RESEARCH WORK UNIT DESCRIPTION Ref: FSM 4070	**1. Number** RMRS-4253	**2. Station** RMRS
	3. Unit Location Provo, Utah	

4. Research Work Unit Title
Shrubland Biology and Restoration

5. Project Leader (Name and address)
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6. Area of Research Applicability	**7. Estimated Duration**
Western United States	5 years

8. Mission

Develop knowledge, plant materials, and technology for successful long-term restoration of diverse shrubland plant communities to meet resource needs and values.

9. Justification and Problem Selection

Shrubs are the dominant form of plant life on vast areas in North America, as well as on other continents. Shrub dominance is a consequence of major climatic and geologic patterns. Approximately 350 million acres (142 million hectares) in the Western United States are characterized by shrub dominance. Sizeable additional areas of forests, grasslands, and riparian areas also include an important shrub component. Despite the large size of these shrub ecosystems, they have been generally undervalued, poorly understood, and abused as a natural resource. Natural shrub ecoystem dynamics have been disrupted by large-scale clearing for agriculture, the introduction of an extensive domestic livestock grazing industry, a change in the native fauna, the advent of alien weeds often accompanied by an increased frequency of fire, and human-caused insect and disease epidemics. Together, these disruptions have led to land management classification of large shrubland acreages (24 percent of Forest Service administered rangelands) as being in unsuitable or declining condition. Furthermore, the impacts of global climate change and atmospheric CO_2 enrichment on shrublands are poorly understood.

The value of healthy, intact, and productive shrub ecosystems is only just beginning to be recognized. The processes of restoring disturbed shrub ecosystems to

10. Approach to Problem Solution (Start at conclusion of item 9.)

Signature	Title	Date
Recommended: /s/ M. Dean Knighton	Assistant Director for Research	May 5, 2000
	Assistant to Staff Director	
	Staff Director	
Approved:	Station Director	
Concurred:	Deputy Chief for Research	

stable conditions or rehabilitating them to more productive, useful and aesthetically pleasing states are difficult and poorly understood. Considerable progress in development and testing of plant materials and establishment techniques for rehabilitating degraded shrubland ecosystems has been accomplished by this Research Work Unit, its antecedents, and cooperators over the past three or four decades. Healthy, stable shrub ecosystems are mandated by several legislative actions, including the Endangered Species Act of 1973 and its amendments, the National Forest Management Act of 1976, and the Public Rangelands Improvement Act of 1978. Concerns about maintenance and enhancement of biodiversity, the effect of global change, and protection and management of rare plant and animal species in the West's vast shrublands all merit additional research attention so that ecological integrity is maintained and land management options remain open.

An ecosystem is more than the sum of its parts. Before ecosystems and their included communities can be understood, managed, rebuilt, or restored, their constituent parts need to be characterized and better understood. This is no small task. West of 100° W longitude in the conterminous United States, using the criteria or regional dominance, some 15 plant families (Anacardiaceae, Asteraceae, Caprifoliaceae, Chenopodiaceae, Ephedraceae, Ericaceae, Fabaceae, Fagaceae, Fouquieriaceae, Lamiaceae, Polygonaceae, Rhamnaceae, Rosaceae, Scrophulariaceae, and Zygophyllaceae) are represented by one or more dominant shrub species. These families include over 100 genera and nearly 600 species of shrubs in that geographic area. Herbaceous plants increase the magnitude of shrubland complexity considerably. Whereas much progress has been made in characterizing habitats and biology of some of these taxa, much research remains to be done. There is a special need to address the autecology of threatened, endangered, and rare species in Western shrub ecosystems, as well as many of the poorly understood common and incidental species. We need to develop basic knowledge about the genetic makeup, population dynamics, and biology of selected shrubland species deemed important for ecologically sound restoration efforts (Problem 1). Some widely adapted or generalist ecotypes may be suitable to be used in revegetating large geographic areas, depending upon land management objectives. They may be candidates for genetic manipulation and selection for combining or enhancing desired characteristics. Both naturally occurring and manipulated plant materials are tested and made more widely available through cooperative arrangements with the USDA Natural Resources Conservation Service, various State Agricultural Experiment Stations, and other plant development-oriented cooperators. Alternatively, local germplasm may be the key to restoration of many areas with a management objective of restoring natural communities and ecosystems. The importance of genetic considerations in maintenance of long-term population viability needs further clarification. Managers need this type of information, as well as an array of plant materials, so that degraded ecosystems can be rehabilitated or restored both structurally and functionally. Interrelationships among the plants, microorganisms, and insects in key shrub ecosystems are complex and poorly understood. Management based on a better understanding of these relationships can lead to healthier, more productive systems.

