. Quantification of vegetation diversity on intact and deteriorated rangelands: Experiment 1 - Plant diversity on sagebrush steppe rangelands varying in ecological condition. (Lee E. Eddleman & Pat Dysart, Department of Rangeland Resources, Oregon State University)

A total of 101 species were encountered during the three years of the study. Nineteen of those species were encountered only in 1995, eighteen of the species were encountered only in 1996, with only one additional species encountered in 1997 that was not present in 1995 or 1996. Seasonal changes in species richness did occur. In both years, species richness was significantly different between the Good/Fair and the Poor condition sites, but the species richness number alone could not distinguish among the two higher condition classes. The significant trend was seasonal with more species being encountered in the spring in both years across all condition classes and the least being encountered in the fall. More species in general were encountered in 1996. Seasonal species/area curves show a wide range of minimal areas that would be necessary to adequately represent the plant species assemblages on individual hectares and in the condition class. For the individual hectares, these sizes range from 5 M^2 on a Good site in the spring to 25 M^2 on a Poor site in the fall. Species area curves also show that greater than 45 M^2, the sample size used in this study, would be necessary to capture the number of species projected by the Jackknife estimators for an individual hectare. An area greater than 135 M^2 would be necessary to capture the estimated species richness within a condition class. On this range site, species richness alone provided a complicated picture of condition classes, therefore, its use as a management tool may be limited. The results indicate that apriori delineation of the physical and temporal scale for measurement is an essential condition of using species richness of vascular plants as a rangeland condition evaluation tool. Commonly used diversity indices such as Shannon's and Simpson's index use either cover or number of individuals in their calculations. These indices because they attempt to incorporate both richness and evenness were difficult to interpret. Hill's three indices, one of which is the total number of species in the sample (species richness), one is the number of abundant species, and one is the number of very abundant species may be useful since Hill uses species units that can be directly interpreted. The overall trend in cover by Raunkiaer type follows the same general trend as species richness. Changes that occur in one condition class occur with almost the same magnitude in the other condition classes. Another functional analysis was performed using the USDA/NRCS life form classification based 14 life form groups. The main advantage of this classification over Raunkiaer biological types is that, it classifies based on native and introduced species in the category name and such a distinction may be important for system management. Two possible disadvantages are 1) it may not be subtle enough to detect trends toward irreversible thresholds, and 2) the large number of categories are cumbersome to use. For example, on this range site, cover of introduced annual grasses, mainly cheatgrass, although contributing a small amount to the overall cover, the amount was nevertheless significantly different on the quadrat and hectare levels with main effects of season and year being the reason for the differences among hectares. On the condition class level, in 1996 the Poor condition class had 3-12 times more cover of introduced annual grasses than the Fair or Good condition sites (Table 9). This life form category could distinguish

between the extremes (Poor and Good), but not between Fair and Good. Preliminary results indicate that the technology of mixed bed ion exchange resins (PST-1 capsules) could be used successfully in wildland situations to provide an index of available soil nutrients. Preliminary results indicate that 1) there may be an available soil nutrient index that can identify sites by condition and 2) that although traditional bulk soil nutrient analyses may represent a total nutrient potential for any given soil, they are likely to overestimate the amount of nutrients actually available to the plants at any given time under varying climactic conditions.

3. 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)

Land managers are often faced with difficult decisions on how to use plants in solving land management problems. Managers must decide the appropriate species and techniques to establish plants for revegetation, reclamation or restoration of plant communities. VegSpec is a World Wide Web-based expert system developed to help land managers in selecting and planning revegetation projects. Using a series of species selection rules relating to the climate, soils, and specific uses, the VegSpec program queries three databases to match adapted plants with the specific site conditions. The three databases are: (1) the NRCS currently published soil surveys for all 50 states; (2) long-term monthly temperature and precipitation data for selected climatological stations in each of the 50 states; (3) a plant database of more than 2000 species with more than 70 fields of growth and adaptation characteristics for each plant. The VegSpec user is asked a series of questions related to soil mapping unit, and the climatological station that best describe the site. After describing the site, the user selects a series of objectives for revegetation, such as rangeland plantings, forest products, erosion control, filter strips, landscaping, windbreaks, or pasture lands. Each objective has rules associated with it that select plants that meet those criteria. Thus, the user is provided with a list of potential plants that will establish, grow, and withstand the conditions and uses of that site. After species selection, the user is prompted to construct the planting design. VegSpec provides a programmed spreadsheet for calculating seeding and planting designs. When completed, the user may print a report describing the site and the selection process. VegSpec is reached through a link at the address http://plants.usda.gov. During 1999, VegSpec 3.0 was released. This version defaults the user to a site-specific recommendation of plants that will not allow the user to continue past the site description page until all required data are provided. Also, expert system rules were installed that provide a series of warnings to the user about the plants or the selected techniques. The planting calculation and windbreak planting tools are now operational. The validation of VegSpec continues. Data from 30 randomly selected sites within Major Land Resource Areas in 6 western states are collected from the NRCS Ecological Site Information System (ESIS) database. Each site's soil and climate information are used as inputs into VegSpec. The ESIS plant list is compared with the list of recommended plants provided by VegSpec when site information for each site are used as input information in VegSpec. VegSpec correctly selects about 60 % of the ESIS list of plants at a given site. We are using list of plants that VegSpec incorrectly matched to determine if VegSpec rules or plant data need adjusting. This validation will be completed in the current year.

4. Risk and establishment of *Taeniatherum caput-medusae* with management applications (Michelle Stubbs, Department of Forest Science, Oregon State University, and David A. Pyke, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, OR)

