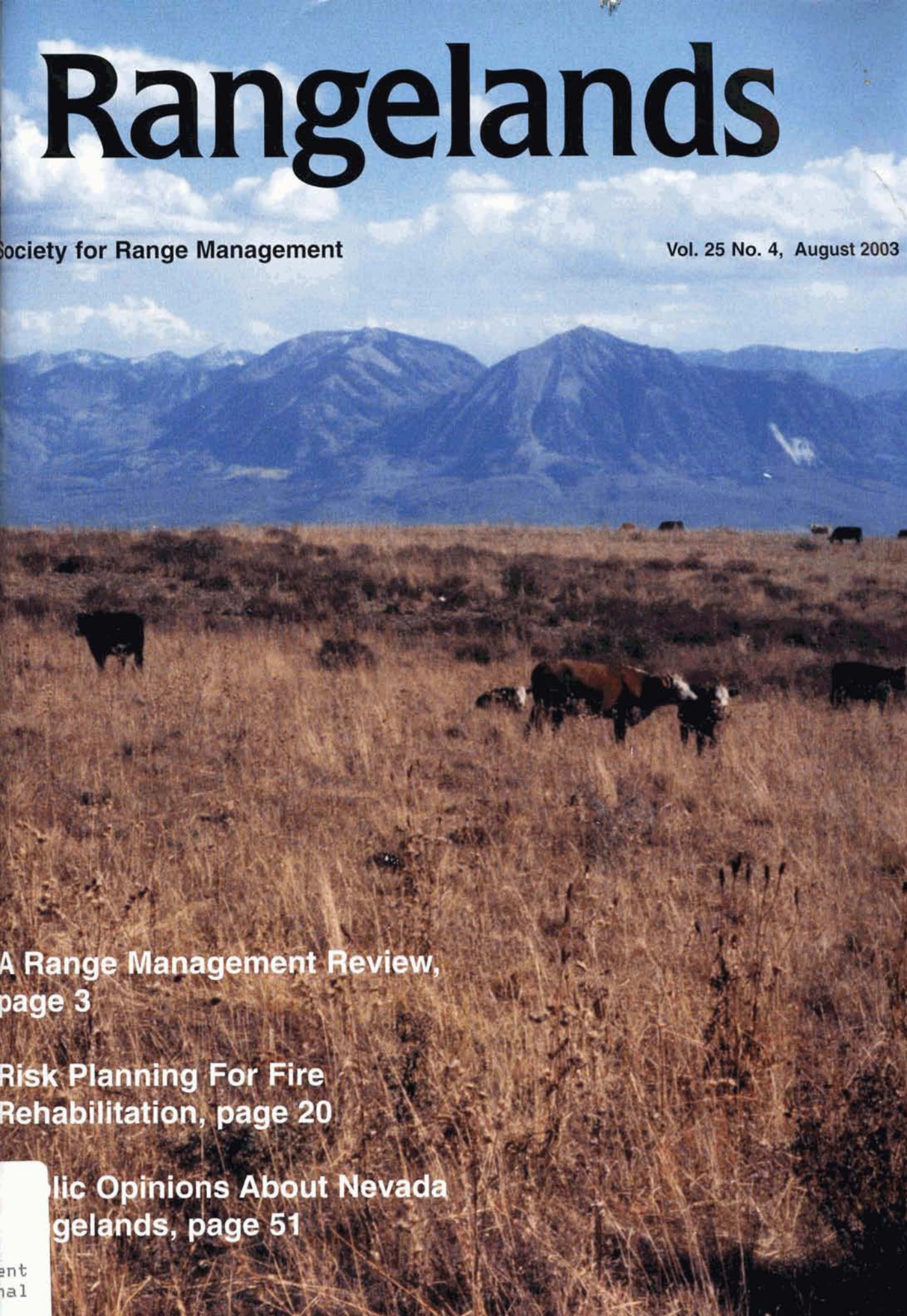
Rangelands

Society for Range Management

Vol. 25 No. 4, August 2003



A Range Management Review, page 3

Risk Planning For Fire Rehabilitation, page 20

lic Opinions About Nevada gelands, page 51

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The objectives for which the corporation is established are:

—to properly take care of the basic rangeland resources of soil, plants and water;

—to develop an understanding of range ecosystems and of the principles applicable to the management of range resources;

—to assist all who work with range resources to keep abreast of new findings and techniques in the science and art of range management;

—to improve the effectiveness of range management or obtain from range resources the products and values necessary for man's welfare;

—to create a public appreciation of the economic and social benefits to be obtained from the range environment;

—to promote professional development of its members.

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Rangelands

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Volume 25 No. 4
August 2003

Published bimonthly—February, April, June, August, October, December
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EDITORIAL CORRESPONDENCE, concerning manuscripts or other edited matters, should be addressed to the Technical Editor, 7820 Stag Hollow Road, Loveland, Colorado 80538.

RANGELANDS (ISSN-0190-0528) is published six times yearly (February, April, June, August, October, and December) by the Society for Range Management, 445 Union Blvd., Suite 230, Lakewood, Colorado 80228, Phone 303-986-3309. PERIODICALS POSTAGE paid at Denver, Colorado and additional offices.

POSTMASTER; Return entire journal with address change—Address Service Requested—to Society for Range Management, 445 Union Blvd., Suite 230, Lakewood, Colorado 80228.

PRINTED IN THE USA

Rangelands

FEATURE ARTICLES

A Range Management Review
by David Bradford, Justin McConkey, and Floyd Reed 3

Range Plant Development in Utah: A Historical View
by R. Deane Harrison, N. Jerry Chatterton, E. Durant McArthur, Dan Ogle, Kay H. Asay, and Blair L. Waldron 13

Risk Planning for Fire Rehabilitation
by Marina Whitacre and Nicole McCoy 20

Biosolids in a Chihuahuan Desert Ecosystem
by David B. Wester, Ronald E. Sosebee, Richard E. Zartman, Ernest B. Fish, and J. Carlos Villalobos 27

Can Locoweed Be Good Feed?
by Levi Newkirk 33

Letters-to-the-Editor from 25 Years Ago
by David Fischbach and Don Cox 35

Response to *JRM* Task Force Report
by Michael Ralphs, Elaine Grings, and Robert Gillen 39

Thoughts on the *Journal of Range Management*
by Gary Frasier 41

Improving the *Journal of Range Management*: Some Management Science Philosophy and Ecological Observations
by David L. Scarnecchia 43

Public Opinions about Rangeland Resources in Northeast Nevada
by J. Kent McAdoo 51

Society for Range Management Annual Meetings
by Sylver Smoliak 58

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DEPARTMENTS

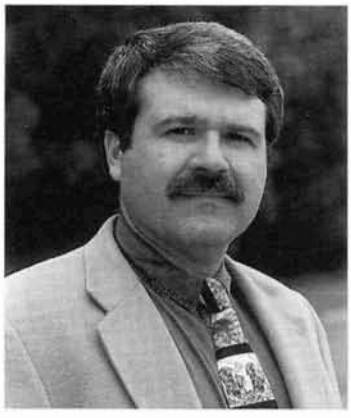
2 EVP Comments
47 Interpretive Summaries
60 Browsing the Literature
64 Book Reviews
37 Resource Roundup
57 Letters to the Editor
62 Listening to the Land

COVER

Cover: Cattle in High Park on West Terror allotment. West Elk Mountains in background in western Colorado. Photo by David Bradford. (See related story starting on page 3.)

EVP's Comments

Changes in Rangelands



What in the world is going on? We are barely three years into the twenty-first century and it seems that everything is changing. The Natural Resources Conservation Service is contracting out technical services. The US Forest Service and the Bureau of Land Management is not far behind.

The public is demanding more than traditional use for public lands, with extreme fringe groups popping up all over. Some of these groups seem to operate by the philosophy that the squeaky wheel gets the grease so they are screaming bloody murder that grazing is evil. Some other groups subscribe to the management by lawsuit strategy, where every time they don't like some action taken by the government, they file a lawsuit.

University and college rangeland programs have almost all been converted to departments within schools of natural resources. Our own demographics show a cultural shift of massive proportions, moving toward a much more diverse membership base.

Debates continue on genetic modifications of crops and livestock. Pesticides, herbicides, antibiotics and growth hormones are in the news every day. There is even a debate on the definition of native seed. For example, does native mean within 100 miles, 1 mile, or 100 meters? I've heard from members who say that one state won't use seed from a neighboring state for road construction revegatation projects because it's not "native".

But is any of this really new? I am finishing a book on the history of geology. It seems that in the early 1600's, scientists were extremely perplexed by fossil seashells found in rocks on mountaintops. While some thought it must be Noah's flood as the root cause, others believed that seashells could actually grow inside solid rock. Most everyone agreed that the planet could not be older than 6,000 years. Professional scientific societies were organized around this time and the debates about scientific methods, and which scientific philosophy was correct got to be pretty hot. The world was certainly moving at an extremely fast pace back then with printing presses being the technology that provided new information worldwide.

To me, the real champions of the book on the origins of geology are those scientific societies and the founders of those organizations. While a lot of emotion went into those debates, just as emotion seems to run much of the debates in today's organizations, the root goal to further the advancement of science was the driving force. I believe that today's Society for Range Management continues to have a common goal of trying to further the advancement of rangeland science. We will continue to move forward on determining what is the best rangeland management practices, what biodiversity and ecosystem approaches can be applied, and we might even try to define what is native seed. One thing seems clear. Change is constant.

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A Range Management Review

By David Bradford, Justin McConkey and Floyd Reed

This year marks the 25th anniversary of *Rangelands*. We also need to remember that this past 25 years also represents about half the time that the science of range management has been in existence – the American Society of Range Management being formed in 1948. In essence, the rangelands of the United States have been managed by scientific principles for at least 50 years.

Yet there is an increasing clamor that our public rangelands are still in unsatisfactory condition—that livestock grazing has destroyed the public rangelands and the only way to save them is to remove livestock from those lands. These statements beg the question—has range management failed?

This is a formidable question for range management professionals to ponder. Yet we need to confront the issue. Has the science, efforts and funding of the last 50 years been mistaken, misdirected and misspent? What have we done for the past 25 or even 50 years? Has the profession of range management succeeded or failed? We would like to address these questions from the perspective of a book that was published in 1976. A book titled *Public Grazing Lands: Use and Misuse by Industry and Government.*

The 1970's are generally considered to be the decade of the flowering of the American environmental movement. Nearly 50 environmental laws were passed by the U.S. Congress in the 1970's—including the Endangered Species Act, the National Environmental Policy Act, the National Forest Management Act, the Forest and Rangeland Renewable Resources Planning Act, the Public Rangelands Improvement Act, etc.

