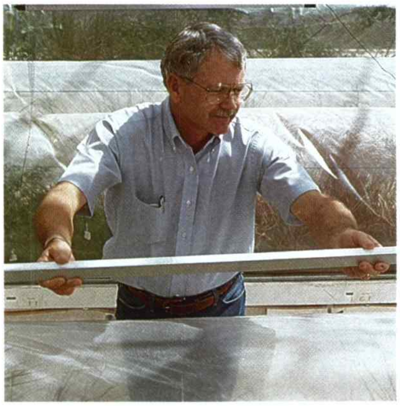
ARS Range Research

R. Dennis Child and Gary W. Frasier

Why Range Research?

The earth's land surface is approximately 51 percent range and permanent pasture. Range and pasture are found in every state and cover 55 percent of the land surface of the United States and about 80 percent of the western states. These range and pasture lands provide forage for some 70 million cattle, 20 million deer, 8 million sheep, 500,000 pronghorn antelope, 400,000 elk, 55,000 wild horses and burros and many other grazing animals.

To many people, range has narrowly been identified only for its tradition of supporting livestock. The goods and services rangeland provides and the important linkages it has with other components of the production system have often been forgotten when range is thought of as a "use" and not a "type" of land.



Range scientist Herman Mayeux checks light-sensing bars that indicate solar radiation in a growth tunnel.

The different users of rangeland, in a multiple use context, have often viewed each other as competitors, and have not joined voices to express opinions on its common importance. In addition, many of the goods and services marketed from range and pasture land have a value that is marketed separate from the land which produced it.

Many people believe that much of the land that is classified as rangeland has or is undergoing change. This change, for the most part, is perceived to be destructive in nature and lowering the productive capacity of the land. In contrast to a global downward trend, the condition of the range and pasture lands in the United States has improved on a substantial fraction of both private and public lands in the last thirty years. **Research has played a key role in this improvement.** Balancing the many uses of rangeland for the benefit of society requires a research program that is conducted within an ecological framework.

Relevant Outside Influences

Change has characterized the 1980's and the first part of this decade. Change is reflected in all components of our world. Some of the major changes related to rangeland ecosystems are:

Global Environmental Change. The specter of Global Environmental Change haunts contemporary society. The 1987 report, *Our Common Future,* published by the World Commission on Environment and Development, concluded that the environmental crisis and the developmental crisis were one and the same and that sustainable development was the only way to ameliorate the crisis. They defined "sustainable development" as: "Development that meets the needs of the present without compromising the ability of future generations to meet theirs."

World Political Change. In the past few short years, we have experienced unprecedented change in the political environment throughout the world. A workshop co-sponsored by Colorado State University and Senator Wirth held in October 1989 focused on global change. During the workshop, the expression was made, stop the "cold war" and begin the "green war." Many nations that in the past would have been unlikely partners are now ready to join forces and work together for our environmental future.

A Changing Public Opinion. We are in an era of renewed environmental awareness. It seems obvious that changes on rangeland have ties to global environmental change. If the general public continues to shift thinking and priorities toward long-term payoff, or an ecological outlook, and if we are seen to have a strong ecological base as well as interests in sustainable production systems on rangeland, range research should rise in priority.

Research Program and Areas of Emphasis

Range research in the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) currently has an appropriation of about $13 million. Approximately 37 percent of the 1991 ARS appropriation for range research is allocated to Great Plains ecosystems, 20 percent to sagebrush and desert grasslands, and 13 percent to more arid shrub types. The remaining 30 percent is categorized as "other rangeland" and is mostly allocated to range insect research, remote sensing, brush and weed control, and other management practices.

In November 1988, scientists from the ARS and other research and academic institutions were asked to identify accomplishments and products they would anticipate to be completed during the next decade. For the most part, their inputs build from and represent the direction that current ARS programs are taking. A brief overall

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summary of the expected accomplishments follows:

...New releases of grass, legume and shrub germplasm with: (1) improved heat tolerance, (2) elimination of post harvest dormancy, (3) drought resistance, (4) forage yield, (5) winter hardiness, (6) digestibility, (7) seedling vigor, (8) nitrogen fixation, and (9) adaption to saline soils.

...A comprehensive synthesis of seed and seedbed ecology of major plant species along with innovative or "natural" methods for distributing and establishing seedlings of desirable plants.

...Procedures and integrated management systems that will consider all users of rangelands, protect existing water supplies and prevent soil and water contamination.

...Techniques for managing unwanted plants including biological control methods using the grazing of sheep, camels or goats, insects or the use of pathogens.

Management tools (geographical information systems (GIS), artificial intelligence (AI) and other models) to develop cost effective management strategies.