This project is nearing completion. The following provides an overview of the findings of this project. The spatial and temporal heterogeneity of available nitrogen are critical determinants of the distribution and abundance of flora and fauna in ecosystems. Evidence for the resource island theory suggests that soils in the vicinity of tree and shrub canopies contain higher amounts of resources, including nitrogen, than are present in interspace areas. Disturbances, such as prescribed fire and cutting of woody plants, are common management practices in juniper sagebrush ecosystems, but it is not known if they affect resource islands. From August 1997 to October 1998, available soil nitrogen was measured regularly across months from canopy and interspace plots within four juniper-sagebrush sites along a precipitation gradient in central Oregon, USA. At each site, soil cores were collected from untreated plots as well as plots in which woody plants were removed by cutting or prescribed fire in fall 1997. Untreated areas had higher nitrate (NO3) and ammonium (NH4) concentrations under juniper canopies for nearly all months. Wetter sites showed less of an effect through time than did the two drier sites. Nitrate and ammonium concentrations in canopy plots were elevated following fire for four months and remained significantly higher than interspace plots for the duration of the study. Woody plant removal did not affect relative differences in nitrogen concentrations of canopy and interspace plots. In relation to inorganic nitrogen, resource islands appear to be dynamic in this ecosystem, tending to be more ephemeral in wetter sites, and demonstrating greater stability following fire disturbances. The second component of this project examined the risk of medusahead establishment under a series of management actions. Managers seeking to reclaim and restore grassland communities in semi-arid ecosystems often use prescribed fire or overstory cutting to reduce the density and spread of woody species such as Artemisia tridentata and Juniperus occidentalis. The effect of these practices on the risk of weed invasion and spread is poorly understood. To assess the invasion potential of a particularly noxious weed, Taeniatherum caput-medusae (medusahead), we conducted field studies and developed a stage-structured model in relation to prescribed fire and overstory cutting. In addition, we examined canopy and interspace microsites that differ in nutrient availability affects on the invasion potential of medusahead. Studies were conducted at four disjunct sites along a precipitation gradient in western juniper-basin-big sagebrush ecosystems of central Oregon, USA. Prescribed fire caused a high risk of medusahead invasion regardless of spatial location and year, whereas removal of juniper did not increase the risk of medusahead invasion above that of untreated areas and did not contribute significantly to higher population growth. Seedbanks were very small or non-existent for medusahead.

5. Idaho habitat change: Geographic information system formatting of ecological data from the Shoshone Resource Area, Bureau of Land Management, southern Idaho (Steve J. Popovich and David A. Pyke, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, OR)

All data received from the BLM Shoshone District has been cleaned, metadata were created, and the cleaned data and metadata transferred to the BLM. The first set is a long list of

GIS layers that were essentially converted from their MOSS formats to Arc/Info format. No attributes were added - just a conversion. The second set of layers was the fire data. The polygons were converted from MOSS, linked to the attribute data and organized into fire episodes. The point data were developed by establishing their locations in real-world coordinates based on the legal description of each fire. They were also linked to attribute data. Included in the second set are data layers developed by Gordon from existing data BLM data - Locations of Grasshopper Monitoring Plots and a Land Treatments data layer (these did not exist in MOSS as data layers). These layers are listed as: (1) Fire_Master - ArcView shapefile of fire polygons from 1956-1998 including extensive attributes on fire frequency; (2) Fire_Points - ArcView shapefiles of point locations of all fires from 1941 to 1955 and all class D and smaller fires from 1956-1998; (3) Grasshopper_Plots - Plot locations of grasshopper monitoring sites from 1988-1995; (4) Land_Treatment - Arc/Info region coverage of land treatment activities from 1944-1993. Preliminary findings indicate that 1370 fires occurred in the district from 1956 to 1998. These fires create 3960 unique fire polygons of fire frequencies from 1 to 9. Most of the burned locations (1583) have only burned once. There is one 7 ac area that has burn 9 times in the 43 years of study. A model to create a fire polygon that estimates fire locations for fires where we only have point locations was attempted. The fire shapes are irregular. The direction of the larger fires is generally east of the point of ignition. We took the 45 G-class (> 5000 ac), 119 F-class (1000<5000ac) and 183-E-class (300<1000 ac) fires and were able to place a burn probability surface around each class of fire. The shape of the G-class fires tends more toward an ellipse with the point of ignition near the western focal point, whereas the E-class fires begin to approach a more circular shape. We were not able to create geometric shapes to represent these fires. The final report of this project is being prepared.

6. Evaluating emergency wildfire rehabilitation efforts and monitoring methodologies of sagebrush steppe ecosystems on BLM Land, southern Idaho (Steve J. Popovich and David A. Pyke, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, OR)

Data entry was completed, but few analyses were completed before funding was exhausted for this project. Metadata for these data were completed. Data entry allowed us the first opportunity to examine these monitoring plots for potential analysis. Although data may have usefulness in evaluating appropriate plot sizes and numbers for use in future monitoring studies, the lack of replication at sites and the confounding of treatments at various sites make it impossible to provide anything more than simple statistics for the separate treatments. Spreadsheet files for each treatment will be provided to the BLM along with a final report that will include some of the simple statistics regarding these studies.

7. Fire History in the Intermountain Sagebrush Steppe (Richard F. Miller, Department of Rangeland Resources, Oregon State University, Burns, OR)

The first year of sample collection and measurements was completed. Currently eight locations across southeast and central Oregon, and northeast California were sampled. A number of other sites have been searched for potential fire history sampling, of which two more sites, Dry Mt and Silver Lake area, will be sampled during the year 2000. A total of 37 samples have been collected and prepared for cross dating. Sixteen of these samples representing nine sites have been cross-dated. Incomplete results of fire return intervals and length of the fire period are

reported in Table 2. Mean fire return intervals across nine sites (7 locations) vary between 12 to 20 years for mountain big sagebrush communities. Earliest cross-dated fire scares date back to 1656. Age structure and presettlement dynamics in aspen stands have been summarized and currently in the peer review process. Over 85 % of nearly 100 aspen stands measured throughout southeast Oregon, northeast California, and northwest Nevada were over 90 years old. Pre-1900 mean disturbance intervals occurring within two large aspen stands located on Steens Mountain and Fish Creek Rim, was 10 to 12 years, with replacement of the entire stand occurring approximately every 60 years.

8. 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).

The main task for 1999 was planning and preparation for the first field season, which is scheduled to begin in April 2000. This consisted of a meeting in Moab UT of the participants from the two regions involved (northwest Great Basin based in Corvallis OR and Columbia Plateau based in Moab), and field trips to find suitable sites for the project. Because the project involves contrasting ecological regions and multidisciplinary field measurements and lab analyses, planning sessions dealt with refinement of field and laboratory protocols, discussion of regional conditions, definition of optimum field sampling seasons for each region, and formulation of working strategies for field crews. The process began by consulting with BLM and NRCS staff in each area in order to obtain suggestions for sites based on their first-hand experience with the area, and to assemble a library of maps and soils information. Preliminary site selection was aided at some BLM offices by using layers of pertinent GIS data. Sites on the preliminary list were inspected in the field, resulting in a final list of seven suitable sites in each region. Given our requirements of avoiding overlapping piospheres, staying on relatively homogeneous terrain and soils, and avoiding sites that had been sprayed, burned, or reseeded, suitable sites were less numerous than anyone had expected. Minor deviations from the original site plan may be made at some locations in order to accommodate the variability of terrain, soils, and human manipulations encountered. Sampling is planned in the first year on six sites per region, so we have an extra site in each region as insurance against unforeseen problems. A trial run of field protocols was conducted in autumn 1999 at a field site south of Moab. The trial run allowed us to test the feasibility and duration of the planned measurements. It was determined that sampling at each site could be completed by a team of four persons in five days. The double-sampling technique originally planned for biomass estimation was replaced by a procedure involving weighing samples in the field and retaining a subsample of each vegetation type for moisture content determination. It was also decided to observe selected soil morphological features at each of the five locations in each site to verify accuracy of the published soil surveys. Based on the sampling time for each site and consideration of regional climates and plant phenology, we decided to employ two separate field crews. The Colorado Plateau crew will begin field work in mid-April; the northern Great Basin crew will spend a training week with the Colorado Plateau crew in early May and then travel north to begin sampling in mid-May. Field crews also were employed throughout fall 1999 to develop, test and verify various soil sampling methods. At each of these sites, the following methods were tested: (1) Soil surface shear strength using a Torvane shearmeter; (2) Soil stability using the slake test. A new slake kit based on specifications provided by J. Herrick (USDA-ARS) was field tested; (3) Relative infiltration capacity using unconfined single-ring infiltrometer; (4) Soil compaction