Among the important aspects in restoring or establishing shrubland communities are the sequential steps of obtaining quality, adapted seed and application of that seed in the appropriate manner. For many large-scale projects, direct seeding will be the only cost-effective alternative. This will require extensive field cultivation of native seed and the knowledge prequisite to producing seed without altering genetic makeup at the population level. Problems with pathogens can become more acute when wild plants are grown as monocultures using agronomic protocols. Effective field seed production technology will need to incorporate measures based on specific knowledge of host-pathogen interactions.

Substantive progress has been made for several species on seed harvesting, storage, germination syndromes and standards, dormancy and stratification, and on seedbeed ecology and seed orchard or plantation culture. However, much is still unknown. For example, the role of microorganisms, both as facilitators of and as detriments to successful seedling establishment, needs to be elaborated. This includes free-living soil and cryptobiotic crust organisms as well as amensals, symbionts, and pathogens. With persistent recurring needs to rehabilitate or restore large-scale and important degraded and disturbed shrub ecosystems, we need to develop and establish appropriate seed sources and effective techniques for establishing high diversity shrubland communities from seed (Problem 2). Needs are especially acute for small seeds (e.g., *Artemisia* spp.) for endangered, threatened, and rare plants and for field mixtures of different sizes and types of seeds.

Shrublands of the Interior West include a number of community types. The most widespread are the sagebrush, shadscale, and blackbrush types. Pinyon-juniper and mountain brush communities, while not strictly shrublands, are closely associated with shrublands, and in many cases include species in common with and form mosaics with shrublands. Community complexity ranges from near monocultures to highly diverse communities composed of many shrubs, forbs, and grasses. Large tracts of land within each of these community types have been impacted by natural and human-caused disturbances (e.g., grazing, weed infestation, mining, construction, fire, and exotic insects and plant pathogens). Rehabilitation or restoration of shrub communities requires an understanding of community-level interactions between plant species as well as a more detailed understanding of the consequences of disturbance. Such concerns as:

a) community establishment and factors affecting re-establishment of a plant community after disturbance;
b) impacts of domestic livestock and wildlife on native, rehabilitated, and restored communities;
c) effect of mechanical treatment on community development and successional processes;
d) between-plant interactions including the effects of species introductions (through seeding, exotic plant introductions, or weed infestations) on community diversity, stability, and succession;
e) importance of plant-pathogen and plant-insect herbivore interactions in influencing successional trajectories through such phenomena as gap formation and mass-dieoff;
f) effects of cryptobiotic soil crusts and their disruption on shrubland nutrient dynamics, hydrology, and successional processes; and
g) the impact of global climate change and CO_2 enrichment on shrubland ecosystem communities and species

need to be addressed so that we can develop a better understanding of community-level consequences of past and present management practices and provide recommendations consistent with ecosystem management policies (Problem 3). Community-level considerations also include the integration of the microbial component.

10. Approach to Problem Solution

Problem 1 -- Develop basic knowledge about the genetic makeup, population dynamics, and biology of selected shrubland species deemed important for ecologically sound restoration efforts.

Research under the mandate of previous Research Work Unit Descriptions has led to valuable knowledge about the adaptation, breeding systems, genetic relationships and characterization, use, and ecology of broadly distributed species complexes within the genera *Artemisia* (sagebrush), *Atriplex* (saltbush), *Chrysothamnus-Ericameria* (rabbitbrush), *Cowania-Purshia* (cliffrose-bitterbrush), *Grayia* (hopsage), *Cercocarpus* (mountain mahogany), and *Penstemon* (beardstongue). Research following up the leads of the earlier efforts on these groups should provide useful management information and provide plant materials for revegetation efforts. Similar characterizations have been and are being made on several weedy species that need to be better understood so that better control of these species might be possible and restoration or rehabilitation of sites that they occupy might proceed; these include *Bromus tectorum* (cheatgrass), *Chondrilla juncea* (rush skeletonweed), and *Centaurea virgata* var. *squarrosa* (squarrose knapweed). As time and resources allow, we will work on additional taxa including rare, threatened, and endangered species. Selection of these species will be in consultation with appropriate personnel in National Forest Systems, Bureau of Land Management, Fish and Wildlife Service, and other land management agencies. Autecological studies of key shrubland ecosystem species will focus on factors that regulate life history parameters. These include the interaction of genotype with abiotic environmental factors and with biotic factors such as insects, pathogens, and mutualistic microorganisms. These factors act in concert to regulate plant growth, life span, reproductive output, and regeneration biology.