The Society for Range Management identified seven broad research areas for rangeland in the 1990's. These areas used by the ARS to organize its range research program are:

1) **Water Quantity, Quality and Management**
2) **Basic Ecology**
3) **Soil, Plant, Animal Relations**
4) **Integrating Land Uses**
5) **Integrated Systems Research**
6) **Plant Improvement and Protection**
7) **Weed and Brush Management**

ARS Organizational Structure and Research Approach

Public goals in government have shifted from supporting generalized capabilities (research, information, and education) to programs that are accountable for visible results. There has been a shift in societal thinking regarding agriculture from emphasizing only quantity to seeking for quality and sustainability with an overall concern for the total environment. The research approach and objectives of the next decade must broaden to encompass these values while addressing them within a total production unit framework. This will be one of the challenges for ARS range research in the next decade.

The ARS research approach requires stronger linkages between scientists from a wide variety of disciplines to improve the integrated production systems that typify today's changing world. Workgroups within the major physiographic regions were established to focus limited resources to the most critical problems and help range research achieve greater effectiveness.

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Measurement of plant responses to changes in CO_2. ARS in Fort Collins, Colo.

Seven **Systems Research Regions** have been identified with a lead location to implement specific research objectives. Their primary objective is to learn how production systems work from a basic ecological perspective and adapt this understanding to meeting the needs of resource managers and decision makers in the region. Six locations have also been designated as lead locations for **Specialty Research,** each having a research leadership and coordination role in an application that has broad implication across physiographic regions.

Principal Regional Systems for Sustainable Range/Pasture Crop Production Systems

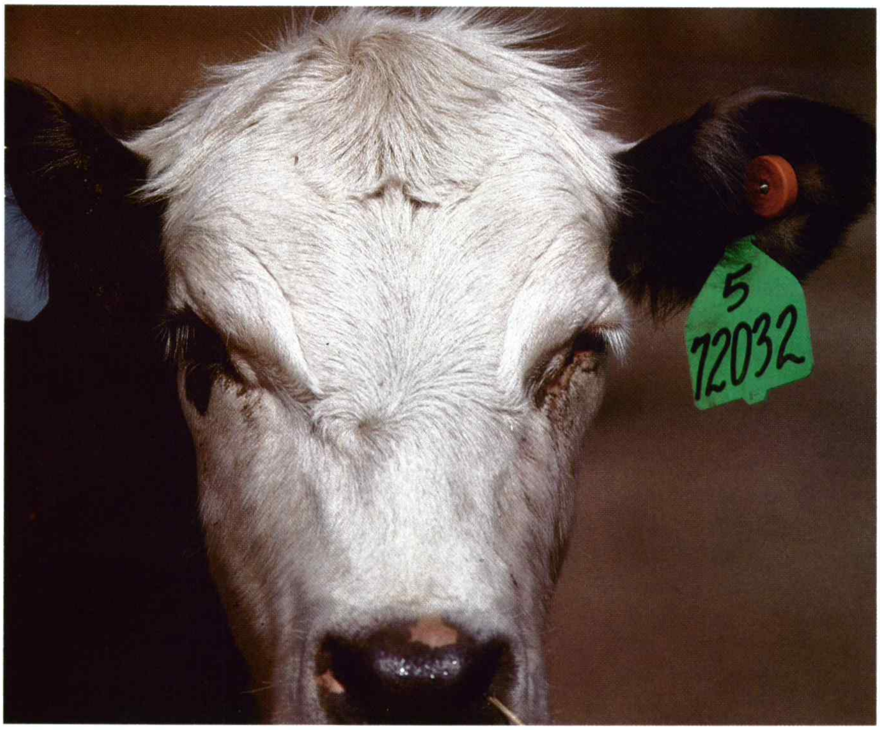
Northern Plains/Systems Research

Principal location—Miles City, MT
Linked locations—Mandan, ND; Sidney, MT; Fargo, ND

The research program at the Fort Keogh Livestock & Range Research Laboratory USDA-ARS, Miles City, Montana is to develop sustainable and economical range livestock production systems for the Northern Great Plains. Fort Keogh, a 55,300-acre laboratory, has a multi-disciplinary research program in four broad disciplines: (1) range ecology and management; (2) range animal nutrition; (3) beef cattle genetics; and (4) beef cattle reproductive physiology. The current emphasis of the research program is on developing beef cattle grazing strategies that maintain the range resource on a sustained basis.

Fundamental to the program is the underlying belief that grazing by large herbivores is essential for maintaining the health of Northern Great Plains rangelands. An important question centers on whether domestic livestock are acceptable substitutes for historically wild ungulates, in terms of imposing equivalent evolutionary impacts on the rangeland resource. At present, no profound evidence is available suggesting livestock are not acceptable substitutes for wild herbivores. With 150 million acres of native rangelands in the Northern Great Plains, an understanding of the potential impacts of current livestock management regimens on the sustainability of these rangeland ecosystems is critical for the development of ecologically and economically sound management strategies.