using an impact penetrometer; (5) Bulk density using corers made of various materials at the different sites. For the grasshopper component, we tested three methods, flush counts, transects, and night cages for estimating grasshopper density. It is difficult to know which method actually produces the more accurate estimate, but since flush counts more closely matched night cage estimates and transects tended to be more variable, flush counts will be used in the future. Species composition of grasshopper communities and relative abundance of each species in the community must also be estimated. A grasshopper relévé technique was compared to the night cage data for species composition. Dominant species were estimated similarly by both techniques. Each technique detected different rare species. Relévés appear to describe the community structure of most grasshopper communities except for some rare species, and will continue to be used, although the number of grasshoppers captured, and the area searched will be increased to try to detect all species in the community. A grasshopper consumption trial was conducted from 27 July to 1 October 1999 in a Stipa comata/Bouteloua gracilis grassland, but failed. Future consumption experiments will use smaller plots, shorter time periods, and higher grasshopper densities.

PLANNED OR POTENTIAL PROJECTS

None

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UTAH

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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 1999. Projects range from basic studies of physiology, ecology, and genetics to applied revegetation trials and weed control procedures.

ONGOING PROJECTS

1. Seed Fate of Native Grasses (Bruce A. Roundy and Carl Adams, Brigham Young University, Provo, UT 84602 and Laurie Abbott, School of Renewable Natural Resources, Univ. of Arizona, Tucson, AZ 85721).

The objective of this study is to model warm- season grass seedling establishment in relation to temperature and available water and to determine why exotic Lehmann lovegrass establishes more successfully than native grasses. Publications on seedling demography and root growth, and on seed fate are currently being prepared.

2. Role of Seedbanks in the Management of Semiarid Rangelands Under Grazing (Jaime Kigel, Hebrew University of Jerusalem, P.O. Box 12, Rehovot, Israel, Avi Perevolotsky, Volcani Center, Bet-Dagan, Israel, Bruce A. Roundy, Phil Allen (Brigham Young University, Provo, UT, 84602, and Susan Meyer, U.S. Forest Service Shrub Lab, Provo, UT, 84401).

The objective of this study is to determine the effects of grazing, topography, and soil moisture and temperature on annual plant germination and emergence in the northern Negev Desert. Funding was secured for another 2 years of research which will include determination of germination behavior of 15 dominant annual species. The afterripening of four annual grass species fit well a hydrothermal time model developed from cheatgrass data. Greenhouse experiments instrumented for moisture and temperature measurement are proceeding to compare germination predicted by the model and actual emergence of seeds with different periods of afterripening.

3. 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.

4. Ecology and Restoration of Cheatgrass Dominated Sites (Stephen B. Monsen, 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 promising native grass source identified selections, effects of row spacing, configuration and rate of seeding on cheatgrass suppression, and rearing techniques to increase efficiency of native seed production. Studies testing the fuel and fire characteristics of different species and green-strip configurations are being conducted in Utah and Idaho. Effects of the nonselective herbicide Oust on reduction of cheatgrass in native grass stands is being tested. Large- scale seed production is being developed for about a dozen forbs which hold promise for revegetation in the Great Basin.

5. Secondary Succession of Montane and Subalpine Vegetation on the Wasatch Plateau (Stephen B. Monsen, 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.

6. 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. Five-year old seed successfully emerged in field studies. Seeds harvested in November and seeded the following June and December in cheatgrass burned and unburned areas germinated, but did not establish. Greenhouse experiments are being initiated to determine the effects of damping-off organisms on seedling mortality. A thermal time model has been successful in predicting changes in the chill response of afterripened seed.

7. 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 patterns of blackbrush. Data on home ranges and caching behavior are being collected.

8. 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. Successful prediction depends on accurate measurement of moisture and temperature in the seed zone. Soil moisture sensor response and accuracy are being compared. Future work will try to compare modeled and measured seedbed moisture and temperature.

9. Genetics of Seed Germination Regulation (Susan Meyer, U.S. Forest Service Shrub Lab, Provo, UT, 84401)

This study is determining the effects of the pollen parent for bitterbrush, and the population parent for cheatgrass on seed germination in relation to temperature.

10. Effects of Achene Weight of Rubber Rabbitbrush on Establishment (Susan Meyer, U.S. Forest Service Shrub Lab, Provo, UT, 84401)

Achene weights of rubber rabbitbrush subspecies vary by nine fold. Larger achenes are associated with harsher environments and their seedlings have a slower growth rate than those from moderate environments. Dispersal of larger and heavier seeds is facilitated by a correspondingly large pappus.

11. 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.

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

Requirements for germination are currently being tested for species *Castilleja*.

13. The Relationship of *Atriplex* Genetics to Reclamation Success (Howard Stutz, retired Brigham Young University, Provo, UT 84602)

Various long-term studies are in progress in conjunction with Broken Hills Products in the four corners area to determine the benefits of *Atriplex* heterozygosity on reclamation success.

14. Enhancing Native Seed Production and Purity (Bruce Welch, U.S. Forest Service Shrub Lab, Provo, UT, 84401)

Experiments determining the most efficient production and cleaning methods of native seed are in progress.

15. 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. 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.

16. Effectiveness of Anchor Chaining and Revegetation Practices on Plant Communities After Wildfire in Utah (E.Durant McArthur, U.S. Forest Service Shrub Lab, Provo, UT 84401, Jeff Ott, and Bruce A. Roundy, Brigham Young University, Provo, UT 84602)

Paired plots were read to evaluate the effects of drilling, aerial seeding, and subsequent chaining or lack of chaining on 7 study sites burned by wildfire in the summer of 1996 in Utah. Chaining resulted in higher establishment of seeded species and less cheatgrass than aerial seeding alone. Revegetation success varied with soils and topography within and among study sites. Data analysis and thesis publication are planned for this year.

17. 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.

18. 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 'Oust' herbicide 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. Various theses and manuscripts are in preparation.