In 1976 William Voigt Jr. published *Public Grazing Lands: Use and Misuse by Industry and Government.* Voigt was a long-time conservationist and former national executive director of the Izaac Walton League of America. In his book, Voigt described the unsatisfactory conditions of the public grazing lands of the United States. Like many controversial issues the story is a complex one. However, the book chronicles the development of livestock grazing in the western United States and reviews the development of range management on the public rangelands of the West. Voigt examines the establishment of grazing management on the National Forests and the remaining public rangelands and the conflicts that developed in the late 1940's and early 1950's on those rangelands between ranchers and public land managers.

The primary element of the narrative was an effort by ranchers to privatize parts of the national forests and public lands. Voigt's final assessment of the agencies land management efforts was that the Forest Service was entangled in a complicated system of range management that entailed large expenditures of appropriated funds for rehabilitative measures, with few grazing concessions by grazing permittees. While the BLM also suffered from this they also lacked the enforcement authority to adequately manage the public rangelands due to shortcomings in the Taylor Grazing Act. Voigt concluded his book with "Until the one (BLM) is given new power and exercises it, and the other (Forest Service) changes its practices, it appears that western public ranges will continue to suffer the ills of 'too early use, too heavy use and too long use'."

Have conditions changed over the past 25 years? Do the Forest Service and BLM manage the public rangelands any differently today than in 1976 or do our public rangelands continue to suffer the ills of too early use, too heavy use and too long use?

What Has Range Management Accomplished?

We need to look at the past in order to evaluate the conditions we have today. Many authors have made such an analysis, including Voigt in *Public Grazing Lands: Use and Misuse by Industry and Government.* Recently Dr. Thad Box in a column titled "Ministers to the Land" in the December 2001

Grazing Use on the National Forests and Grand Mesa, Uncompahgre and Gunnison National Forests

Animal Unit Months (AUMs) of Grazing Use on National Forests in six Western Regions:		AUMs of of Grazing Use the GMUG NF:	
1908*	14,000,000	1917	680,508
1918*	20,400,000	1918	804,760
1928*	12,600,000	1925	694,633
1938*	11,100,000	1935	612,545
1948*	7,982,000	1945	391,461
1958**	8,376,000	1955	270,713
1968*	7,617,000	1965	249,333
1970*	7,408,000	1970	258,751
1980***	8,031,266	1980	334,489
1992***	9,167,927	1990	319,152
2001***	6,023,454	2001	272,812

*Figures from *Public Grazing Lands: Use and Misuse by Industry and Government.* Original source was Forest Service, Washington, D.C.

**This increase is due to the addition of the LU lands that were transferred from the Soil Conservation Service to the National Forest System in 1954. Today these are the National Grasslands.

***Figures from Grazing Statistical Summary, USDA Forest Service. Figures in 1980 represent a change in how an AUM is calculated. The definition of an animal unit month for the earliest figures is the forage required to sustain one animal unit for one month; an animal unit means a cow plus un-weaned calf or five ewes with their suckling lambs. In the 1980's the Forest Service modified this definition to—the amount of feed or forage required by an animal unit for one month. An animal unit is considered to be one mature (1,000 pound) cow or the equivalent based upon average forage consumption of 26 pounds dry matter per day. For cow/calf pairs the animal unit equivalent is currently considered to be 1.32.

Obviously, there has been a significant reduction in grazing use on the national forests. Adjusting the 2001 figures for the change in definition for calculating an AUM, the use in 2001 is approximately 30% of the use that was authorized in 1918; and 51% of the use that was authorized in 1948. The permitted grazing use in 2001 represents a 70% reduction of the permitted use in 1918. These figures portray a dramatic reduction in livestock use.

issue of *Rangelands* wrote a similar chronology. We have used both in the following summary. (See sidebar Grazing Use on the National Forests and the Grand Mesa, Uncompahgre and Gunnison National Forests (GMUGNF) for details on changes and trends on this use.)

During the early settlement of the West, livestock grazing was uncontrolled and unregulated. The earliest efforts to manage livestock grazing on public lands occurred on the Forest Reserves/National Forests in the late 1890's-early 1900's. The Forest Service developed a permit system that attempted to limit livestock grazing and charged a fee for this use on these forest rangelands.

From 1910—1920 the first systematic approaches to range management were developed by James Jardin, Arthur Sampson and Frederick Clements. However, during World War I the United States encouraged livestock production on the public lands to aid in the war effort– (see Sidebar Grazing Use on the National Forests and Grand Mesa, Uncompahgre and Gunnison National Forests.) This heavy stocking is reported to have had a profound impact on the ranges on the National Forests, while grazing on the remainder of the rangelands of the public domain (today's public lands managed by the Bureau of Land Management) continued to be unmanaged.

In the 1930's the Taylor Grazing Act was passed and the first regulation of domestic livestock grazing on public domain rangelands began. Most range management in this time involved limiting the numbers of livestock and shortening the season of use. These efforts resulted in the so-called range wars of the 1940's and 1950's. The result of these efforts was a reduction in use—grazing use on the National Forests declined 45% from 1918 to 1938.

In the 1940's the science of range management became formalized with the creation of the American Society for Range Management and the creation of range science departments in various land grant colleges in the West. In Colorado, the Department of Grazing and Range Management at Colorado A&M (today's Colorado State University) was created in 1947. In the 1950's the profession of range management expanded and various techniques and grazing strategies were developed. The first systematic range analysis was conducted on the national forests.

Big Blue Creek on Big Blue allotment in 1948 and 2001

Photo by Arthur Cramer, 8-16-1948 - Denver Public Library, Western History Collection

Allotment was grazed season-long by 450 cow/calf pairs from July 1 to October 15. This area was grazed by approximately 100 pairs for the season. Cramer noted that stream bank was undercut by excessive run-off. Precipitation for the year was "average."

Photo by David Bradford, 8-02-2001 U.S. Forest Service

The allotment was converted to a 4-pasture rest rotation system in 1966 and grazed by 175 cow/calf pairs from 7/16-10/15. This pasture was rested every 4th year. Livestock last grazed the allotment in 1996. Precipitation for the year was 88% of average.

From the 1960's to 1970's grazing entered the stage of more intensive range management. Grazing rotations combined with extensive structural and non-structural range improvements were developed and implemented. These efforts generally focused on producing increased amounts of forage. However, the emphasis was often on expensive land treatments such as range seeding and mechanical or herbicidal treatments of undesirable vegetation, such as oak-brush or sagebrush. These efforts often produced dramatic responses of increased forage but if the management of the livestock was ignored or minimally addressed the results were often temporary or unsatisfactory.

By the 1980's the emphasis moved towards "grazing systems." These systems were essentially grazing schedules that focused on moving or rotating livestock into a system of pastures to limit the amount of time that an area was grazed by livestock. The systems generally had fixed schedules. These systems usually failed to consider plant physiology, plant species composition and plant-animal inter-relationships. While the overall system generally included a variety of range improvements, including fencing, water developments and non-structural improvements, especially prescribed burning, the emphasis was mostly on the grazing schedule.

In the 1990's the emphasis has been to incorporate ecological processes into range management. There has been increased emphasis on riparian areas, wildlife—including threatened, endangered, and sensitive species and recreation uses. In the Forest Service this emphasis was called "Change on the Range." This switch was later applied to all Forest Service programs and given the title "Ecosystem Management." As applied to range management this has resulted in an increasingly complicated process of planning that incorporates the time of grazing intensity of grazing and frequency of grazing with plant physiology, plant responses to grazing and livestock nutritional requirements. On the GMUG NF this approach has allowed us to use domestic livestock grazing as a tool to manage vegetation for a variety of objectives, including species composition and vegetation structure.

Have Conditions Improved?

Have these efforts resulted in improvement or even changes on the ground? Since the late 1990's we have been re-evaluating conditions on the Grand Mesa, Uncompahgre and Gunnison National Forests. We have included past monitoring data points and photographs taken in range inspections over the past 50 to 100 plus years as part of these evaluations. These efforts include photographs and inspections referred to by Voigt in *Public Grazing Lands: Use and Misuse by Industry and Government*. The Forest has evaluated literally thousands of sites, including several hundred of the historic photo-points,

We have included several examples of these photographs in this article. These photographs are valuable for several reasons. First, they show that improperly managed livestock grazing can and does cause significant environmental damage. Second, they show that properly managed livestock grazing can maintain and in fact provide for recovery of damaged areas.

These photographs and our evaluations indicate recovery **of all sites** that were identified as depleted, damaged or unsatisfactory. All the sites we have looked at are ecologically functioning and in satisfactory condition. The comparison photographs provide convincing examples of that improvement. **It is important to note that the improvement at these sites took place *with* the continuation of grazing.** The improvement being due to 1) adjustments in stocking and 2) changes in management. This is not to say that conditions are perfect or even what they should be in all areas. But they all show improvement and generally dramatic improvement.

Wildlife is another significant component of our Western rangelands. While there are many species of wildlife there is often little information on what those populations were prior to settlement or what they currently are for that matter. However, it is widely accepted that following early settlement, the populations of big game—deer, elk etc. were severely depleted due to over-hunting.

In the 1920's the big game populations for the entire state of Colorado were estimated to be 23,859 deer and 5,384 elk. In the year 2000, those populations were estimated to be 516,000 deer and 230,000 elk. The increase in deer numbers

Bear Trap Park on Dyer allotment in 1948 and 2001

Photo by Arthur Cramer, 10-15-1948 - Denver Public Library, Western History Collection

Allotment was grazed season-long by 1,048 cow/calf pairs from May 15 to October 15, 1948. Note 2-foot deep, raw gully, bare ground and lack of vegetative cover. Shrubs are primarily snowberry. Precipitation for the year was "average."

Photo by David Bradford, 10-18-2001 U.S. Forest Service

Dyer allotment now managed under a deferred/rest rotation system. This pasture is rested every other year-it was rested in 2001. In the years this pasture is grazed, 425 cow/calf pairs use it for 27 days. Precipitation for the year was 88% of average.

statewide from 1920 to 2000 exceeds 2,000%; the increase in deer numbers on the GMUG NF from 1924 to 2000 represents a 1,145% increase. The change in elk numbers is even more dramatic—statewide from 1920 to 2000 it is over 4,000% while the increase on the GMUG NF is over 3,000%. (See Sidebar Colorado Deer and Elk Populations for more details.) These increased populations have had impacts on our rangelands—see Photograph on elk grazing on Robinson Flats. Managing these impacts are some of the challenges that we continue to face as rangeland managers.