Drought-Grazing Interaction Studies. Field studies are designed to examine fundamental drought-grazing interactions in a timely and scientifically sound manner in temporarlly variable environments. In addition to quantifying the interaction effects of drought and grazing on the long-term stability of Northern Great Plains rangeland ecosystems, concurrent detailed plant physiological studies are being initiated to identify key mechanisms associated with induced changes. Such studies are designed to provide insight into how plant communities respond to imposed climatic stresses, how such responses are altered by grazing, and whether such responses result in temporary or permanent change in the structure and function of Northern Great Plains rangeland ecosystems.



Tagged for study.

Seed Bank Dynamics Studies. Studies are underway to quantify the seed bank dynamics of indigenous Northern Great Plains rangelands. Knowledge of seedbank dynamics is critical for the development of sustainable vegetation management strategies. For example, how vegetation communities respond to a disturbance event such as fire, herbivory, plowing, herbicide application, and severe drought is conditioned in part by the seeds present at the time of disturbance.

Range Renovation Studies. There are a number of fundamental problems associated with renovation of rangeland ecosystems. In the Northern Great Plains, the two annual bromes, Japanese brome and cheatgrass, are classified as invader species. Both are assumed to seriously depress perennial grass production and to be of limited nutrient value to grazing livestock. Unfortunately, quantitative data validating these assumptions is absent. A major effort is underway to quantify the ecological niche that these two annual grasses fill in Northern Great Plains rangeland ecosystems and to assess their potential economic impact on the beef cattle industry.

A second problem associated with renovation of rangelands is related to post-establishment persistence. This is of a major concern throughout the central Great Plains Region of the United States because of the vast number of acres of farmland currently committed to the Conservation Reserve Program. How should these lands be managed once they are released from the program? A portion of the range research program is focused on quantifying the multi-facet impacts of defoliation, fertilization, and/or irrigation on regrowth potential and nutrient quality of several introduced forages.

Range Animal Nutrition. The range animal nutrition research program focuses on the efficient harvest and utilization of the Northern Great Plains forage base on a sustained basis. This requires a basic understanding of various management strategies as they relate to balancing the relationship between plant growth and reproduction, and removal of the growing tissue via the grazing process.

The goal during the next 5 years is to attain a creditable data set that clearly identifies the factors that drive Northern Great Plains successional processes and to relate the effect of these factors to beef cattle production. To successfully meet this goal will require recognition of different steady and transitional ecological states and associated critical thresholds. Once the successional dynamic processes are known governing the Northern Great Plains rangeland and the associated factors altering these processes, research will be initiated to develop effective management schemes for steering succession.

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Central Plains Systems Research

Principal location—Ft. Collins, CO

Linked locations—Cheyenne, WY; Akron, CO, Lincoln, NE; Clay Center, NE

Research of the Rangeland Resources Research Unit, Cheyenne, Wyoming/Fort Collins, Colorado is directed toward understanding the interrelations and interactions of the shortgrass and mixed grass prairies of the Central Great Plains in Wyoming, Colorado and adjoining states. The area is flat to gently rolling with minor topographic features except the drainages of the Platte and Arkansas Rivers. The area is ideally suited for grazing by large animals. Native vegetation is dominated by blue grama and buffalograss with some western wheatgrass, needle-and-thread, other midgrasses and dryland sedges. Midgrasses become more abundant in the mixed grass prairies. Many broad-leaved plants or forbs are found, but none are as abundant as the grasses. There is significant variability in the amount and timing of annual rainfall which affect forage production.

A major portion of the research is conducted at two experimental field facilities, the Central Plains Experimental Range (CPER), Nunn, Colorado and the High Plains Grasslands Research Station (HPGRS), Cheyenne, Wyoming. Some of the major research objectives are: to develop improved germplasm for use in semiarid rangeland regions; develop an understanding of soil-water-plant relations of desirable range grasses, legumes, and shrubs based on sound plant physiological responses; develop management alternatives for disturbed lands and marginal soils; develop grazing management techniques for sustainable economic returns and; develop an understanding of the factors affecting forage quality in the semiarid rangeland regions.