19. Dark Respiration Measured From Microcalorimetry as an Indicator of Plant Adaptation to Temperature and Water Stress (Bruce N. Smith and Lee Hansen, Brigham Young University, Provo, UT 84602)

Collections of native plants from different populations are being measured for dark respiration rates. This technique has promise in predicting adaptive potential of specific ecotypes.

20. Control of Squarrose Knapweed (Pat Fosse, Bureau of Land Management, Philmore, Utah, Steve Monsen, U.S. Forest Service Shrub Lab, Provo, UT 84401, and Scott Walker, Utah Division of Wildlife Resources, Ephraim, Utah)

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.

21. 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. Establishment, soil cover, and soil erosion effects of the different seed mixes will initially be compared over a 3-year period.

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UTAH

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INTRODUCTION

This report summarizes land rehabilitation and related research at Utah State University from June 1999 through April 2000. Research is conducted through the Department of Rangeland Resources, the Watershed Science Unit, and the USDA-ARS Forage and Range Research Laboratory.

NEW PROJECTS

No new projects this year.

ONGOING PROJECTS

1. Spatial and Temporal Heterogeneity of Resource Availability in the Sagebrush-Steppe (M.M. Caldwell, Department of Rangeland Resources)

The objectives of this long-term research are to: 1) characterize resource heterogeneity in space (patches) and time (pulses) at scales of days to weeks and decimeters to meters above and below ground; 2) assess plant perception of resource availability (in space and time) including foliage and root characteristics, acquisition of resources, competition with other plants and microbes for resources and translation of resources gleaned from patches and pulses into fitness and seedling recruitment; 3) assess plant response to incongruity of resources and factors that might smooth heterogeneity (mycorrhizae and water efflux from roots); and 4) develop simulation models, based in part on ecological field theory and kriging interpolation, to assess the significance of heterogeneity.

2. Pulsing of plant-available moisture and nitrogen in Great Basin communities: interactions of microbial processes, root depth distributions and hydraulic lift (M.M. Caldwell, Department of Rangeland Resources; L.E. Hipps and D. Or, Department of Plants, Soils and Biometeorology; J.M. Stark, Department of Biology; C. M. Neale, Department of Biology and Irrigation Engineering)

This study brings expertise in ecophysiology, soil microbiology, soil physics, root biology, biometeorology, simulation modeling and remote sensing to bear on how plants of different life form (ranging from annual grasses to trees) and soil microbes react to and influence

moisture and nitrogen (N) pulses in a Great Basin ecosystem. Seventeen hypotheses are addressed on the general themes: 1) how timing of growth and reproduction of different plant life forms coincide with intermittent supplies of nitrogen and water at different soil depths; 2) how microbes mediate the N supply and are affected by changing carbon supply and abiotic conditions; and 3) how effectively different life forms translate this resource capture into seasonal carbon gain.

3. Seed Dispersal by Domestic Livestock: Application for Rangeland Revegetation (C.A. Call, Department of Rangeland Resources)

The objectives of this project are to: 1) determine the validity of using in vitro analysis as a screening tool for the selection of various grass, forb, and shrub species that can survive passage through the ruminant and nonruminant digestive tracts; 2) investigate the influence of seed size and shape, and seed coat thickness on the passage of viable/germinable seed through the ruminant and nonruminant digestive tracts; and 3) relate fecal material micoenvironmental factors to germination and seedling establishment under field conditions.

4. Potential for Bank Stability Decline Due to Drastic Flow Level Change in the Bear River (J.P. Dobrowolski, Department of Rangeland Resources and Watershed Science Unit)

Research will determine the stability of selected banks of the Bear River in relation to the different conditions during the rising and falling of a ramping event. Changes of bank strength conditions and occurrence of different types of instability will be examined on the basis of physical property change in the near bank environment.

5. Watershed-Scale Research in the Pinyon-Juniper Ecosystem (J.P. Dobrowolski Department of Rangeland Resources and Watershed Science Unit)

A long-term, watershed-scale study will perform mechanistic research in pinyon-juniper ecosystem dynamics, e.g. energy flow, water and nutrient cycling, organismal structure and function at relevant scales, sediment source/sink relationships, while simultaneously addressing the more pragmatic concerns associated with management by objectives, the effects of drastic disturbance, or the result of custodial management. This interdisciplinary research effort will involve investigators from across the USU campus, and will be coordinated with other regional studies at Los Alamos National Laboratory, Oregon State University, and the University of Nevada, Reno.

6. Range Grass Breeding (K.B. Jensen, and T.A. Jones, USDA-ARS Forage and Range Research Laboratory)

Long-term research goals have focused on the development of improved germplasm and cultivars of selected species and interspecific hybrids of introduced plant materials (*Agropyron*, *Glymus*, *Elytrigia*, *Pascopyron*, and *Pseudoroegneria*) and native plant materials [Great Basin wildrye (*Leymus cinereus*), Indian ricegrass (*Oryzopsis hymenoides*)], and blue bunch wheatgrass (*Pseudoroegneria spicata*) for range revegetation programs. Research has also focused on the development of efficient methods of stabilizing and manipulating interspecific

hybrid populations for use in breeding programs and the evaluation of new plant materials in terms of establishment and persistence.

7. Range Forage Physiology (D.A. Johnson, USDA-ARS Forage and Range Research Laboratory)

The objectives of this long-term project are to: 1) define the physiological basis of plant resistance to environmental and biological stresses; 2) develop practical selection techniques and indices for screening grass and legume populations; 3) determine nodulation and N-fixing capabilities of promising range legumes and determine the effects of environmental stress on these processes; 4) expand the genetic resources of perennial forage species in the National Plant Germplasm System through plant exploration.

8. Integration of upland, riparian and and stream condition monitoring for intermediately sized watersheds on rangelands (G.A. Rasmussen and J.P. Dobrowolski, Department of Rangeland Resources)

This two-year study 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 km^2). 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.

9. Use of green strips to manage wildland fires in the Intermountain West (G.A. Rasmussen and C.A. Call, Department of Rangeland Resources)

Research will: 1) determine the plant species acceptable for use as green strips to help manage wildland fires, and 2) establish the appropriate management strategies needed to maintain the effectiveness of green strips.

10. Competition from native grasses for restoration of cheatgrass-infested range (E.W. Schupp, Department of Rangeland Resources)

The overall goal of this research is to develop a method to restore productivity to degraded weed-infested rangelands using native disturbance-adapted species to suppress weeds and promote succession to native rangeland. The objective of the present study is to experimentally quantify competitive relationships among the exotic weed cheatgrass, the disturbance-adapted native grass bottlebrush squirreltail, and the desirable long-lived native bluebunch wheatgrass during plant establishment.