At the same time these other changes have occurred there has been significant changes in our human populations. Since 1970 the world population has increased 64%, the United States population has increased 38%, the population in Colorado has increased 94% and the population in Delta County has increased 77%. (See sidebar on Human Populations for details.) These increased human populations have translated into increased pressures

This allotment is grazed by 1,066 cow/calf pairs on a holistic management based grazing strategy. The allotment has 30 pastures that are grazed from 3 to 18 days. This area, a 5 acre park known as Robinson Flat was broadcast seeded to smooth brome, orchardgass and timothy in the 1960's. Grazing use by elk and cattle was measured in 1996–1998. Elk use measured from 39–76% in those three years. The use shown above measured 76%. Cattle did not move into this pasture until 8–31. Obviously this amount of grazing by elk is having an effect on conditions on this site.

Colorado Deer & Elk Populations

	State-wide		GMUG NF**	
Year:	Deer	Elk	Deer	Elk
1920	23,859	5,384		
1924			5,320	1,122
1930	45,000	17,000		
1940	171,030	23,155		
1950			84,000	8,000
1960			62,000	11,000
1970			79,000	10,800
1980			89,981	38,707
1990	700,000	180,000	77,781	35,536
2000	516,000	230,000	66,252	38,887

*Source—Colorado Division of Wildlife.

**Source—Grand Mesa, Uncompahgre and Gunnison National Forests Annual Range and Wildlife Reports.

These figures show significant and dramatic increases in wildlife numbers. The increase in deer numbers statewide from 1920 to 2000 exceeds 2,000%; the increase in deer numbers on the GMUG NF from 1924 to 2000 represents a 1,145% increase. The change in elk numbers is even more dramatic—statewide from 1920 to 2000 it is over 4,000% while the increase on the GMUG NF is over 3,000%.

Wildlife populations have generally been controlled by adjusting hunting pressure. The increases in deer and elk numbers from 1920 to 1940 occured by severely restricting hunting. The resulting increases put so much pressure on the winter ranges that the Colorado Division of Wildlife initiated a supplemental feeding program. However this was expensive and generally exacerbate the problem. Hunting seasons were liberalized and wildlife pressure on the winter ranges decreased.

Elk numbers have continued to show a constant increase while deer numbers have declined in the last ten years. The cause(s) of this decline have been studied with a number of factors being identified—1) Deterioration and loss of habitat (Primarily increases in woody vegetation such as piny-on-juniper woodlands), 2) competition with elk, 3) predation (coyotes, mountain lions and black bear), 4) disease and 5) hunting. The exact cause remains speculative and the issue continues to be controversial. In all likelihood all five factors probably contribute in varying degrees.

The effect of deer and elk populations on the land continues to be discussed and debated. Wildlife can and do have significant impacts on land conditions. Many western states, including Colorado, have wildlife damage laws to compensate landowners for damage to private property by wildlife. In the 1980's elk began to winter in the North Fork Valley and started causing severe damage to the fruit orchards in the valley. As a result the CDOW paid to fence the orchards with game fencing to keep the elk out. On the GMUG NF we have observed and documented significant effects of elk grazing on rangelands. While generally very localized—these areas vary from 1 to 10 acres in size; the grazing by elk has significant effect on the condition of these sites.

Owens Creek allotment 1949 and 2000

Photo by Arthur Cramer, 9-27-1949 - Denver Public Library, Western History Collection

Slope above Owens Creek on Grand Valley RD. Photograph taken to show gully formation. Allotment was grazed by approximately 3,546 head of cow/calf pairs from June 16 through late October 15. Precipitation for the year was 110% of "average."

Photo by Bob Mosher, 10-13-2000 U.S. Forest Service

View of same site in 2000. The allotment is currently managed using a deferred-rotation grazing strategy. This area was grazed by 2,188 cow/calf pairs from about September 25 to October 5, 2000. Precipitation for the year was 80% of "average."

Horse Fly allotment 1950 and 2001

Photo by Arthur Cramer, 6-13-1950 - Denver Public Library, Western History Collection

Allotment was grazed season-long by 1,443 cow/calf pairs from May 16 to October 15. Cramer noted 1-2" stubble on Kentucky bluegrass with use estimated at 70–80% by June 13. He stated the grazing was much too early and use was too close. Precipitation for the year was 84% of "normal."

Photo by Floyd Reed, 6-18-2001 U.S. Forest Service

Original allotment was broken up into 4 allotmentments, grazed by 1,500 cow/calf pairs. This area is now part of the Horsefly allotment and grazed with 107 cow/calf pairs, 6/6–10/15. Allotment now managed under a deferred rotation system. Precipitation for the year was 88% of "normal."

The Human Population*

Year	World	United States	Colorado	Delta County
1950	2,556,000,053	151,325,089	1,325,089	17,365
1960	3,039,451,023	179,323,175	1,753,947	15,602
1970	3,706,618,163	203,302,031	2,224,610	15,316
1980	4,453,831,714	226,542,199	2,209,036	21,470
1990	5,278,631,759	248,709,873	3,303,377	21,036
2000	6,082,966,421	281,421,906	4,320,191	27,034

*Figures from U.S. Census Bureau

These figures indicate significant and dramatic changes in the human population for our world, the United States, Colorado and Delta County. Since 1950 the world population has increased 137%, the United States population has increased 85%, the population in Colorado has increased 226% and the population in Delta County has increased 56%.

Since 1970 the world population has increased 64%, the United States population has increased 38%, the population in Colorado has increased 94% and the population in Delta County has increased 77%.

These increases have put increased pressures on the natural resources on the planet, the United States, Colorado and Delta County. There are more houses and buildings, more roads, cars and traffic. We are all using more energy, more water and require more food. In addition we have more time and we are spending more of that time recreating on public land. These increases translate to more conflicts between all users on public lands.

on all lands in these areas. These pressures include increased demand for food, water, fiber, housing, energy, recreation, etc., and the numbers of people using public lands has increased dramatically.

So, Has Range Management Failed?

We posed the question in the introduction - has the science, efforts and funding of the last 50 years been mistaken, misdirected and misspent? No—we do not believe so. We believe that the science and profession of range management has solved many of the problems on America's rangelands.

Looking at the question from the perspective of the issues that Voigt raised in his book we no longer have too early, too heavy and too long grazing use. Comparing sites that were identified as damaged, depleted or unsatisfactory in the 1950's, range management has succeeded without question. This has occurred in spite of significant increases in both big game and human populations in the West.

Yet the question "Are America's rangelands healthy?" is continuously being raised. While this is a simple question, it is a difficult one to answer simply. This difficulty lies in the complexities of ecological processes, plant physiology and the inherent variation of natural landscapes. The question should public lands be grazed by livestock is usually raised in a simplistic and rhetorical manner. As a profession we generally fail to respond in a similar fashion.

Is the land healthy? This will probably always be a contentious issue—we have difficulty defining what the potential of the land is, what it would be without human influence, and what it looked like before American settlement. With the increasing passage of time and the increasing changes we continue to make to the land this creates great difficulty in assessing what is human caused or influenced and what is "natural." In our view it is probably more appropriate to evaluate the land from the perspective of functionality—is the land functioning as a healthy landscape?

Undoubtedly, this review and these photographs will not convince all those who oppose livestock grazing on public lands. For many of these individuals their opposition is philosophical, emotional and complete. We have found that debating the merits of grazing domestic livestock with individuals who have a rigid anti-grazing paradigm to be unproductive. However, there are many individuals who are opposed to domestic livestock grazing on public

lands due to a lack of knowledge or the misinformation that is being spread so aggressively by anti-grazing zealots. We have found that providing factual and accurate information on grazing livestock on public lands **can** affect the understanding and attitudes of open-minded but uninformed or misinformed people. The answer to reaching these people is education.

As mentioned in the introduction nearly 50 laws were passed in the 1970's that relate to management of the national forests. However Congress did not ignore the national forests before or after the 1970's —today there are nearly 200 federal laws that affect the management of those lands. This has created a complex and sometimes conflicting array of mandates. This is not necessarily efficient, economic or even effective. The public land agencies will continue to manage the public lands as best as they can, though in all likelihood this will continue to be inefficient, costly and at times ineffective.

Management of the public lands is increasingly focused on process and not on the actual conditions on the land. This focus on process has created what the Chief of the Forest Service and others call "analysis paralysis." Possibly this may be the price of managing public lands in a democratic society. However, we believe that our best chance for successfully managing the public rangelands lies in management based on actual and factual on the ground conditions. Not on speculation and process.

There has been a dramatic improvement in range conditions over the past 50 years and America's public rangelands are generally healthy and functional. This improvement should be attributed to the efforts of the range managers and range scientists of the past 50 years.

Can America's public rangelands still be improved – absolutely! The science and profession of range management will continue to evolve – as it should. A profession that does not continue to grow will become stagnant, moribund and irrelevant. But in the course of change the profession should not lose sight of its basic reasons for existing. The following are two of the objectives of SRM—*to properly take care of the basic rangeland resources of soil, plants and water and to improve the effectiveness of range management or obtain from range resources the products and values necessary for man's welfare.* We believe these objectives correlate to Gifford Pinchot's description of the purpose of the national forests in 1907, "the land should be managed for the greatest good of the people in the long run." Let us continue our efforts keeping in mind this goal and these objectives.

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Range Plant Development In Utah: A Historical View

A history of heavy grazing and semi-arid climate have given Utah a unique challenge in developing range plants suited to the West.

by R. Deane Harrison, N. Jerry Chatterton, E. Durant McArthur, Dan Ogle, Kay H. Asay, and Blair L. Waldron

Editor's Note: We put the spotlight on Utah as SRM members gear up to attend the 57th Annual Meeting of the Society for Range Management January 24–30, 2004 in Salt Lake City.

The native vegetation of Utah at the time of Mormon settlement in 1847 was not documented. However, early day species composition was indicated. Brigham Young received a letter two days before he entered Salt Lake Valley in 1847, from advance scouts, Orson Pratt, Willard Richards and George A. Smith stating that grass was plentiful and if they wanted to grow sagebrush they better bring seed (Cottam 1947). Cottam (1947) reviewed Orson Pratt's journal and found that on July 21, 1847 Pratt commented that the "very luxuriant" green grass cover extended for miles in the valley with bunchgrass growing on the upland valley plains. Government Explorer Howard Stansbury (1852) reported that the Salt Lake Valley afforded perennial pasturage and the hillsides furnished bunchgrass.

But, prolonged heavy livestock grazing, beginning shortly after Mormon pioneer settlement of Utah in 1847, led to rangeland degradation. By the 1880's and 1890's, livestock numbers peaked in Utah. The 1890 U.S. Agriculture Census recorded 3.8 million sheep and half a million cattle in the state (Fig. 1). This unsystematic and heavy grazing eventually led to vegetation community change.