> **50 years of grazing research has shown that moderate grazing intensities maintain shortgrass prairie vegetation and that short-term climate changes have more effect on vegetation change than does grazing.**

There is a major need for legumes in pastures and rangelands in the area. Two species, cicer milkvetch and yellow flowered alfalfa are being emphasized. Forage quality of cicer milkvetch is equal to that of many common legumes; however, it does not cause bloat. It is also a winter-hardy, long-lived perennial that has excellent potential for maintaining productivity and sustainability on rangelands in the northern half of the United States. The yellow-flowered alfalfas have several desirable traits, including cold and drought tolerances that are of considerable value in the rangeland environments of the Central Great Plains. Both legumes have the possibility of elevating nutritive value available to livestock themselves and for increasing the nutritive value of other species grown with them.

Fifty years of grazing research has shown that moderate grazing intensities maintain shortgrass prairie vegetation and that short-term climate changes have more effect on vegetation change than does grazing. The type of grazing system utilized did not have any major effect on the total plant and grass cover or the dominant species frequency and density values. Procedures have been developed to estimate the most profitable stocking rates and returns based on items such as forage supply, forage utilization, and costs.

Carbon and nitrogen cycling studies on marginal highly eroded croplands are being used to evaluate the soil benefits that might be achieved from the Conservation Reserve Program land in the Central Plains area and to develop alternative management systems that would prevent further degradation. Germination and seedling establishment characteristics of desirable rangeland plants are being evaluated for application in returning disturbed and eroded lands back to diverse, stable, and productive plant communities, for improving the quantity and quality of the forage resource, and for preserving the aesthetic features of the landscape.

Future grazing research will focus on optimizing the use of native vegetation by defining vegetative growth and quality factors and matching these factors with the nutritional requirements of animals. Low palatability shrubs and grasses will be incorporated in the rangeland plant community for trapping snow and conserving soil moisture which is necessary for optimizing plant sustainability, utilization, and production. Historical trends and current projections of future patterns in atmospheric levels of CO_2 indicate a continued global enrichment. Changes in the global CO_2 levels are bound to have significant impacts on the composition and nutritional values of range plant communities. It is expected that the changes in the atmospheric gasses will affect both above and below ground plant growth processes with some long term impacts. Future work will be to evaluate the range plant community response to various aspects of the environment.

Water conservation by snow management, Cheyenne, Wyoming.

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Southern Plains Systems Research

Principal location—Woodward, OK

Linked locations—El Reno, OK; Temple, TX; College Station, TX

The USDA-ARS Southern Plains Research Station, Woodward, Oklahoma, serves an extensive area of rolling plains in Oklahoma, Texas, New Mexico, Kansas, and Colorado. The major land uses in the area are cattle grazing on native rangeland and improved pastures, and wheat farming. These uses are often combined within operational units and managed to optimize forage use from both grass and wheat pasture.

Research is directed toward investigating the structure and function of Southern Plains rangeland and related ecosystems to select and develop enhanced germplasm of native and introduced forage species and to develop efficient forage-livestock production systems. Program areas are: plant materials improvement; plant physiology, morphology, and ecology; soil-plant relations; plant-animal interactions; and systems ecology.

Forage Variety Development. Development of superior plant materials is a major research effort. The Woodward station is known for its work on native grasses, weeping lovegrass, and Old World bluestems, and more recently eastern gamagrass. Other plants under development include accessions of big and sand bluestem. A long-lived cool season plant, Texas bluegrass, may increase the availability of high quality forage during fall, winter, and early spring.

Old World bluestem releases during the past decade are estimated to have generated $100 million annually for the economy of the Southern Plains. The drought tolerant Woodward variety 'WW-Spar' Old World bluestem, released in 1982, is boosting productivity on more than 1 million acres. A chaffy seed harvester developed at Woodward contributed significantly to this accomplishment. 'WW-Iron Master' bluestem has proven useful on iron-deficient cropland. Other grass releases include 'Woodward' sand bluestem, 'Coronado' sideoats grama, and 'Morpa' weeping lovegrass, now grown on millions of acres in the Southern Plains. These releases have benefitted livestock production, the seed industry and the general economy of the region while conserving millions of tons of soil through reduced erosion.

Much of the current work centers on eastern gamagrass, a native warm-season grass, which shows promise for increasing forage production in many parts of the Southern Plains and in south and eastern U.S. It produces forage earlier in the spring than most other warm-season grasses, allowing deferment of native rangeland during the critical early-summer growth period. Eastern gamagrass can increase the productivity of areas with high water tables, while stabilizing sites and reducing erosion. High productivity for green-chop, hay or silage or for intensively managed pastures makes eastern gamagrass a candidate for incorporation into complementary forage systems and drought and other emergency feeding systems.