Accomplishments planned during the next 5 years:

1. Continue to characterize natural sagebrush hybrid zones and evaluate the competing hybrid zone maintenance hypotheses (Ephemeral Hybrid Zone Hypothesis, Mosaic Hybrid Zone Hypothesis, and Bounded Hybrid Superiority Hybrid Zone Hypothesis). Evaluate the relative importance and management considerations of hybrid populations of sagebrush in comparison to parental stock.

2. Determine the adaptive significance and extent of apparent *de novo, in situ* polyploid *Artemisia tridentata* ssp. *vaseyana (mountain big sagebrush).*

3. Determine between-population and within-population variability of blackbrush (*Coleogyne ramossissima*) and shadscale (*Atriplex confertifolia),* and provide insights to their establishment and management through autecological and synecological studies.

4. Investigate the effects of maternal and paternal plant and populations on seed and seedling characteristics of antelope bitterbrush (*Purshia tridentata*) and examine differences in antelope bitterbrush accessional morphology, and relate these differences to management needs.

5. Determine the importance of between-population and within-population genetic variation in regulating germination processes for key shrubland species, including the exotic annual cheatgrass as well as antelope bitterbrush, rubber rabbitbrush, Lewis flax, Sandburg bluegrass, Thurber needlegrass, and other important native species.

6. Refine the model developed to predict germination timing and establishment success for facultatively fall-germinating species such as cheatgrass and bottlebrush squirreltail, using laboratory-measured germination parameters and macro and microclimate data.

7. Determine the significance, variations among selected interacting components, and management implications of the cheatgrass-head smut (*Bromus tectorum--Ustilago bullata*) pathosystem.

8. Determine the etiology and epidemiology of shrub diseases such as shadscale wilt and root rot, sagebrush wilt and root rot, leaf and stem rust of sagebrush, bigtooth maple decline, winterfat decline, and seedborne diseases of bitterbrush.

The benefits and beneficiaries of this research are many. Benefits include current, comprehensive, and reliable information on the genetics, biology, and restoration technology for ecologically sound shrubland restoration projects. Beneficiaries include geneticists and plant breeders interested in shrubland ecosystems, ecologists interested in plant autecology, and resource managers with responsibilities for shrubland management. Although this problem will not be "solved" in the 5-year study period, the probability is great, in excess of 90 percent, that significant contributions will add to the knowledge base for sagebrush hybrids and polyploids, blackbrush ecology and management, the physiology of germination for key shrubland ecosystem species, and the provision of information of shrubland plant diseases. This information will assist land managers in making resource management decisions.

Environmental considerations: Environmental considerations will be documented in study plans and competitive research proposals. For the most part, work planned is categorically excluded from documentation of environmental impacts because little environmental manipulation is required (FSM 1950). Where manipulation is required, environmental analyses will be prepared by the cooperating National Forest or Bureau of Land Management field offices.

Problem 2 -- Develop and establish appropriate seed sources and effective techniques for establishing high diversity shrubland communities from seed.

Two major obstacles to progress in shrubland restoration on a large scale are (1) lack of availability and high seed cost of seed of native species, and (2) lack of effective techniques for seeding successfully onto weed-dominated sites and under unpredictable semi-arid climatic regimes. At present, most native seed for shrubland ecosystem rehabilitation is collected from wildland stands and sold with little or no regulation. Some species have been developed into cultivars--several through participation of this Research Work Unit and its cooperators. But a more systematic approach is necessary to meet increasing demand for seed. First, we need better regulation to guarantee the origin of wild-collected seed. Second, we need to develop technology for field seed production of specific ecotypes of key native species, with safeguards to maintain genetic integrity and diversity. Third, we need to develop plant materials to meet specific management needs through a program of selection, testing, and when warranted, hybridization. Large-scale seeding in semiarid systems will always be risky; the goal is to maximize the probability of success by using the right combination of seed mix and seeding technique. Traditional agronomic practices do not always work; innovative methods that work with natural processes are more effective. The presence of highly competitive exotic annuals

increases the complexity of the problem. Increasing use of native species in seed mixes for shrubland rehabilitation or restoration to stable native communities as a preeminent goal means that more information about native plants needs to be gathered, analyzed, and disseminated. However, it is important that work be continued on some key non-native plant materials, e.g., alfalfa (*Medicago sativa*), forage kochia (*Kochia prostrata*), and small burnet (*Sanguisorba minor*). Our work will also integrate the roles rodents, insects, diseases, and microorganisms in restoration and rehabilitation efforts. This Research Work Unit is in a strong position to guide new interagency efforts aimed at shrubland restoration.