Figure 1. *Sheep reached their peak in Utah at 3.8 million in the 1880's and 1890's.*

In 1932, Pickford reported that the vegetation on the Great Basin's eastern foothills had changed from 49–81% perennial grass and 10% sagebrush to mainly sagebrush ground cover. Soil surveys and correlated ecological range site descriptions completed in Utah by the United States Department of Agriculture, Natural Resources Conservation Service ([NRCS] formerly the Soil Conservation Service) support similar findings.

Passey et al. (1982) also reported similar findings in their classic studies conducted from 1958 through 1969 on several protected relict foothill areas. Hull and Hull (1974) reported that in Cache Valley Utah, perennial grasslands had changed to dense stands of sagebrush and cheatgrass. As a result of degraded ranges, catastrophic flooding occurred in the late 1800's and early 1900's in several Utah counties including Sanpete, Uinta, Duchesne, Davis, Emery, and Salt Lake. The city of Manti, in Sanpete County, was on the verge of being abandoned until livestock use was discontinued and a watershed program was developed for Manti Canyon.

Due to continued flooding, the USDA Forest Service (FS) created the Great Basin Experiment Station (now the Great Basin Experimental Range) in 1912 in Sanpete County and the Davis County Experimental Watershed in 1933.

Many ranchers, including the first author's grandfather, under the authority of the 1916 Stock-raising Homestead Act, continued to deplete the native vegetation, through grazing livestock too early and too heavily on homesteaded land and adjacent public lands. Rangelands continued to deteriorate, even though the Forest Reserve Policy was established in 1891 and management areas like Manti National Forest (approved in 1903) were created and the Taylor Grazing Act implemented in 1934.

In 1936, the U.S. Senate published the document, "The Western Range" which reported the serious condition of western rangelands. Among other things, the report emphasized the need for seeding of grasses to stabilize the soil and improve the depleted range. Walter Cottam (1947) posed the question, "Is Utah Sahara Bound?" as he discussed the degraded state of rangeland in Utah and suggested the need for plant materials and reseeding to reclaim abused land.

Plant Materials in Utah

It is not clear whether Utah was included in the 1,500 Western Seeding Trials conducted by the Federal Government in 1895, which were largely failures; or in the 500 tests conducted in 11 western states by the Forest Service in 1907, which reported only 16 % success (Chatterton and Young, 2002).

However, A. W. Sampson, who some consider the father of range management, established plots of various plant species at the Forest Service Great Basin Experiment Station in 1912 and 1913. During the autumn of 1912, he planted timothy, Kentucky bluegrass, orchardgrass, white sweetclover and red clover. In some cases sheep were herded over the seeded areas to trample in the seed (Fig. 2). In 1913, three thousand six hundred plant cuttings and sprouts of aspen, willow, mountain elder, and "other

Figure 2. *In the early 1900's, A.W. Sampson had sheep herded over broadcast seedings at the Great Basin Experiment Station, near Ephraim, UT.*

Figure 3. *A.W. Sampson's 1913 plant material plots at Great Basin Experiment Station, near Ephraim, UT.*

promising shrubs" were planted at the headwaters of mountain streams (Fig. 3) (Keck 1972). Willow was the only cutting that grew satisfactorily. Other grass species, including Idaho fescue, oniongrass, and bluebunch wheatgrass, were planted on a related project. At the end of 10 years, a report stated that satisfactory performance at the headwater sites, was obtained from penstemon, sweetsage, yarrow, slender wheatgrass, mountain brome, bottlebrush squirreltail, timothy, smooth brome and Kentucky bluegrass. Reseeding trials and plant selection efforts were greatly expanded in the Intermountain area when an organized testing program was developed by the USDA-FS in the 1920's.

In 1888, the Utah Agricultural Experiment Station (UAES), under the 1887 Hatch Act, was established at Logan, Utah. In 1903, 103 acres were acquired at Nephi, Utah for a new experiment station. This location is the oldest continuously operated dryland Experiment Station farm in the United States and has been the testing site for numerous rangeland plant materials.

The federal government purchased 3,240 acres of abandoned farmland in 1934 and established the Benmore Experimental Range for research (Astroth and Frischknecht 1984). In the fall of 1938 and the spring of 1939, the units were fenced, plowed, and seeded to a mixture of crested wheatgrass, smooth brome, slender wheatgrass, western wheatgrass, and tall oatgrass. Crested wheatgrass was the best adapted species and soon dominated 95% of the area. Those plantings represent some of the oldest crested wheatgrass seedings in the West. Later tall wheatgrass, intermediate wheatgrass and Russian wildrye were planted with some success. It was at the Benmore station that L.A. Stoddart and C.W. Cook from the UAES and N. C. Frischknecht of the Forest Service's research branch (then the Intermountain Forest and Range Experiment Station) did early plant material research (Fig. 4).

Reseeding, along with contour trenching was accomplished at the Davis County Experimental Watershed (established in 1933). It is believed that the species used for reseeding were intermediate wheatgrass, smooth bromegrass, and yellow sweetclover, which were included in the standard USDA-FS revegetation mountain seed mixture.

The USDA-FS Desert Experimental Range, at Utah's west desert, was established in 1933. The primary purpose of the Desert Experimental Range is to evaluate grazing intensities and season of grazing. However, adaptation of plant materials are also tested there. For example, fourwing saltbush has been planted around the headquarters buildings for adaptation and conservation evaluation.

The NRCS established several Soil Conservation Plant Nurseries (Plant Materials Center's [PMC]) in the 1930's. Utah is served by the PMCs in Aberdeen, Idaho (established in 1939); Los Lunas, New Mexico (established in 1937); Tucson, Arizona (established in 1935); and by the Upper Colorado Environmental Plant Center at Meeker, Colorado (established in 1975).

Figure 4. *Thousands of degraded Utah rangelands were plowed and seeded to plant materials, as occurred at the Benmore Experiment Station.*

Some of the early plant materials used in Utah that were released from PMCs include; 'Manchar' smooth brome–1943, 'Sherman' big bluegrass–1945, 'Greenar' intermediate wheatgrass–1945, 'Primar' slender wheatgrass–1946, 'Bromar' mountain brome–1946, 'Whitmar' bluebunch wheatgrass–1946, 'Ioreed' reed canarygrass–1946, 'Alkar' tall wheatgrass–1951, 'Topar' pubescent wheatgrass –1953, 'P-27' Siberian wheatgrass–1953, 'Nordan' crested wheatgrass–1953, and 'Sodar' streambank wheatgrass–1954.

Additional plant materials used in Utah that have been released by PMC's in more recent years include 'Nezpar' and 'Rimrock" Indian ricegrass, 'Garrison' creeping foxtail, 'Regar' meadow brome, 'Secar' Snake River wheatgrass, 'Bannock' thickspike wheatgrass, 'Pryor' slender wheatgrass, 'Goldar bluebunch wheatgrass, 'Magnar' basin wildrye, 'Rosana' western wheatgrass, 'Luna' pubescent wheatgrass and many others.

In 1936, Wesley Keller was the first USDA Bureau of Plant Industry (BPI) employee hired under the cooperative program with the Agricultural College of Utah (Utah State University). In the 1940's, he joined with Bateman and Packer of the College to field test several pasture mixes that resulted in the "University Mix." In 1954, BPI became part of the United States Department of Agriculture, Agriculture Research Service (ARS) and many researchers were transferred to the new agency. The USDA-ARS, Forage and Range Research Laboratory in Logan, Utah has released twenty-one cultivars and pre-variety germplasms. The Laboratory released seven alfalfa lines including 'Desert' during the 1970's and early 1980's.

A few of the rangeland cultivars that were released in the 1980's and 90's include: 'Newhy', RS-1, and RS-2 Hybrid wheatgrass; 'Hycrest', 'Douglas', and 'CD-II' crested wheatgrass; 'Bozoisky - Select' and 'Tetra-1 tetraploid' Russian wildrye; 'Vavilov' Siberian wheatgrass; 'ARS-2678' kura clover; 'SL-1' wheatgrass hybrid; 'Scarlet' and 'Munroe' globemallow; 'Timp' Utah sweetvetch; 'Sand Hollow' squirreltail grass; 'Rimrock' Indian ricegrass; 'Road Crest' turf-type crested wheatgrass; and P-7 bluebunch wheatgrass. Many of these were released jointly with other cooperators.

In 1975, the USDA-FS created the Shrub Sciences Laboratory as a unit in the Intermountain Forest and Range Experiment Station on the Brigham Young University campus in Provo, Utah. This laboratory was an outgrowth of previous plant ecology research and plant materials development from the Great Basin Station or Great Basin Experimental Range under a cooperative effort that included the

Utah Division of Wildlife Resources big game habitat restoration unit. A. Perry Plummer led the combined efforts of the Laboratory for many years. In cooperation with other agencies, the Shrub Science Laboratory has made fifteen separate releases.

Some of the releases of the 1980's and early 1990's include 'Appar' blue flax, 'Rincon' fourwing saltbush, 'Ephraim' crested wheatgrass, 'Immigrant' forage kochia, 'Lassen' antelope bitterbrush, 'Hatch' winterfat, 'Paiute' orchardgrass, 'Hobble Creek' mountain big sagebrush, and 'Gordon Creek ' Wyoming big sagebrush.

help build on each other's goals; acknowledge whom would take leadership for each plant species; designate a leader for seed increase; and enhance coordination of plant releases.

As a result of the discussion, the first Utah State Interagency Plant Materials Committee meeting was held in April 1985 and included both developers and users (Table 1). During the meeting the following areas were reviewed: 1) new research, seed availability of new plant releases, and adequate plot size; 2) user group needs; and 3) resource problems and priorities. It was agreed that before new plant materials were released the following should occur: 1) more evaluation and testing through a standard coordination procedure; 2) more demonstration plots and field plantings were needed; 3) seed should be available for purchase when plant materials are released; 4) better communication between the developer and user as to the value of the new plant; 5) seed quality testing for certification; and 6) a plant material priority list should be developed.

Table 1. Agencies Present at the 1985 Materials Correlation Meeting.

Agencies
USDI-Bureau of Land Management
United States Department of Agriculture, Natural Resource Conservation Service (NRCS)
USDA-NRCS Plant Material Center Aberdeen, Idaho
Utah Division of Oil, Gas, and Mining
USDA Agricultural Research Service, Forage and Range Research Lab
Utah State University Extension
USDA Forest Service Intermountain Research Station Shrub Sciences Laboratory
USDA Forest Service Intermountain Region
Upper Colorado Environment Plant Center
Utah Division of Wildlife Resources
Utah Department of Agriculture, Division of Plant Industry
Utah Crop Improvement Association
Utah State Lands and Forestry

Utah Interagency Plant Material Committee

In 1985, NRCS was involved in developing a long range plant material plan for Utah and felt it necessary to receive input from other agencies that were developing and/or using plant materials. During discussions about the plan, R.D. Harrison, E.D. McArthur, K.H. Asay, N.J. Chatterton, F.T. Holt, J.C. Gibbs, and M.M. Petersen decided plant material development and use could benefit from interagency coordination by those that use plant materials and those that develop them.