The germplasm research is conducted in an ecosystem context. Plant materials screening and evaluation includes measurements of stem/leaf ratios, rates of leaf and stem production per unit of soil water and solar energy, and CO_2 uptake rates. Potential cultivars are evaluated for their soil conserving characteristics, establishment and production requirements, fertility needs, palatability, forage quality, grazing tolerance, and red meat production potential. Work is also underway to identify plants which are able to tolerate adverse conditions such as low soil fertility, saline conditions, temperature and moisture extremes, and insect and disease problems.

Ecologist Wayne Polley uses a surface neutron meter to monitor moisture levels in various parts of a growth tunnel.

Rangeland Ecosystem Management. Understanding, developing, and maintaining grazing land systems is another main area of research. The focus here is investigation of methods to maintain and improve existing native communities, and to establish and use forage plant species on marginal farmlands. Research thrusts include the effect of fire and grazing intensity on the long-term health of rangeland condition, and the development of more cost-effective grazing through the alteration of plant quality characteristics such as leafiness and digestibility.

Fifty Years of Grazing Research. —Fifty years of grazing research at the station has produced a knowledge base from which management recommendations of regional and national significance are made. Forage systems research has provided more resource efficient management practices. Land requirements per yearling steer, for example, can range from 8 acres for yearlong grazing of native rangeland to as little as one acre for double-cropped warm- and cool-season annuals. Production per yearling remained similar for all systems while gain per acre steadily increased from around 50 to 400 lbs with significantly increasing levels of management intensity.

Future Research. Work on forage-livestock production systems will emphasize the use of native perennial pastures to complement the mixed grass prairie. In these studies eastern gamagrass and Texas bluegrass will be tested for their potential to provide high quality forage in sufficient quantities to the complementary system. A long-term goal is to develop eastern gamagrass into a dual purpose forage-grain crop. Research to understand climate-soil-plant systems interactions for a range of utilization strategies will continue. This work will increasingly rely on the use of mathematical descriptions of plant growth dynamics that more precisely define and prioritize the gaps in the knowledge required to efficiently manage these resources.

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Great Basin Systems Research

Principal location—Burns, OR
Linked locations—Reno, NV; Dubois, ID; Logan, UT; Boise, ID

The USDA-ARS has 5 research locations in the Great Basin area concerned with the sagebrush steppe and associated forested range at the higher elevations. These research programs are directed from the Forage and Range Research Laboratory, Logan, UT; U.S. Sheep Experiment Station, Dubois, ID; Northwest Watershed Research Center, Boise, ID; Range and Meadow Management Unit, Burns, OR; and the Landscape Ecology of Rangelands Unit, Reno, NV.

Many of the range research programs in the area have dealt with range improvements and/or range weed control. The spread of halogeton across the Great Basin increased the push to develop weed control strategies. Many acres of crested wheatgrass were seeded to biologically suppress halogeton. No other viable control strategy was found. Range research at Logan, Dubois, Burns, and Reno centered around the development and testing: of appropriate germplasm; seeding technology; and chemical control of weedy species. The development of 2,4-D during World War II opened a new area of research—the chemical control of big sagebrush and subsequent release of native perennial grasses. Much of our knowledge of the genetics of wheatgrasses was developed by ARS scientists at Logan, and germination responses of native and introduced species and seeding techniques were extensively tested by the ARS team at Reno. Additionally, research on the genetics and physiology of sheep was conducted at the U.S. Sheep Experiment Station, resulting in the development of the Columbia, Targhee, and Polypay breeds. The program at Burns acquired much information on nutrition and management of cattle on the sagebrush steppe. The Northwest Watershed Research Center provided information on water supply, flooding, and sedimentation.

There has been a general shift toward explaining *why* we see a particular response. We still do not have a complete picture of the reasons for success or failure of various reseeding trials. We know juniper can establish on a site and eventually eliminate many other species, but the reasons have only recently been documented. There is also recognition that we need to apply results to more sites than just those where the data were collected. The best way to accomplish this task is to determine which factors influence the success of a particular management practice.

The Northwest Watershed Research Center serves as the basis for development and testing of models that predict hydrologic responses to climate and management. At Reno, NV, data on seed germination serves as a starting point in determining why and when seedlings become established in the field. A common garden of plant material from around the world has been assembled at Logan, Utah. This collection serves as the basis for plant breeding programs, and for the study of cytogenetics and plant physiology. New cultivars of grasses, forbs, and legumes have been released from the breeding program. The grass release 'Hycrest' crested wheatgrass is currently the second most widely planted cool-season grass in the U.S. Research at Logan has also contributed to a better understanding of water use efficiency, carbohydrate metabolism, cool-temperature growth, and taxonomic relationships of the various species and cultivars of interest. The effort has expanded to include native, as well as, introduced species.