Accomplishments planned during the next 5 years:

1. Evaluate the following plant materials for their suitability in rehabilitating cheatgrass-dominated and other degraded shrublands, and participate in their development as source-identified, select, tested, or cultivar releases: Lewis flax, silver sagebrush, Wyoming big sagebrush x silver sagebrush, western yarrow, bluebunch wheatgrass, Thurber needlegrass, muttongrass, and forage kochia.

2. Determine factors regulating seed yield for key species such as big sagebrush, antelope bitterbrush, and forage kochia, and develop methods for maximizing seed production both in wildland stands and in field cultivation.

3. Develop seeding technology for cost-effective large-scale rehabilitation of cheatgrass-infested wildlands, including use of the herbicide Oust (sulfometuron methyl).

4. Examine the feasibility of establishing high-diversity, all-native shrubland communities from seed through small-scale demonstration plantings in cooperation with federal and state agencies.

5. Publish the manual "Restoration of Western Ranges and Wildlands" to provide managers with state-of-the art guidelines.

6. Publish approximately 20 species contributions to the revision of the Forest Service Handbook, "Seeds of Woody Plants in the United States."

7. Continue laboratory and field techniques for propagation and establishment of cryptobiotic crusts.

8. Develop standards for testing quality and viability of seeds of key native species.

The benefits and beneficiaries of this research are many. Research output on seed harvest, field production, and storage will increase seed availability for a wide array of species, stabilizing prices at levels that are equitable for wildland harvesters, growers, dealers, and buyers in both the public and private sectors. Research output on effective seeding techniques will improve return on seed and reduce the probability of seeding failures, thus making restoration and rehabilitation seedings more cost-effective and less risky. This in turn will result in conversion of large acreages of disturbed or degraded shrublands to plant communities that meet multiple use objectives. The probability of some significant success is high, probably at 90 percent.

Environmental considerations: Environmental considerations will be documented in study plans and competitive research proposals. For the most part, work planned is categorically excluded from documentation of environmental impacts because little environmental manipulation is required (FSM 1950). Where manipulation is required, environmental analyses will be prepared by the cooperating National Forest or Bureau of Land Management field offices.

Problem 3 -- Develop a better understanding of community-level consequences of past and present management practices and provide recommendations consistent with ecosystem management policies.

Previous research of the Research Work Unit and its predecessors has resulted in the establishment of a series of research plantings and companion-protected exclosure sites for which long-term climatic and vegetation data are available to evaluate species compatibility and community development. Work will be directed to determine when a restored state has been reached and through cooperation with land management personnel, an effort will be initiated to determine the bounds of desired future condition of degraded lands on a case by case basis. Our established sites will be utilized to study species relationships and consequences in successional development of seeded and protected communities within subalpine herblands ("tall forbs"), aspen, mountain brush, and especially pinyon-juniper, sagebrush, and shadscale community types. Practices and restoration projects employed to stabilize and restore deteriorated sites will be evaluated to determine if recovery and reestablishment of native species and communities were attained. Protected sites will be investigated to determine species composition and successional changes that have occurred as a result of climate and controlled grazing. These areas will be used to compare with companion rehabilitated sites to determine similarities with species presence and plant composition. This work will be conducted in cooperation with scientists of the Utah Division of Wildlife Resources and other agencies as appropriate and as opportunities arise. Previous research has determined that seedling establishment of selected shrub species is regulated by the presence of compatible native species. Future studies will focus on how shrub species, particularly big sagebrush, can be established by artificial seeding or natural recruitment as a component of entire communities in sites where weeds currently dominate. Existing facilities at the Desert and Great Basin Experimental Ranges will be utilized to investigate the influence of domestic livestock and wildlife upon restoration projects and species composition of semiarid and mesic rangelands. Through controlled plantings, we will investigate the establishment of complex plant communities and successional relationships involved in restoration of native shrublands.