11. Effects of woody vegetation on plant recruitment in Utah rangelands (E.W. Schupp, Department of Rangeland Resources)

Objectives at this stage are to experimentally evaluate the hypothesis that the net effect of the interaction between nurse plants and juniper recruitment shifts across a gradient of physical stress, with a stronger net facilitative effect in more stressful environments. In addition, whether population-level juniper seed source influences the outcome of the interaction and test the hypothesis that in the same environment, the balance between facilitation and interference varies among potential nurse plants, with some plants having a net facilitative effect on juniper recruitment and others a net interference effect. Research will investigate the hypothesis that in the same environment and with the same suite of potential nurse plants, the balance between facilitation and interference varies between different species of recruits (juniper vs. ephedra), and whether maternal-level ephedra seeds source influences the outcome of the interaction.

12. Seed and Seedling Ecology of Utah Juniper (E.W. Schupp, Department of Rangeland Resources)

Several experiments have been designed to: 1) quantify flower and fruit production, and fruit availability for seed dispersal; 2) determine the identity of the seed disperser assemblage; 3) estimate the spatial pattern of seed dispersal; 4) quantify the extent and pattern of post dispersal seed predation; and 5) quantify germination, seedling establishment, and early growth and survival of Utah juniper (*Juniperus osteosperma*).

13. Seed Accumulation and Natural Regeneration Across a Juniper Invasion Front (E.W. Schupp, Department of Rangeland Resources)

Research will: 1) quantify patterns of seed movement (with pitfall traps) and seed accumulation (with soil cores for seedbank analysis) with respect to microhabitats across an invasion front from the interior of a juniper (*Juniperus osteosperma*) woodland, through the edge, and into adjacent sagebrush (*Artemisia tridentata*) grassland; and 2) quantify natural patterns of seedling recruitment in the same microhabitats.

14. Postfire Restoration for Ecosystem Management at Arid Installations (E.W. Schupp, Department of Rangeland Resources)

This research at Dugway Proving Grounds in west-central Utah has the following objectives: 1) screen native grass species for potential use in revegetation of burned areas; and 2) collect data on the ability of bottlebrush squirreltail (*Sitanion hysterix*) to compete with cheatgrass (*Bromus tectorum*).

15. Bottlebrush squirreltail competition with cheatgrass: Implications for restoration of native rangelands (E.W. Schupp, Department of Rangeland Resources)

Research efforts are underway to collect preliminary data that will form the foundation of a larger study with the overall objective of developing an ecologically-based method for restoring degraded rangelands with native species where appropriate. Specific objectives include: 1) assess the ability of squirreltail (*Sitanion hystrix* syn. *Elymus elymoides*) to establish in high- and low-density stands of cheatgrass; and 2) assess the ability of squirreltail to suppress growth and seed production of cheatgrass (*Bromus tectorum*).

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WYOMING

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INTRODUCTION

This report summarizes the revegetation, seed physiology, seedbed ecology, and general reclamation research of the Rangeland Resources Research Unit at Cheyenne, Wyoming and Fort Collins, Colorado. Portions of this research are cooperative with the University of Wyoming, Department of Renewable Resources; Colorado State University, Department of Rangeland Ecosystem Sciences; the University of Saskatchewan; Agriculture and Agri-Food Canada; and the mining industry. Partial funding for portions of this research comes from the Wyoming Abandoned Coal Mine Land Research Program, University of Wyoming, Wyoming Wildlife Habitat Trust Fund, and the Abandoned Mine Land Program, Wyoming Department of Environmental Quality.

COMPLETED RESEARCH

1. Evaluation of reclamation methods used to ameliorate soil sodicity and enhance revegetation of reclaimed bentonite mine lands (G.E. Schuman, G.F. Vance, K.D. Edinger, and L. King; USDA, ARS, High Plains Grasslands Research Station, Cheyenne, WY, Department of Renewable Resources, University of Wyoming, Laramie, WY and Wyo-Ben Inc., Greybull, WY).

Evaluation of 10-12 year old reclaimed bentonite mined lands revegetated under the Abandoned Mine Land Program revealed that 90-95% of the abandoned bentonite lands that were reclaimed using wood residue and gypsum amendments to ameliorate the high clay content and sodicity were successful. Only small areas (0.1-0.2 ha) showed sign of no vegetation establishment or die-back after original vegetation establishment. Spoil evaluations showed that the areas where revegetation was not successful or where vegetation was dying the spoils were very sodic and had very low concentrations of exchangeable and soluble calcium. After thoroughly evaluating several bentonite reclamation sites in two geographic areas of Wyoming we concluded that the original sampling protocol used to determine amendment (wood residue and gypsum) rates were probably inadequate and field contract oversight needed improvement. Recommendations coming from this research were that spoil sample frequency should be increased 50% and that compositing should be limited to achieve 3 spoils samples from each treatment area (0.8 ha) rather than a single composite sample. This protocol has been adopted by the Wyoming Abandoned Mine Land Program for reclamation of abandoned bentonite mined lands.

2. Sagebrush seed production on mined land compared to adjacent unmined land (D.T. Booth, Y. Bai, and E.E. Roos; USDA, ARS, High Plains Grasslands Research Station, Cheyenne, WY and Agriculture and Agri-Food Canada)

Wyoming Coal Rules and Regulations require shrubs be returned to mined land and the revegetation be "self renewing." We evaluated the self-renewing potential of sagebrush [*Artemisia tridentata* Nutt. ssp. *wyomingensis* (Beetle & Young)] by measuring the effect of mining, big game herbivory, and environmental modification on seed production at 5 sites on the Dave Johnston Coal Mine near Glenrock, WY. Mined-land stands ranged in age from 5 to >20 yr. Single sagebrush plants on mined and adjacent unmined land were given environment-modifying treatments: (1) fabric mulch around the sagebrush plant base, (2) windbreak on the north and west, (3) both fabric mulch and windbreak and (4) no treatment. Plants were fenced and compared with unfenced, untreated, neighboring plants. Seeds were harvested each fall for 3 years and data collected on seed-stalk numbers, bulk weight of seeds produced , and seed quality parameters. The experimental design was a split-plot and the statistical analysis use the "Mixed" procedure in SAS. We found fenced mined-land plants produced greater amounts of seed compared to all other combinations of land and fence. The difference was significant all 3 years of the study. Plant environmental modification resulted in greater seed production on some plants in some years. We concluded that sagebrush seed-production potential on mined lands such as these is equal to and often several time greater than that of adjacent unmined lands. However, browsing by wild ungulates can eliminate the mined-land advantage observed.