Research at Dubois, ID, and Burns, OR, has been focused on livestock and the influence of livestock on native and introduced plant species. At Dubois, the major emphasis is on co-species grazing (primarily sheep and cattle) and using livestock to manage noxious weeds. Scientists at Dubois have shown that exposing lambs to leafy spurge early in life can increase consumption of this weedy species by 50%. Studies from Burns provide information on the relative palatability of both native and introduced species, and alternative management strategies, such as nontraditional seasons of grazing. In addition, Burns, Dubois and Reno have programs addressing the influence of grazing on riparian zones.

Future research will address questions like: how might global climate change influence water and vegetation patterns? How does management influence biodiversity and what can be done to enhance habitat diversity? The emphasis on multiple uses of rangelands and sustainable resource use will continue to increase.

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Southwest Desert Systems Research

Principal location—Las Cruces, NM

Linked locations—Tucson, AZ; Temple, TX

In 1908 E.O. Wooton, a New Mexico botanist, published a report on the range problems in the Southwest. Wooton cited a 1905 Public Lands Commission survey of 118 New Mexico stockmen, of which 102 believed that rangeland grazing capacity had been reduced in the prior two decades due to either overstocking or drought. Wooton speculated that from 20 to 100 percent improvement in nearly all of these ranges could be obtained through ordinary sound judgement, livestock control and good management practices.

Research at the USDA-ARS, Jornada Experimental Range, Las Cruces, New Mexico, have provided many of the tools required for good management, especially those related to revegetation practices, livestock grazing management strategies and brush control technologies. With identification of some basic management principles, range livestock producers have developed their own site specific grazing strategies and methods.

Current rangeland condition assessment show a continued need for focused research, but in new directions. Demands for wildlife habitat, especially for threatened and endangered species (the desert tortoise and mexican wolf are examples), recreational areas, development of mineral and fossil fuel resources, watershed protection, as well as livestock forage requirements are vigorously vocalized in the Southwest.

We must thoroughly understand how desert ecosystems function before we manipulate management on any scale. A basic understanding of pertinent mechanisms becomes even more important if we are to anticipate ecosystem responses to ongoing environmental changes, such as increases in specific atmospheric gasses. We are no longer simply interested in monitoring forage responses after attempts to remove undesirable species. The focus now

Harvesting 'WW-SPAR' Old World bluestem with the Woodward flail-vac seed stripper. ARS, Woodward, Okla.

is to more fully understand why these undesirable species are successful, how desirable species can be competitive, and how so-called undesirable species may be effectively utilized. Our contributions to basic research efforts include examination of above and below ground processes which can explain competitiveness of encroaching shrubs.

Demands for information on resource conditions are escalating. New technologies must be developed that provide stewardship agencies with methods for rapid and accurate analyses of large land areas. Research in the Southwest includes an emphasis on integration of remote sensing technologies and geographic information systems. It is envisioned that these tools will enhance stewardship efforts, including wildlife habitat management. Further development of decision support systems should incorporate this technology into usable forms. Developing capabilities to use these technologies for land management becomes more crucial as evolving instrumentation is more applicable, more miniaturized, and less expensive.

Finally, we need to search for new products that can be conservatively harvested from these desert rangelands. Considerable emphasis has been placed on the biological basis of sustainable uses within these ecosystems. It is important to recognize that sustainability requires profitability. Equally important is the exploration for new economic values that could be tapped by users and lead to new economic ventures.

Ninety years of range research in the Southwest have led to established guidelines for sustainable range livestock production and improved resource conditions. Our new challenges are to establish criteria for sustaining a variety of additional uses, meld new techologies into sound stewardship practices, and develop new economic and sustainable values for these renewable resources.