Accomplishments planned during the next 5 years:

1. Evaluate the compatibility of introduced perennial herbs and native species within the subalpine herbland, aspen, mountain-brush, and pinyon-juniper communities to determine how deteriorated sites can be restored to support important native species, including the impacts of domestic livestock and wildlife.

2. Characterize the relationship of annual weeds, introduced perennial grasses, and native grasses upon the reestablishment of native shrubs including antelope bitterbrush, winterfat, big sagebrush, fourwing saltbush, and Martin ceanothus.

3. Evaluate the impacts of domestic livestock on desert shrub communities, i.e., shadscale/winterfat. Particular attention will be given to changes in reproductive output, seed bank dynamics, species composition, population stability, and weed invasion.

4. Evaluate effects of selected revegetation practices on habitat for upland game birds and big game habitat.

5. Develop a system for evaluating the weed-proneness of shrubland ecosystems based on shrub population dynamics, climate, degree and type of disturbance, and edaphic factors.

6. Publish symposia proceedings: Shrubland Ecosystem Genetics and Biodiversity, and Shrubland Ecosystem Seeds and Soils.

7. Publish General Technical Reports on (1) Big Sagebrush Ecology, (2) Forage Kochia Users Guide, (3) and Annotated Bibliographiy of Desert Experimental Range Publications.

8. Examine the effect of vesticular-arbuscular mycorrhizal fungi on plant reproduction in shrubland ecosystems.

9. Complete the study and prepare a report for "Evaluation of the Bureau of Land Management Rehabilitiation of the 1996 Rangeland Fires."

10. Complete the study and prepare a report on "Biodiversity of High Elevation Mountain Big Sagebrush Stands."

11. Evaluate the effects of fire and past mechanical revegetation treatments on the integrity and function of selected (sagebrush-grass and pinyon-juniper) shrubland ecosystems.

12. Examine effects of management and post-Little Ice Age waning and fire-history, community structure, composition, and stability for eastern Great Basin and pinyon-juniper and ponderosa pine-pygmy forest woodlands.

The benefits and beneficiaries of this research are many. Benefits include current, comprehensive, and reliable information on the successes and failures of past management/restoration projects with improved technology for future managers. Beneficiaries include resource managers and others interested in technology to meet ecosystem management expectations of the future. The probability of solution is approximately 80 percent.

Environmental considerations: Environmental considerations will be documented in study plans and competitive research proposals. For the most part, work planned is categorically excluded from documentation of environmental impacts because little environmental manipulation is required (FSM 1950). Where manipulation is required, environmental analyses will be prepared by the cooperating National Forest or Bureau of Land Management field offices.

Staffing

As currently staffed, the Research Work Unit has five scientist years (SY's), two one-half time professional support positions, and four techician positions funded by an appropriated amount of $920,000. Extramural funding, for the past several years, has averaged about $250,000 a year and has been used to increase the work time for the professional support positions and to fund term and temporary positions as well as to increase research operating budgets. The unit operating budget is also enhanced by close working relationships with the Utah Division of Wildlife Resources, the Bureau of Land Management, Brigham Young University, National Forest System Units, and other cooperators. Our effectiveness is also enhanced by the contribution of volunteers, especially a retired scientist who continues to work a regular schedule.

Distribution of RMRS SY's through the 5-year term is as follows:

Problem Area	Scientist Years Per Years of the RWUD				
	1	2	3	4	5
1	2.0	2.0	2.0	2.0	2.0
2	1.0	1.0	1.0	1.0	1.0
3	1.0	1.0	1.0	1.0	1.0
Totals	4.0	4.0	4.0	4.0	4.0

The Current Staffing is as follows[1]:

Scientists:

Project Leader (Geneticist)	GS-15
Botanist	GS-14
Ecologist	GS-14
Plant Physiologist	GS-14

Professionals:

Botanist	GS-11 (50%)
Geneticist	GS-12 (50%)

Technicians:

Biological	GS-07
Biological	GS-07
Biological	GS-07[2]
Range	GS-07

[1]The positions in the table are permanent positions. The part time positions are sometimes made more than the time listed by extramural funding. Additional term positions are also extramurally funded and include a full time GS-09 Ecologist and an 80 percent time GS-05 Biological Technician (term employees) and two GS-03 biological part-time student temporary appointments. Additional temporary appointments fluxuate with work loads and budget resources.

[2]This position is in the process of being converted to a wage grade facilities management position.