The group felt that coordination would be useful to: minimize duplication of efforts; provide a forum to maximize plant material production; inform users of new species and varieties; reduce competition;

It was unanimously voted to form an interagency plant material coordination committee that would meet each year. The second annual meeting was held in March 1986 in Logan, Utah at which time a coordinated planting guide was discussed. Howard Horton, USDA-ARS, who had been working on a guide for range and pasture seeding was asked to chair a Planting Guide development committee. The

Interagency Forage and Conservation Planting Guide for Utah was subsequently published in 1988 and was revised by USDA-ARS and others in 2001 as the Intermountain Planting Guide.

The Utah Interagency Plant Material Committee has evolved over the years as a forum to annually exchange information relating to plant materials development and use. It has been the inspiration for several states to initiate similar plant coordination forums and has expanded to include participants from Idaho and Nevada. A separate committee of scientists from agencies (USDA-ARS, USDA-NRCS, USDA-FS, and appropriate state agencies) that develop plant materials meet every two to three years and discuss many of the details as outlined in the original concepts discussed earlier in this paper.

Looking Ahead

Even though rangeland condition has improved in some areas, questions continue to be asked, "Is Utah Sahara bound"? Is desertification occurring in Utah? Are there needs for more and better plant materials? Bureau of Land Management officials state that fire and cheatgrass have created a weedy wasteland in The Great Basin and that a large part of it lies on the brink of ecological collapse. Sheldon Wimmer, Utah BLM Fire Management Officer stated, "In the early 1970's BLM Utah had an average of 25,000 to 30,000 acres of range fire per year. Now there is an average of 130,000 acres of cheatgrass related fires annually." The increasing trend of wildfire in Utah is also occurring in other Intermountain West States.

Steve A. Dewey, USU Extension Weed Specialist, reports that noxious weeds in Utah increase at a greater rate than the national average of 14 to 16% per year. Obviously, there is still a need for new and better plant materials. However, just as important is the need for plant materials coordination, better land management practices and the increased education of private users in range health and trend.

We refer to the initial purpose of the Utah Interagency Plant Material Committee: 1) minimize overlapping work; 2) provide a forum for cooperation; 3) reduce competition and establish who would take research leadership for each plant species; 4) designate leader for seed increase; 5) cooperate more fully on plant releases; and 6) provide information about new species and varieties for users and allow users to inform developers of their needs. The Utah Interagency Plant Materials Committee and its sister organizations continue to serve a useful role for land managers and plant developers.

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Risk Planning for Fire Rehabilitation

A step-by-step guide for conducting a risk-adjusted cost-effectiveness analysis as part of a fire rehabilitation plan.

By Marina Whitacre and Nicole McCoy

Wildfires are a popular topic of local and national news media, whose stories describe danger, devastation, heroes and scandal. The effort and expenditure required to rehabilitate the blackened landscape are not nearly as exciting as the fires themselves and receive little to no media attention.

Behind the scenes, however, range managers write and implement revegetation plans, often before the fire is extinguished. Just as the media ignores the essential but perhaps unfamiliar topic of revegetation following fire, range managers often neglect including an economic analysis in their revegetation plans.

Following is a step-by-step guide for conducting a risk-adjusted cost-effectiveness analysis to illustrate how it can benefit land managers and future rehabilitation efforts by accounting for the risks and expenditures of post-fire revegetation projects.

Risk plays a critical role in project decision-making.

Post-fire Revegetation on Western Rangelands

In 1999, the National Interagency Fire Center reported a record fire year. Three thousand sixty-four fires in the Great Basin burned over 2.8 million acres (1). Largely responsible for the increase in fire size and frequency is the spread of cheatgrass, an invasive annual grass. Its ability to germinate in cool temperatures, exploit early spring moisture, and tolerate dry conditions has enabled cheatgrass to establish in unvegetated areas and provide a continuous understory of fuel.

The outcome is a shortened fire cycle that can result in fewer perennial plants, accelerated soil erosion and inadequate forage and wildlife habitat (2). Cheatgrass can also serve as a precursor to secondary weeds and subtle ecosystem alterations including changes in nutrient cycling and soil morphology (3).

Efforts to rehabilitate burned rangelands are limited by budget and personnel constraints and by the availability of seed and equipment. Fall seeding is recommended in the Great Basin prior to wetter winter and spring months.This creates a narrow window for rehabilitation and a bottleneck period when limited resources are in high demand. In addition, restoration efforts can be hindered by rough terrain and unpredictable and dry climatic conditions. As a result, only a small percentage of burned landscapes are seeded. For example, only 14% of the 3.2 million acres that burned in the West in 1996 was reseeded, costing over $21 million (4). Similarly, in 1999 it cost $40 million to reseed 33% of the 2.8 million acres burned in the Great Basin (1).The expense and uncertainty inherent to fire revegetation necessitates the evaluation of previous projects to make informed management decisions.

The Importance of Cost-Effectiveness Analysis

Benefit-cost analysis is a common measure of economic efficiency in which alternatives are evaluated by comparing monetary costs to benefits. However, benefit-cost analysis may be an impractical tool when seeking the least expensive means to reach a non-monetary goal or when benefits are difficult to monetize (e.g. soil stabilization and its benefits). In the context of rangeland rehabilitation, a different tool, cost-effectiveness analysis, may be more appropriate for determining the costs and effectiveness of proposed revegetation projects.

Unlike benefit-cost analysis, cost-effectiveness analysis does not assign a dollar amount to a project's benefits. Instead, it compares costs (in dollars) to measurable, but non-monetized benefits to generate an effectiveness ratio (e.g., number of seeded plants/dollar).

To complete a cost-effectiveness analysis, a manager must determine four pieces of information:

(1) project goals and objectives,
(2) estimates of plant establishment from similar, previously revegetated sites,
(3) the cost of potential reseeding techniques, and
(4) project risks.

In the broadest sense, the goal of revegetation is to increase plant cover. However, the project-specific goals will depend upon managerial objectives. For instance, one may seek high species diversity with an emphasis on restoring native vegetation, or if the threat of a weedy invasion is significant, managers may seek only to establish a given density of any perennial species.

The species specified objectives will measure project effectiveness, and as such, must be quantifiable (e.g., 4.5 seeded plants/yd^2). This effectiveness measure will be used to rank establishment results and estimate plant density for the proposed site. While no site will be identical to that of the proposed project, an effort should be made to acquire data from areas where soils, topography, range site, precipitation and seeding time are similar. Further, comparison sites should have been seeded using techniques feasible for the proposed project.

Next, the total cost of each reseeding technique must be calculated. These costs include (but may not be limited to) seed purchases, equipment purchase or rental, fuel, and labor hours. Although costs from comparison sites may provide a working estimate, current cost information is required for final calculations.

Risk plays a critical role in project decision-making. Rangeland seeding in semi-arid sites (sites receiving less than 12 inches of rainfall/year) presents a significant risk of failure from a lack of moisture.Other risks may include pest outbreaks or wildfire. To help quantify risk, probabilities are assigned by asking, "What is the probability that the seeding will receive sufficient rainfall for good establishment?" or "What is the probability of a grasshopper outbreak during seedling development?"

While it is tempting to treat the likelihood of these events as unknowns, we can assess the probability of success for each strategy by specifying a set of comprehensive and mutually exclusive contingencies. In other words, possible outcomes are specified such that only one will occur. A rehabilitation site will receive either greater or less than 12 inches of annual precipitation in a given year (but not both). This process is called an expected outcome analysis.

To illustrate the use of a risk-adjusted cost-effectiveness analysis for rangeland rehabilitation, we will apply it to a hypothetical planning process.

Case Study: Revegetation in Skull Valley, Utah

The area we want to reseed lies within a burn located in Skull Valley, Utah (Figure 1) and is adjacent to the Davis Knolls burn where there is a six-year-old 5900-acre seeding of Nordan crested wheatgrass.

Project Goals and Objectives

The goal of our project is to reduce the risk of cheatgrass invasion and soil erosion by establishing crested wheatgrass, a well-adapted, competitive species introduced from Eurasia. To measure success of our seeding and determine the most-cost-effective technique, we will use Vallentine's (1989) plant establishment guidelines for a foothill rangeland site in the Intermountain West: excellent establishment: greater than 6.75 plants/yd^2 (36,300/acre), good: between 4.5 and 6.75 plants/yd^2 (20,230-

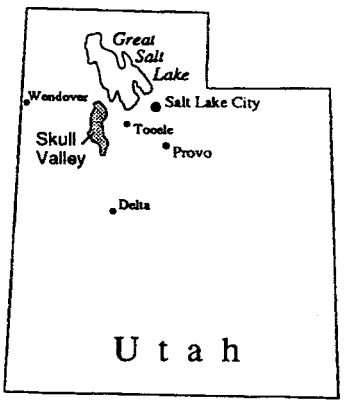

Figure 1. *Skull Valley, Utah (9).*

36,300/acre), fair: 2.25 to 4.5 plants/yd^2 (10,120-20,230/acre) and poor: fewer than 2.25 plants/yd^2 (10,120/acre). Our goal is a seeded plant density greater than 4.5 plants/yd^2 or 20,230 plants/acre (i.e., "good" establishment).

Site Descriptions

Both our project and the seedings used for reference are located within the mid-elevation zone of Skull Valley (between 4,590 and 5,250 ft) where soils are shallow to moderately deep and well drained. The dominant vegetation is shadscale, Indian ricegrass, bottlebrush squirreltail, Wyoming big sagebrush, Russian thistle and cheatgrass.

The local 41-year average annual precipitation is 7.6 inches with maximum and minimum yearly amounts totaling 15 and 3.3 inches, respectively. Most precipitation arrives during the winter and early spring, with little rain between mid-June and October. As such, precipitation during the first 6 months of the year is critical for seedling establishment, and fall seeding provides an opportunity for cool season plants to acquire early spring moisture.

The plant establishment data we used to evaluate the potential effectiveness of our project are from three, 1996 fall fire rehabilitation projects in Skull Valley. The seed mix consisted primarily of crested wheatgrass and was applied aerially (with and without chaining) and by drill seeding, methods appropriate for use on our site. Two of the rehabilitation projects were completed within the Davis Knolls burn, and the third site was within the Sheeprock burn (Table 1). The range site at our proposed site is the same as Davis Knolls, a semi desert gravelly loam.