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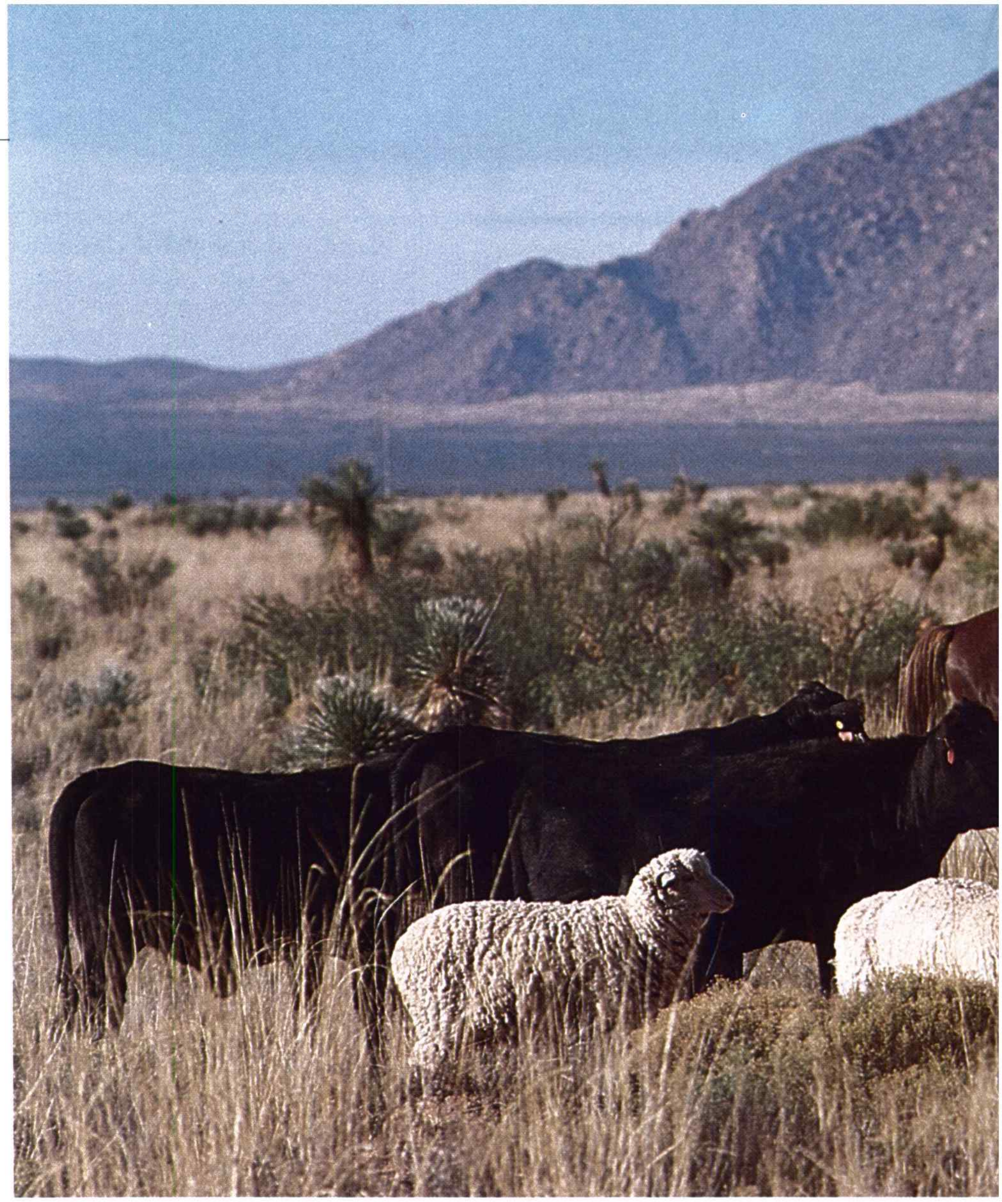