ONGOING RESEARCH

1. Grass competition and sagebrush seeding rates: Influence on sagebrush seedling establishment (G.E. Schuman, M.I. Fortier A.L. Hild; USDA, ARS, High Plains Grasslands Research Station, Cheyenne, WY and Department of Renewable Resources, University of Wyoming, Laramie, WY)

This study examines effects of grass competition and sagebrush seeding rate on establishment of big sagebrush seedlings at the Belle Ayr Coal Mine near Gillette, WY. Experimental plots seeded at three Wyoming big sagebrush rates **(**1, 2, and 4 kg PLS/ha) and seven rates of a grass mixture (0, 2, 4, 6, 8, 10, and 14 kg PLS/ha) were used to assess effects of sagebrush seeding rate and grass competition on sagebrush seedling density and survival. Data from four sagebrush seedling counts in 1999 (June 30, August 3, August 31, and October 25) show a decline in sagebrush seedlings at the higher grass seeding rates, although the differences were not statistically significant. The lack of significant differences was attributed to the above normal precipitation received in the spring and early summer 1999. However, sagebrush seedling density was greater for the 4 kg/ha than the 2 and 1 kg/ha sagebrush seeding rates. Mean seedling density on the June 30 differed among all three sagebrush seeding rates whereas the August and October densities were similar for the 1 and 2 kg/ha seeding rate. We anticipate that a more normal precipitation year in 2000 will result in moisture competition between the grass seeding rates and sagebrush establishment and will be reflected in the sagebrush seedling density that is able to be maintained over the long-term.

2. Designs for sagebrush habitat on Wyoming coal mined lands (D.T. Booth and S.H. Anderson, USDA, ARS, High Plains Grasslands Research Station, Cheyenne, WY and Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, WY).

Four shrub-establishment treatments are being compared at the Buckskin and Jacobs Ranch Mines in Wyoming's Powder River Basin. The treatments are (1)standard method (SM), in which the mined used standard shrub establishment methods for meeting the Wyoming shrub density requirement; (2)standard method plus snowfence (SM+SF), which is the same as #1 except that temporary snowfences were erected on the seeded area; (3) parallel-belt design, which consists of 3 belts of fabric mulch, spaced 49 m (Buckskin Mine) or 24 m (Jacobs Ranch Mine) apart, arranged perpendicular to prevailing winds, and planted with 2 rows of sagebrush; and (4) underlined V design, which is similar to #3 except that 1 belt of fabric mulch is perpendicular to the wind and the other belts are at 60 and 120^{o} to the first belt. The plots were seeded the fall of 1997 and big game exclosures were erected around 1 replication at each mine in 1998. All sagebrush seedings failed and the SM plots were reseeded in March 1999. Seed spots in fabric mulch treatments were replanted with 3400 two- and three-week-old, greenhouse-grown sagebrush seedlings produced in 1.3 x 13 cm "Booth Tubes" from Western Polyacrylamide, Inc. Installation of the Booth-Tube transplants was accomplished in 7 hr (on-site plant time) by a 3-person crew. Transplant survival was 52 and 74%, and seedling heights averaged 42 and 92 mm at the Buckskin and Jacobs Ranch mines, respectively. Seedling densities in the SM and SM+SF plots were 0.5 and 4.5, 1.3 and 2.5 seedlings/m^2 at the Buckskin and Jacobs Ranch Mines, respectively. Height of these seedlings ranged from 16 to 35 mm.

PLANNED PROJECTS

1. Relationship between soil organic matter content and sustainable nutrient cycling in reclaimed soils (P.D. Stahl, G.E. Schuman, and L.K. Spackman; Department of Renewable Resources, University of Wyoming, Laramie, USDA, ARS, High Plains Grasslands Research Station, Cheyenne, WY, Department of Environmental Quality, Land Quality Division, Cheyenne, WY)

Impacts of surface mining on soil often include a reduction in soil organic matter (SOM) content as well as in microbial biomass and activity. Soil organic matter and soil microorganisms are critical components of the plant-soil systems due to its role in nutrient cycling, plant nutrition and soil stability. Relationships between SOM levels, microorganisms, and nutrient cycling in reclaimed mine lands, however, are poorly understood by critical to accurate assessment of reclamation success. This research is designed to examine the relationship between SOM, sustainable nutrient cycling and reclamation success. In addition, we will test a promising new technique that may provide a simple, economical and reliable indicator of a soil's or "substitute plant growth medium's" ability to sustain nutrient cycling. The relationship of SOM levels to sustainable nutrient cycling will be examined by correlating levels of SOM in reclaimed mine land soils to standard assays used in the direct analyses of nutrient cycling and to methods for assessment of revegetation success. Data obtained from this work will enhance the ability of the mining industry and regulatory agencies to develop guidelines for plant growth media selection that will ensure long-term sustainability of reclaimed ecosystems

without inputs of fertilizer and/or other amendments. This research is funded by the Wyoming Abandoned Coal Mine Land Research Program and will be initiated summer 2000.

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WYOMING

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INTRODUCTION

This report summarizes 1999 revegetation and stabilization of disturbed land research activities conducted primarily within Wyoming, with an emphasis on activities of the Department of Renewable Natural Resources personnel at the University of Wyoming. The projects listed below were funded by federal, state and private industry, including the Abandoned Coal Mine Land Research Program (ACMLRP) at the University of Wyoming. The ACMLRP support is administered by the Land Quality Division of the Wyoming Department of Environmental Quality from funds returned to Wyoming from the Office of Surface Mining of the U.S. Department of the Interior.

COMPLETED PROJECTS

1. Climatic Control of Sagebrush Survival for Mined-land Reclamation (B.L. Perryman, R.A. Olson, Ann L. Hild, and A.A. Maier)

The objective of this project was to determine if successful recruitment of the three subspecies of *Artemisia tridentata* Nutt. (*wyomingensis, vaseyana, tridentata*) are climatically controlled in native, undisturbed populations. Dendrochronologic methods were used to determine establishment years for approximately 2200 individual plants. Logistic regression models including mean monthly temperature and monthly precipitation variables for the year prior to, year of, and year after establishment, and the 5 highest recruitment years and 5 random years with no recruitment were constructed at 3 geographic scales (stand, regional stand combination, and statewide) for each subspecies. Results indicate that above normal precipitation during the winter after establishment was critical for high levels of Wyoming sagebrush recruitment. Mountain sagebrush recruitment was most successful when spring precipitation was below normal during the germination and early establishment period, and basin sagebrush was most successful when precipitation was above normal during the first and second growing seasons. Specific amounts of precipitation were not determined since logistic regression requires categorical data. However, reclamation specialists can now perform cultural practices that mimic a known, target set of climatic conditions responsible for high levels of recruitment in native undisturbed areas.