The winter and spring precipitation (1997) following the Davis Knolls and Sheeprock seedings was 188% of average, and the crested wheatgrass establishment was good to excellent for the aerial/chained and drill seeded treatments (Table 1).

Common and Scientific Plant Names

Grasses	
Bottlebrush squirreltail	*Elymus elymoides*
Cheatgrass	*Bromus tectorum*
Indian ricegrass	*Achnatherum hymenoides*
Nordan crested wheatgrass	*Agropyron desertorum*
Forbs	
Russian thistle	*Salsola iberica*
Shrubs	
Shadscale	*Atriplex confertifolia*
Wyoming big sagebrush	*Artemisia tridenta* spp. *wyomingensis*

Costs of Potential Reseeding Techniques

Rangeland drill seeding

In areas accessible by tractor where soil textures are not too fine, drill seeding can be both efficient and effective. Advantages include one-step seeding and soil coverage, calibrated seed boxes for uniform seed distribution, and the ability to adjust planting depth to accommodate the species seeded (5).

These advantages make drill seeding more efficient than other methods, in part because it requires less seed (Table 2), while maintaining high establishment rates that are potentially 3–7 times those of broadcast seeding (6). In addition, implementation costs are relatively low. Table 2 summarizes the costs of the seeding methods.

Broadcast seeding with and without chaining

Broadcast seeding is the act of scattering seed on the soil surface without soil coverage. Seed can be applied from an airplane or helicopter, by hand, or

Table 1. Summary of Skull Valley burn sites used for cost-effectiveness analysis and risk analysis.

Burn	Area reseeded	Method of	Elevation	Average annual rainfall	Range site	Seeded plant density 1997	Seeded plant density 1999
	(acres)	reseeding	(feet)	(inches)		(plants yd^2)	
Davis Knolls	5,000	Drill	5,000	7.7	Semi-desert	9.5	5.1
(34,138 acres)	900	Aerial/chained	5,200		gravelly loam	6.75	6.75
Sheep Rock	2,200	Aerial	5,800	9.7	Upland stony loam	1.8	2.25
(9238 acres)		Aerial/chained§				21.6	7.2

§ BLM report did not specify the number of acres treated by each seeding method.

Table 2. Summary of fire revegetation costs on 5000 acres.

Seeding Method	Seeding rate	Seed total	Seed Cost[1]	Seed Application: Application cost	Seed Application: Seed Handling[3]	Total	Cost/acre
	(lb/acre)	(lbs)		(acres)(cost/acre)[2]			
Drill Seed	2.5	12,500	$26,250	(5000) ($8) = $40,000	$3,182	$69,432	$13.89
Aerial Seed	7	35,000	$73,500	(5000) ($6) = $30,000	$8,840	$112,340	$22.47
Aerial Seed/Chain	7	35,000	$73,500	(5000) ($6 + $20) = $130,000	$8,840	$212,340	$42.47

1.Seed cost based on Nordan crested wheatgrass pure live seed ($2.10/lb).

with broadcasters mounted on a tractor or tillage implement. It is a widely used seeding technique and a quick method of direct planting on rough terrain where drilling is impractical or impossible.

Broadcast seeding is most effective in areas with unconsolidated litter, naturally loose soils, and little vegetation. Species best suited to broadcasting germinate under brief, favorable conditions or in cool, dry environments. Small seeded species are also well suited since they are easily incorporated into the soils.

Limitations include poorly covered and distributed seed, which can result in slow establishment and low success. As a result, heavy seeding rates are necessary because most seeds aren't placed in favorable microsites for establishment and are susceptible to rodent and bird depredation (Table 2).

If aerially broadcast seed is covered, established plant numbers are more comparable to drill seeding. Seed coverage is frequently accomplished by chaining, a mechanical technique used to increase seed-to-soil contact, and although expensive, it can greatly increase seeding success. At Davis Knolls, the 900 acres that were chained yielded four times the plant density than a solely broadcast seeded area (Table 1). Call and others (2000) suggest that follow-up chaining made the difference between excellent and poor seedling establishment and reduced cheatgrass cover.

Project Risk

Our project considers only insufficient precipitation in the risk analysis. Of the risk factors associated with revegetation efforts, it is the simplest to estimate and is recognized as the greatest limiting factor on semi-arid/arid rangelands. Other factors that can be used to predict plant establishment are partially captured in annual precipitation such as consecutive above-average years, temporal distribution, event intensity and associated cooler temperatures. Additional project risks may include grasshopper or Mormon cricket outbreaks, fire, and the presence of invasive weedy species.

To determine how rainfall years before and after the seeding compare to the average, we obtained a long-term precipitation record (1950–2001) recorded by the Western Regional Climate Center at Dugway Proving Grounds, 3 miles from the burn (7). Between January and June of 1997, Skull Valley received 188% more precipitation than the 6-month average (7.9 vs. 4.3 inches). The first 6 months of 1999 also received above average precipitation (131% of normal). By 1999, the plant density at Davis Knolls and Sheeprock was "good", averaging 5.3 plants/yd^2 (Table 1). In contrast, plant density was low at seven similar sites seeded following the 1998 Skull Valley burns (0–1.8 seeded plants/yd^2) (7).

If we assume a lack of precipitation is solely responsible for the failure of the 1998 seedings, then a successful seeding requires precipitation to be between 131 and 188% of average. Additional precipitation and revegetation data would help narrow this estimate and possibly rule out (or in) other sources of risk. However, with no additional data, we decided 150% of normal (6.4 inches) as necessary for success (i.e., a seeded plant density of 4.5/yd^2).

Five (1980, 1986, 1995, 1997, 1998) out of 41 complete years of data collected at the U.S. Army Dugway Proving Grounds received greater than 6.4 inches of moisture within the first 6 months of the year. This equates to a 12% (5/41) chance that a seeding will produce the desired plant density. Further, we assumed that precipitation between 4.3 and 6.4 inches (100–149% of normal) between

January and June will give us a 37% chance of establishing a fair to poor seeding. Below average precipitation (less than 4.3 inches) occurs greater than half the time (51%); therefore, the likelihood of failure is significant.

Does this mean we should not attempt to reseed the site? Not necessarily. In years with normal precipitation, some seeds may germinate and establish while others may "wait" for favorable conditions. There is also a 49% chance that our site will receive adequate precipitation. However, while it is tempting to seed and hope for the best, such a strategy may result in a waste of time and resources. Therefore, we will evaluate possible plant densities based on the probability of each precipitation scenario (above average, average, below average) by conducting an expected outcome analysis.

In Table 3, the far left column shows the probability of each precipitation scenario. While the probability that any one scenario will occur is less than 100%, it's certain that for any given year the amount of precipitation from January to June will fall into one of these categories. Rows 1–3 show expected plant densities for each seeding method/precipitation combination, and the bottom row shows the results of the expected outcome analysis by seeding method.

To calculate *Total expected outcome* for drill seeding, multiply *Probability* (left column) and *Expected outcome by drill seeding* (second column) [i.e., (0.12 x 21,450 = 2,574); (0.37 x 10,115 = 3,746); (0.51 x 0 = 0)]. The sum of these three values (2,574, 3,746, 0) equals *Total expected outcome*

Table 3. Using probabilities to determine expected outcomes (number of seeded crested wheatgrass plants/acre) by seeding method.

	Expected outcomes by seeding method[1]		
Probability	Drill	Aerial/Chain	Aerial
		(plants/acre)	
.12	21,450	32,375	30,350
.37	10,115	14,160	13,310
.51	0	0	0
Total	6,317	9,124	8,567
Expected outcome[2]			

[1]Expected outcomes are based on the seeding rates given in Table 2.
[2]This number does not predict how many plants will occur on our site. Instead, we would expect to generate one of the actual results such as 21,450, 10,115, or 0 for drill seeding.

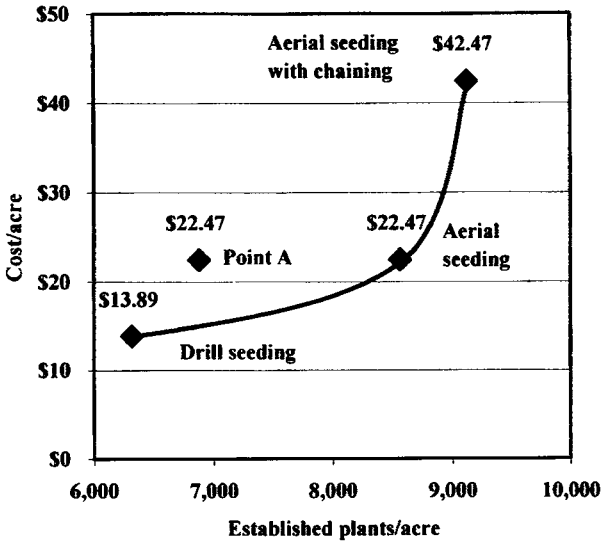

Figure 2. *Cost-effectiveness comparison for seeding crested wheatgrass using 4 different seeding techniques.*

(6317). Note that this number does not predict how many plants will be generated on our site by drill seeding. Instead, it allows us to compare, within our proposed site, the risk of drill seeding with alternative seeding methods. We could also use the total expected outcomes generated to compare seeding risk relative to other revegetation sites.

Putting It Together

Now that we have determined the four required pieces of information, (1) the goal of the project (20,230 plants/acre), (2) estimates of plant establishment from monitoring data collected from sites similar to our own, (3) the cost of various reseeding techniques (drill $13.89/acre, aerial $22.47/acre, and aerial/chaining $42.47/acre), and (4) project risk (total expected seedlings/acre: drill, 6,317; aerial, 8,567; aerial/chaining, 9,124), we can calculate the cost-effectiveness of our project.

Table 4 summarizes the costs and expected effectiveness of each seeding project. These results are shown graphically as an effectiveness curve in Figure 2. Unfortunately, the expected outcome analysis shows the likelihood of any method achieving our goal of 20,230 plants/acre is very low. The largest expected outcome calculated is 9,124 plants/acre. Therefore, we are left with three possible decisions regarding our site: (1) alter our goal to maximize seedling success or to correspond

with a fixed budget, (2) evaluate alternative seeding methods to potentially increase plant density, or (3) abandon reseeding efforts at our site, reserving resources for a site with a better chance of success.

Although this paper will not discuss (2) and (3), it may be reasonable for us to alter our reseeding goal. If we decide the presence of any seeded plant (regardless of density) will benefit the site, one option might be to maximize the number of plants/dollar spent or to minimize the cost/plant. Under either alternative, drill seeding offers both the highest number of plants/dollar (455) and the lowest cost/plant ($.002), making it the most cost-effective choice (Table 4).