2. Long-term Reestablishment of Arbuscular Mycorrhizal Fungi in a Drastically Disturbed Semi-arid Surface Mine Soil (S.M. Frost, P.D. Stahl and S.E. Williams)

Reestablishment of arbuscular mycorrhizal (AM fungi in severely disturbed soil on a surface mine reclamation site inoculated with native endophytes in 1983 was examined in 1997. At the time (1983) research had been initiated on a newly reclaimed site to test the hypothesis that native AM fungi would form effective mycorrhizae and would improve growth of Wyoming big sagebrush (Artemisia tridentata wyomingensis) in severely disturbed reclamation soil. Data collected during 1984 and 1985 did not support that hypothesis and it was concluded that native AM fungi inoculated onto the site were not tolerant of the altered soil environmental conditions in the reclamation soil.

Reexamination of the site in 1997 indicated that soil environmental conditions were becoming more similar to those before disturbance and AM fungi populations were recovering. Soil analyses in 1997 show an approximate 1% increase in soil organic matter content, improvement in soil structure compared to 1983 and decreases in amounts of soluble salts and Na. Mycorrhizal inoculum potential of the disturbed soil and levels of mycorrhizae formation on sagebush roots on the site were much greater in 1997 than in 1985. Also, AM fungal spore density in 1997 was not significantly different in reclamation soil than density in adjacent undisturbed soil. These observations were interpreted as evidence that populations of AM fungi on the site are recovering and becoming more active as soil environmental conditions ameliorate.

3. Remediation and Waste Reduction of Environmentally Sensitive Materials: Rhizosphere Microorganisms and Phytoremediation (P. D. Stahl and S. E. Williams)

A central problem in bioremediation and phytoremediation technology is that it is highly dependent on poorly understood microbial processes and interactions among plants and microorganisms. A lack of knowledge exists regarding the functioning of complex microbial communities in undisturbed and contaminated environments and their interactions with plants which play a vital role in uptake of materials from soil. Our recent work has shown that microbial communities in the rhizosphere of plants growing in copper contaminated soil produce less biomass and are structurally different than those in nearby uncontaminated soil. Investigations we have conducted on occurrence and activity of arbuscular mycorrhizal fungi in metal contaminated soils show significantly smaller populations of these fungi and greatly reduced levels of mycorrhizal formation in contaminated soils compared to nearby undisturbed soil. We propose to conduct field experiments to test the hypothesis that rhizosphere microbial communities associated with plants growing in metal contaminated soil can be manipulated to increase removal of the metal contaminant. Our objectives include: 1) Development of methods to increase biomass production of rhizosphere microbial communities in metal contaminated soil in the field; 2) Determine whether increased rhizosphere microbial community biomass results in an increase in plant metal removal from soil. This research will result in development of inocula of metal tolerant rhizosphere organisms that may enhance plant growth and target metal uptake in contaminated soil.

4. Environmental Selenium Relationships at Fort Carson, Colorado (G.F. Vance, C.P. Skinner and B.K. Schladweiler)

Combination of soils, geology and vegetation contained within 43 descriptive units indicated sites with seleniferous vegetation (Se levels > 5 mg/kg) were located in reclaimed areas

and both native and wetland environments. Projected areas where potential seleniferous vegetation may occur were displayed on different GIS data layers. A soil/geology GIS data layer that represented potential seleniferous areas suggested additional polygons may be conducive to production of seleniferous vegetation. The suitability criteria value for phosphate-extractable soil selenium (Se) that was used in this study was greater than 0.5 mg Se/kg soil. Sites with soils from one or more of the depths sampled (0-25, 26-50,51-75, 76-100 cm) that had extractable Se levels above the suitability criteria were identified. Extrapolated sites with potentially high Se levels within the same descriptive units throughout Fort Carson were also determined.

Because soil series and geological formations were consolidated, it would be useful to dissect the areas within the potentially seleniferous areas to determine if unique soil or geological features are present. Additional studies should be conducted to determine if geology, hydrology, soil type, or other environmental factors are the reason why discrepancies exist in the projected areas. Several of the forbs and shrubs at Ft. Carson are deep-rooted, therefore, it would be expected that these types of plants are capable of accessing Se in subsurface environments. Certain perennial forbs are known to have root systems that extend to depths of 10 meters or more in particular environments. Grasses, however, have very short-root systems that tend to grow primarily in soil surface layers. Se was generally low in soil surface layers within native areas, disturbing sites could result in subsurface Se being brought to the surface if seleniferous geological materials are present. This could enhance the uptake of Se by all types of plants.

6. Toxicologic Evaluation of Selenosis in Wyoming Herbivores (M.F. Raisbeck, J.W. Waggoner, and D. O'Toole)

The project examined the correlation of toxicologic data obtained from controlled experimental feeding experiments conducted during the first and second years of the study with similar parameters derived from natural exposure. Experimental feeding studies drastically limit environmental variables such as weather, dietary selectivity and antagonistic/synergistic nutrients. These factors probably account for some discrepancies in the older selenosis literature. Studies conducted in the this project suggest 5 ppm total selenium in vegetation on reclaimed minelands do not pose a significant toxicological hazard to grazing herbivores under Wyoming conditions.

ONGOING PROJECTS

1. Relationship Between Soil Organic Matter Content and Sustainable Nutrient Cycling In Reclaimed Soils (P. D Stahl, G.E. Schuman and L.K. Spackman)

Impacts of suface mining on soil often include a reduction in organic matter content as well as in microbial biomass and activity. Soil organic matter and soil microorganisms are critical components of the plant-soil system due to their roles in nutrient cycling, plant nutrition and soil stability. Relationships between soil organic matter (SOM) levels, microorganisms, and nutrient cycling in reclaimed mine lands, however, are poorly understood but crucial to accurate assessment of reclamation success. This research is designed to examine the relationship between SOM, sustainable nutrient cycling and reclamation success. In addition, we will test a

promising new technique that may provide a simple, economical and reliable indicator of a soil's or "substitute plant growth medium's" ability to sustain nutrient cycling.

The relationship of SOM levels to sustainable nutrient cycling will be examined by correlating levels of SOM in reclaimed mine land soils and "substitute plant growth media" to standard assays used in the direct analysis of nutrient cycling and to methods for assessment of revegetation/reclamation. The new technique for estimating nutrient cycling potential will be evaluated by correlating results of this technique to results of the standard direct assays of nutrient cycling and methods for assessment of reclamation success.

Data obtained from this work will enhance the ability of the mining industry and regulatory agencies to develop guidelines for plant growth media selection that will ensure long-term sustainability of reclaimed ecosystems without inputs of fertilizer and/or other amendments. Identification of a simple, reliable and economical method to estimate sustainable nutrient cycling potential would provide a valuable tool to the mining industry as well as regulatory agencies to evaluate reclamation success.

2. Microbial Community Structure in Surface Mine Reclamation Soils (Peter D. Stahl and Daniel L. Mummey)

We have initiated a project to examine and compare microbial community structure in surface mine reclamation soils and adjacent undisturbed soil. Microbial communities will be assessed in terms of biomass, diversity and community composition. Molecular methods employing small subunit ribosomal RNA and DNA, whole community fatty acid methods and other biochemical analyses will be used in these studies. Relationships between microbial community structure, vegetation community structure, soil physicochemical characteristics and reclamation success will also be investigated. Results of this work may help facilitate the establishment of a stable, functionally diverse soil community, which in turn may enhance soil aggregation and plant community development.

3. Smooth Brome Control in a Reclaimed Cool-Season Grassland Community (B.L. Perryman, P.D. Stahl, and M.D. Stacy)

The objective of this project is to determine the efficacy of grazing, burning, herbicide (Gramoxone), and mycorrhizal inoculation for controlling smooth brome without imposing detrimental effects on the native, reclaimed community constituents. Smooth brome, an introduced cool-season grass species, is excluded by statute from reclaimed communities characterized for grazing land use in Wyoming.

4. New Strategies for Establishment of Wyoming Big Sagebrush in Wyoming (B.L. Perryman, P.D. Stahl, and Rena J. Baldwin)

This project is testing non-classic methodologies for sagebrush establishment, including: 1) planting sagebrush concurrently with only warm-season grasses; 2) planting sagebrush concurrently with sunflowers; 3) planting sagebrush with no competing vegetation; and 4) planting sagebrush with mycorrhizal inoculation vs. no inoculation. The design also includes

combinations of the listed treatments. This is essentially a competition study that takes advantage of differing phenologies and soil moisture conservation strategies to discover more effective ways of establishing Wyoming big sagebrush.

5. Systematic Assessment of Ambient and Tissue Fluoride Concentrations and Their Effects on Rangeland Plant Communities of Southwest Wyoming (B.L. Perryman and K.J. Reddy)

The objectives of this project are: 1) assess plant tissue concentrations in big sagebrush and bluebunch wheatgrass along a distance gradient from plant and tailings pond fluoride emission sources; 2) assess fluoride concentration effect on aboveground biomass production, seed viability, and plant cover; and 3) conduct acute hydrogen fluoride and silica fluoride toxicity tests on big sagebrush and bluebunch wheatgrass. Overall project expectation is to provide information necessary to begin negotiations regarding both ambient and vegetative fluoride concentration standards with regulatory agencies.

6. Ecological Assessment and Evaluation of Snowfence Areas and Snowfence Mitigations (B.L. Perryman, P.D. Stahl, and J.D. Shirley)

A comprehensive study of the ecological effects of snowfences on soil and microbial biomass has yet to be attempted. Long-term efficacy of previous mitigation efforts likewise have not been assessed. The objectives of this study are: 1) assess grass species response since the initial trial in 1992; 2) assess soil fertility in snowfence drift areas compared to adjacent areas where drifts do not form; 3) assess soil microbial biomass and mycorrhizal fungi in snowfence area of influence as compared to adjacent non-drift areas; and 4) assess decomposition rates in drift and non-drift areas. A long-term assessment of previous mitigation activities will provide a more comprehensive understanding of the success or failure of individual species and cultural practices. Assessing soil fertility, microbial biomass, and decomposition rates in snowfence areas will provide necessary information to characterize this unique microsite. The project will identify current and potential problems needing mitigation.

7. The Effects of Varying Topsoil Replacement Depth on Various Plant Parameters Within Reclaimed Areas (B.K. Schladweiler, P.M. Wolken, L.C. Munn and R. Haroian)

The project was divided into five major tasks: 1) review existing vegetation/soil information from the WDEQ-LQD and obtain permission from the WDEQ-LQD to conduct the proposed variable topsoil study on Rochelle Coal Mine, 2) establish and construct the study site at the Rochelle Coal Mine, 3) obtain quantitative field data of three treatments on reclaimed areas and the corresponding reference areas, 4) summarize findings from the field sampling and provide annual/final recommendations, and 5) disseminate the information to interested parties.

Task 1 has been initiated and will continue throughout the project. Task 2 was begun in spring 1998 with a randomized complete block design chosen because of mine limitations. Within the block design, one contiguous rectangle area was selected within the reclaimed topography with three distinct replicate blocks. Treatment alternatives include: 1) 22 inch designated permit replacement depth, 2) 12 inch replacement depth, and 3) 6 inch replacement

depth. The treatment blocks were constructed on: 1) a uniform site to control variables other than topsoil depth (e.g., similar slope, aspect, stockpiled topsoil source, and seed mix) and 2) a landscape position that would best represent a pre- and post-mine Breaks Grassland community. Slopes are generally 5:1 and are west-facing. The three designated depths were approximate over the treatment replicate and will have minor variation based on weather limitations present during 1998, topsoil source, and equipment utilized for topsoil replacement. Task 3 will involve vegetation and soil quality field sampling and will be initiated in the summer of 2000. Cover, productivity, and plant diversity will be evaluate over all treatment levels.

8. Determination of Contribution to Cumulative Groundwater Impacts from Coalbed Methane Development and Surface Coal Mining (L. Borgman, J. Kerr, K. Peacock, M. Brogan, J. Meyer, T. Dobson, and R. Shafer)

The objectives for this two year project were to: 1) Investigate the existence of anisotropy of hydraulic conductivity in the coal aquifer for the purpose of evaluating modeling methods used by Peacock and Kern (1995), and to verify the presence or absence of inter-aquifer communication at these test sites, 2) Develop methods to differentiate groundwater changes due to surface coal mining activities from those associated with non-mining related aquifer stresses, and 3) Acquire and assess all available data from Permit to Mine Applications using all available means for the four active mines nearest the Marquiss CBM development.

Work completed over the last year includes: 1) an additional large scale pump test with inner and outer rings of observation wells, 20 finalization of a regional scale geological model for the coal aquifer in the Powder River Basin based on 1996 well logs, 3) development of a regional conceptual hydro-geologic model for the Powder River Basin between Gillette and Wright, Wyoming, 4) setup and application of MODFLOWP to investigate model sensitivity and calibration in steady state, and 5) publication of new statistical techniques for testing the null hypothesis of isotropy versus anisotropy and methods to estimate confidence intervals for axes of anisotropy.

9. Reconstructed Stream Channel Dynamics in an Alluvial Valley Floor (B.L. Perryman and P.D. Stahl)

The objective of this research is to monitor several hydraulic geometry parameters at six crossections along a 300 m reach of reconstructed stream channel on a reclaimed site in North central Wyoming. Vegetation cover will also be monitored in the uplands surrounding the channel. The hydraulic geometry should adjust to the vegetation conditions in the surrounding uplands in a predictable way if construction was performed correctly. Work will commence spring 1999.

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