Summary

The expense and uncertainty associated with semi-arid revegetation make rehabilitation efforts risky. Although risk cannot be eliminated, it can be evaluated within the context of various rehabilitation practices with the use of expected outcome and cost-effectiveness analyses.

We utilized a risk-adjusted cost-effectiveness analysis to evaluate a hypothetical revegetation project in Skull Valley, Utah. Our cost-effectiveness analysis employed an expected outcome calculation to incorporate risk by assigning probabilities to several precipitation scenarios. The analyses showed the likelihood of achieving our goal (20,230 plants/acre) was very low. This may be reason to evaluate additional seeding methods, modify the project goals, or revegetate an alternate site.

Table 4. Cost and effectiveness summary for seeding crested wheatgrass using 4 seeding techniques

Cost and Effectiveness	Aerial/Chaining	Aerial	Drill	Point A[§]
Cost/acre[1]	$42.47	$22.47	$13.89	$22.47
Effectiveness (number of plants/acre)[2]	9124	8567	6317	6880
CE ratio (cost per plant)	$4.65 x 10^{-3}	$2.62 x 10^{-3}	$2.20 x 10^{-3*}	$3.27 x 10^{-3}
EC ratio (plant per $1 spent)	215	381	455*	306

1. Includes the cost of seed, seed handling and application
2. Risk-adjusted established plant numbers
§ Hypothetical seeding technique
*CE or EC ratio of the most cost-effective alternative

Another option is to maximize the number of plants/acre. Although it's considerably more expensive than the other two methods, aerial seeding with chaining is expected to generate highest density (9,124 plants/acre). This may be a viable alternative if there is a threshold, say 9,000 plants/acre (1.9 plants/yd^2), below which any establishment is considered a failure. However, if we are concerned about both threshold success and working under a budget constraint of $25/acre, then aerial seeding (without chaining) becomes the most cost-effective solution.

Key to this discussion is understanding that any of the methods we select are potentially cost-effective and that the most cost-effective alternative is solely dependent upon how we have defined our goals. This is not to say, however, that any reseeding method could be cost-effective. Suppose we evaluated a fourth reseeding method (Point A) that costs the same as aerial seeding yet results in fewer plants/acre. This would not be a cost-effective solution (Table 4, Figure 2).

It should be noted that we provide a simplified example where only one risk (insufficient precipitation) is included and one species (crested wheatgrass) is seeded. Although these calculations are more straightforward than those that include a risk of insect infestation, they can be misleading. Because we are attributing any seeding failure to a lack of precipitation only our calculations are less likely to reflect true probabilities, and may underestimate the likelihood of success. For instance, during the spring of 1999 there was an outbreak of Mormon crickets, which likely had a negative effect on plant density for the 1998 seedings (8). This creates an obvious complication. How much of the difference in plant establishment on the 1996 and 1998 seedings can be attributed to insect herbivory, and how much to less rainfall?

Another simplification made, concerns plant species selection. Crested wheatgrass is commonly

used in rehabilitation projects on western rangelands. However, if natives were seeded it is likely that revegetation costs would increase and plant establishment would decrease. The overall result would likely be higher costs and lower effectiveness.

When interpreting the results of a cost-effectiveness analysis, it is important to recognize the omission of risks that are difficult to quantify. However, regardless of the necessary simplifications, cost-effectiveness analysis provides a tangible comparison of revegetation practices and enables managers to make better-informed decisions. In addition, the practice of quantifying the cost and expected plant density may increase awareness regarding the expense and risk of fire rehabilitation and encourage the development of more proactive range management practices.

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Drought Tolerant Forage
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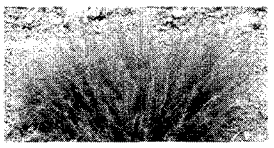
Weed Suppression
Habitat



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Biosolids in a Chihuahuan Desert Ecosystem

Biosolids offer a variety of opportunities to improve semiarid rangelands.

By David B. Wester, Ronald E. Sosebee, Richard E Zartman, Ernest B. Fish, and J. Carlos Villalobos

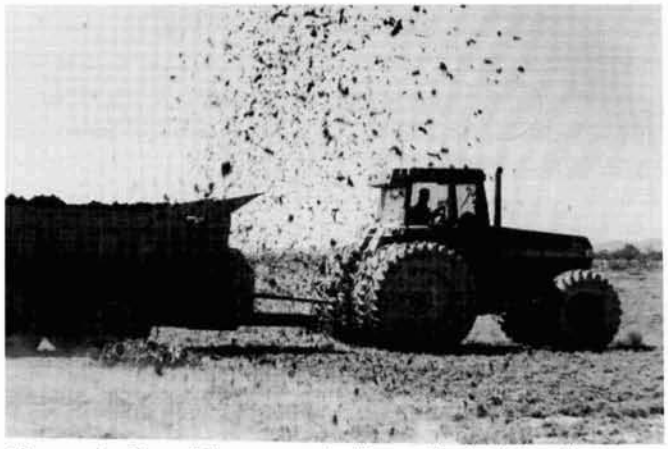

Figure 1. *Biosolids are topically applied with a farm-type manure spreader to rangeland in west Texas.*

Biosolids, formerly called "sewage sludge," are a byproduct of waste water treatment. The U.S. produced 7.6 million tons of biosolids in 1998, and annual biosolids production is expected to increase to 9 million tons by 2010.

Land-based disposal methods include incineration, land-filling, pelletization, composting, and land application. Biosolids contain organic matter and a host of macro- and micro-nutrients (Table 1).

Table 1. Biosolids contain many macro- and micro-nutrients (data from field studies by Texas Tech University).

Constituent	Composition
	(%)
Total nitrogen	3.71
Phosphorus	1.86
Potassium	0.18
Zinc	0.11
Magnesium	0.58
Manganese	0.07
Iron	2.21
Copper	0.09
Boron	0.003
Cadmium	0.0006

Because of the high nutrient value of biosolids, land application is the disposal method of choice. Biosolids can act both as a soil amendment, increasing soil organic matter, and as a fertilizer, increasing forage production and enhancing forage quality via recycling of valuable nutrients.

Land application is also the most economical method of land disposal. In 1998, 43% of all biosolids in the U.S. were land-applied. Increased research and changing societal values have led to predictions that nearly 50% of all biosolids produced in 2010 may be land-applied.

Many states have regulations restricting the conditions under which biosolids can be applied. For example, biosolids usually cannot be applied during precipitation events, or when snow or ice are on the ground. Thus, semiarid areas are choice locations for year-round biosolids application because there is minimal time lost to wet or cold conditions. Southwestern rangelands have therefore received increased attention as suitable areas for land application of biosolids (Fig. 1). Wide-open spaces remote from urban areas, equable climates, and large acreages in private holdings have attracted municipal and commercial sewage disposal entities to pursue possibilities of application in desert grasslands and shrublands in Texas, New Mexico, and Arizona.

In 1992, we began a ten-year research program investigating the effects of topically-applied biosolids at a Chihuahuan desert research site. We have studied the effects of biosolids on soil properties, erosion, runoff and infiltration; soil water quality; forage production and forage quality; plant ecophysiological responses; soil nutrient cycling; and livestock performance. In this article, we highlight some of our results from these studies.

The Research Site: Our study site includes about 900 acres of grassland and shrubland in the northern Chihuahuan Desert near Sierra Blanca in

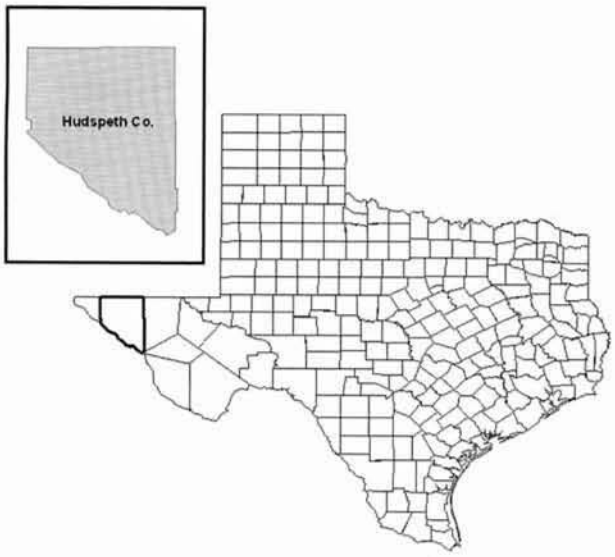

Figure 2. *Map of study site in west Texas.*

Hudspeth County, Texas (Fig. 2). Climate is a southwestern type, with hot summers and mild winters. Annual long-term rainfall averages 12 inches, 65% of which occurs between July and September.

Grassland areas with loamy soils are dominated by tobosagrass and alkali sacaton, with widely scattered mesquite and lotebush (Fig. 3). Fine sandy loam soils support blue grama, black grama, and assorted dropseeds with yucca and ephedra. Shrublands are dominated by creosotebush; fluffgrass and assorted dropseeds characterize the typically depauperate herbaceous component of this plant community.

Figure 3. *Tobosagrass and alkali sacaton are dominant grasses in our study site, with widely scattered mesquite.*

We have coordinated over a dozen research projects involving range scientists and soil scientists with a standardized methodology that includes application rates of 0, 3, 8, 15, and 40 dry tons/acre of biosolids on three range sites. Application rates regulated by the State of Texas range from 3 to 8 tons/acre. Our highest application rate was intended to document effects of excessive application far above amounts that would be expected in a commercial setting.

Applications Increase Soil Water and Reduce Erosion

Biosolids application has important impacts on hydrological processes both at a small scale and at a large scale. Because erosion, runoff, and infiltration of each square foot of rangeland are affected by biosolids application, we can also expect major hydrological consequences on the scale of 1,000-acre land units that are treated in commercial application projects. In order to manage large-scale applications, it is important to understand how biosolids affect the basic processes of soil water infiltration, runoff, and erosion.

We used a portable rainfall simulator to study how infiltration and runoff are affected by biosolids. The simulator applied water at a rate of 6.4 inches/hour for a 30-minute period to plots treated with 0, 3, 8, 15, or 40 dry tons/acre of biosolids on a site dominated by tobosagrass and a site characterized by creosotebush. At the loamy site, we also studied the effects of biosolids applied on top of tobosagrass plants and in bare areas between plants. Experiments required about 2 months to complete after biosolids application.

Biosolids on the soil surface reduced erosion. For example, in the bare areas between tobosagrass plants, even the lowest biosolids rate (3 tons/acre) reduced erosion by about 40% compared to bare areas not treated with biosolids. Increased soil water infiltration was associated with reduced erosion.

These effects are consequences of at least two factors. Topically-applied biosolids provide a surface cover that can absorb the impact of falling raindrops. This reduces the detachment of soil particles that occurs during storms. Biosolids also increase soil organic carbon, especially at the soil surface,

which inhibits crust formation and further promotes infiltration. The net result of biosolids application is reduced soil erosion and runoff and increased soil water infiltration.

Soil Water Quality Not Reduced

Soil water quality issues relate to quality of water that infiltrates into a treated soil, and also to the water that runs off of a treated soil. Our research has investigated both of these concerns.

The quality of water that had passed through soils treated with biosolids was studied with microlysimeters constructed of 10-inch polyvinyl choride well casing. Tubes 2 to 3 feet in length were inserted into a loam soil dominated by tobosagrass and a fine sandy loam soil dominated by black grama, extracted with a soil column intact, and transported to an on-site indoor laboratory. In one experiment, we applied biosolids to the soil surface. Water was hand-sprinkled to simulate rainfall until sufficient leachate was collected from the bottom of the lysimeter for chemical analysis. The leachate was analyzed for chloride, nitrate-nitrogen, pH, orthophosphates, sulfates, calcium hardness, and total hardness; also, we analyzed for 20 elements including aluminum, beryllium, cadmium, copper, iron, lead, and molybdenum.

In general, when biosolids affected concentrations of the elements we tested, these effects were observed at the highest application rate of 40 tons/acre. In fact, our measurements indicated that leachate from soils treated at rates up to 15 tons/acre was generally within USEPA drinking water standards. Our results suggest that soil water quality associated with *topical application* of biosolids should not be a concern.

However, when we repeated this experiment but mixed biosolids into the top four inches of the soil in the lysimeters, we found markedly different results. For example, incorporation in the surface soil increased the release of mobile constituents such as nitrate-nitrogen, sulfate, and chloride. Nitrate-nitrogen was never below drinking water standards even in 0 tons/acre lysimeters.

This indicates that soil water quality may be affected by soil disturbance, even in the absence of biosolids, as well as by biosolids. Our results suggest that water quality of leachate is well within the range of drinking water standards when biosolids are topically applied at commercially-regulated rates.

> The USEPA has established maximum contaminant levels for health-related trace contaminants in drinking water. A trace contaminant is defined as an element or compound with a standard tolerance level allowed which is generally less than 1 ppm. Secondary maximum contaminant levels that affect aesthetic quality of drinking water have also been established; secondary maximum contaminant levels are not related to health issues.

Runoff Water Quality Is Acceptable

We also studied the quality of runoff water from biosolids-treated soils. All of the trace elements and compounds for which a maximum contaminant level has been established were below this level in our runoff water. Likewise, those elements and compounds for which a secondary maximum contaminant level has been established were well below this level except for manganese. Runoff water thus generally meets USEPA standards for drinking water at all application rates except 40 tons/acre of biosolids.

Little Ammonia Nitrogen Is Lost

State and federal regulatory agency guidelines for biosolids application are based on the balance between nitrogen needs of a plant and "plant available nitrogen" supplied by biosolids. This approach is used because nitrogen in biosolids can be lost via ammonia volatilization; thus, plant available nitrogen is more important than total nitrogen in establishing application rates that are beneficial for plant growth.

We studied ammonia volatilization from biosolids as it was influenced by "hot" (68 to 97° F), "intermediate" (43 to 73° F), or "cool" (25 to 57° F) temperatures. Less than 10% of the applied ammonia-nitrogen was lost via volatilization in the first three days following 3 tons/acre application under cool conditions; under hot conditions, about 16% of the ammonia-nitrogen was volatilized within three days.

Air temperature is especially important in the volatilization process during the first few days following biosolids application. Slow drying conditions allowed for more volatilization to occur over a longer time period than when drying was rapid.

Air temperature during and after application also can affect degradation of biosolids. We studied this issue by measuring CO_2 losses over a 29-day period from biosolids applied to a clay loam soil in a sealed, forced-air chamber. The conditions in the chamber [three temperatures (41, 73 or 100° F) and two initial gravimetric soil water contents (5 or 15%)] were similar to conditions at the field test site at Sierra Blanca, Texas.

Immediately after biosolids application, we detected an initial loss of CO_2 that was not caused by microbial degradation. For the next 52 hours of the experiment following this initial CO_2 loss, carbon loss increased significantly as temperature increased. After this time, however, carbon loss was not related to temperature. Since temperature does not affect carbon loss beyond 2 days after application, and we measured carbon loss even at temperatures as cool as 41° F, we conclude that biosolids may be applied throughout the year (local weather permitting).

Increased Forage Production

In addition to adding micro- and macro-nutrients, biosolids on the soil surface provides a physical mulching effect that moderates soil surface temperatures and reduces soil water evaporation. These benefits are expected to vary depending on rate, season, and frequency of biosolids application. Several of our studies investigated the combined effects of rate (0 to 40 tons/acre), season (dormant or growing), and frequency (1 year only, or 2, 3, or 4 consecutive years) of biosolids application on tobosagrass and alkali sacaton forage production. We also studied the effects of supplemental irrigation.

The impact of season of application on grass production was important only during the first growing season following application. Standing crops of tobosagrass and alkali sacaton were enhanced more when biosolids were applied during the previous dormant season (early March) than during the growing season (early July). Standing crop of these species during the second and subsequent growing seasons was not affected by season of application.

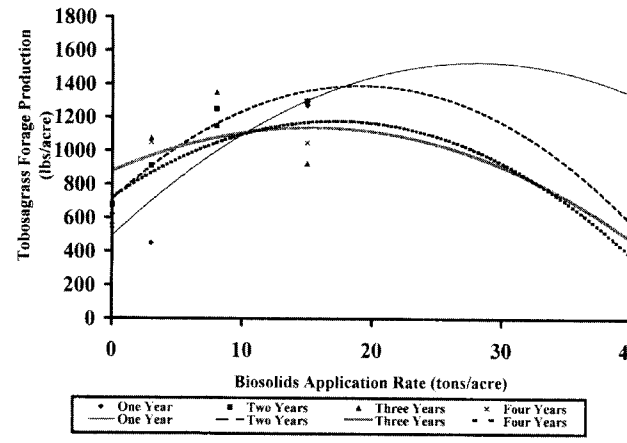

Figure 4. *Tobosagrass forage production at the end of 1996 in nonirrigated plots that were treated with biosolids for one year only (in 1993), or for two years (1993, 1994), three years (1993-1995) or four years (1993–1996).*

In general, although standing crop increased as biosolids application rate increased, it increased at a decreasing rate (Fig. 4). Standing crop usually decreased at the 40 tons/acre rate, especially after multiple applications, compared to lower application rates. However, in almost every case we investigated, standing crop in treated plots equaled or exceeded standing crop in untreated plots. We conclude that biosolids generally have a neutral or positive effect on aboveground production of these species. And from our irrigation studies, we learned that the beneficial effects of biosolids on forage production did not depend on water availability.

Measurements of standing crop are production-oriented indices of plant response to biosolids. We also investigated how biosolids applications affect leaf area, photosynthesis, and water use efficiency of tobosagrass and blue grama.

In general, leaf area was increased by biosolids when soil water was adequate. Tobosagrass photosynthesis on the first day following irrigation was also increased by biosolids application; although photosynthesis decreased thereafter, it was still higher in irrigated and biosolids-treated plants than in untreated plants. Blue grama had higher photosynthetic rates when treated with biosolids. Biosolids application also increased water use efficiency of our plants. Greater leaf area and higher photosynthetic rates are involved in overall plant pro-

Economics of Sale Weight, Herd Size, Supplementation, and Seasonal Factors

Russell Tronstad and Trent Teegerstrom

Quantifying the rate of gain for a calf on the range is critical for evaluating the profitability of different production protocols and market strategies. Tradeoffs between calf sale weights and cow numbers, seasonal forage and price conditions, supplemental feeding, and the price spread between light and heavy calves were evaluated for 2 ranching regions in Arizona. Heavier sale weights were not sufficient to overcome lower prices for yearlings. The most profitable calf sale weight and supplemental feeding strategy was found to differ marginally for the 2 regions.

Characterization of Diversity among Three Squirreltail Taxa

T.A. Jones, D.C. Nielson, J.T. Arredondo, and M.G. Redinbaugh

Squirreltail is a complex of five taxa whose systematic interrelationships are uncertain and ecological amplitudes are poorly understood. An analysis of several ecological and physiological traits of materials collected in the 10 contiguous western states described variation between and within *Elymus elymoides* ssp. *elymoides*, *E. elymoides* ssp. *brevifolius*, and *E. multisetus*. These taxa were found to be ecologically distinct from each other, and three distinct groups of accessions were found within *E. elymoides* ssp. *brevifolius*. These results highlight the highly ecotypic nature of the squirreltails, suggesting that restoration practitioners should match site with genetically and ecologically appropriate squirreltail material.

Seed Germination of Willow Species from a Desert Riparian Ecosystem

James A. Young and Charlie D.Clements

Recruitment of seedlings of native willow species is desirable for the restoration of riverine riparian areas following mechanical, herbicidal, or biological control of invasive tamarisk. The germination characteristics of seeds of tree willow and coyote willow at a wide range of constant or alternating incubation temperatures were evaluated. The germination responses and overlapping phenology of these 2 species are very similar meaning they probably compete for germination safesites. The management of riverine willow populations to enhance seedling recruitment is obviously a very complex undertaking.

Comparison of Two Techniques for Monitoring Vegetation on Military Lands

C.W. Prosser, K.M. Skinner, and K.K Sedivec

The U. S. Army Land Condition Trend Analysis Program is being used on Army installations worldwide, but it may not accurately depict species diversity and composition. The Program was compared with quadrat sampling techniques on a military installation in the transitional grasslands between the tall and mixed grass prairies in east-central North Dakota. The military sampling program did not detect a third of the plants, was labor intensive and time consuming. There is a need to re-evaluate the program across the various ecosystems worldwide to determine if the Army's sampling technique is adequate to make long-term management decisions on military installations.

Initial Beaked Hazel Growth Responses Following Protection from Ungulate Browsing

Jody N. Best, Edward W. Bork, and Norm Cool

Despite the importance of beaked hazel for ungulates in western Canada, little information exists on the response of this shrub to intensive wildlife herbivory. This study compared changes over 2 years in beaked hazel stem morphology (total twig length and number) and current annual growth in browsed shrubs, with shrubs recently protected from herbivores in Elk Island National Park, Canada. Although results varied among sites, beaked hazel stems generally increased in growth with protection. Additionally, documented changes at the shrub stem level did not match those of the plant community, suggesting observed responses vary with the scale of measurement.