Principal Workgroups for Specialty Research

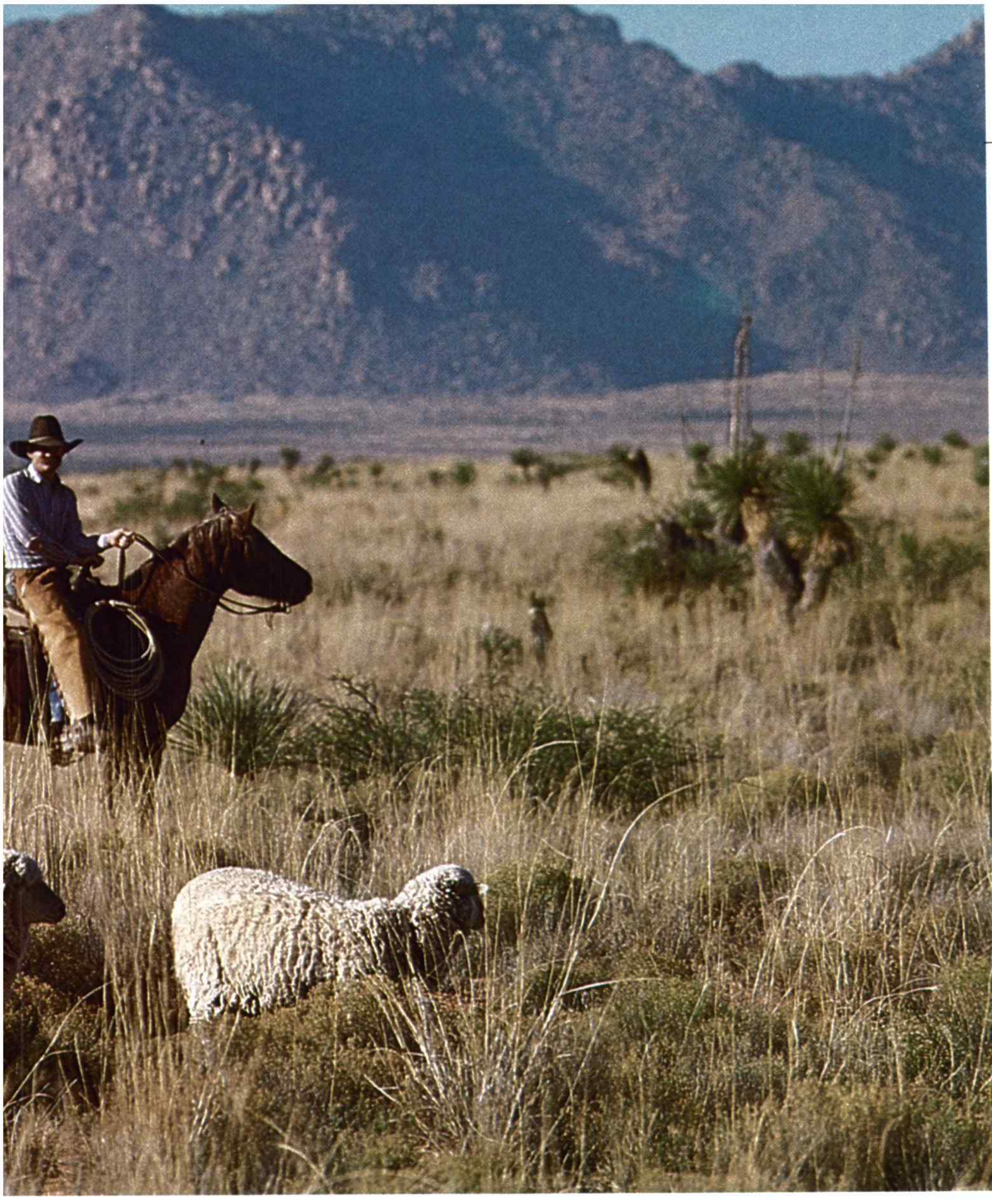
Dryland Plant Improvement Research

Lead location—Logan, UT
Linked locations—Mandan, ND; Temple, TX; Woodward, OK; Lincoln, NE

Research at the USDA-ARS Forage and Range Research Laboratory Logan, Utah, is directed toward the development of plant materials for improving soil and water resources and reclamation of rangelands. New plant materials are needed that can be easily established to provide proper ground cover, stabilize eroding soils, including riparian areas, and produce vegetation for forage, aesthetic, and recreational purposes. The need for a proper vegetative cover is a common objective of the many diverse constituents who frequently have conflicting views on proper land use. In many cases, it is extremely difficult, if not impossible, to re-establish those plant species that earlier occupied an area.

The general approach is to collect and evaluate a broad genetic base of plant germplasm and fix selected characteristics in stable populations through intra- and interspecific hybridization. A multidisciplinary team approach provides basic information in biochemistry, physiology, cytogenetics and molecular genetics, pathology, and ecology.

Assemblage of the world's largest living collection of Triticeae grasses at Logan provides a ready and important source of genetic variability for plant breeders world-wide. One thousand to 1,500 seed requests are provided to other scientists each year.



Numerous new grass and legume germplasms and varieties that have been released from the breeding program include: Kura clover, *Trifolium ambiguum*—a material with tremendous potential for stabilization of riparian areas and for providing nitrogen fixation on otherwise deficient soils; Hycrest crested wheatgrass—a cross between a diploid (*Agropyron cristatum* and tetraploid (*A. desertorum)* crested wheatgrass which expresses a high degree of hybrid vigor in and greatly improved seedling vigor. It s currently the most widely grown grass for conservation in the U.S. and has an estimated annual economic return of $50 million; Bozoisky-Select- A Russian wildrye *(Psathyrostachys juncea)* which has significantly better seedling vigor, seedling establishment, and forage production than other varieties of Russian wildrye. It has excellent forage quality and remains green later in the season than crested wheatgrass; NewHy—a hybrid between *Elytrigia repens* (quackgrass) and *Pseudoroegneria spicata* (bluebunch wheatgrass) which combines the best qualities of the parental species and yields a plant with excellent salt tolerance forage quality, grazing tolerance, and a moderate degree of drought resistance; and Alfalfa, *Medicago sativa*—two germplasms adapted for use on drylands that have been used in the development of proprietary cultivars by private industry.

Future research efforts will focus on the development of improved plant materials to meet the needs of both public and private land managers. Molecular biology techniques will be used to complement conventional methods of germplasm enhancement. Plants will be developed with enhanced growth under cool temperatures to provide winter feed for wildlife and livestock. The development of improved forb and legume species will provide materials to improve species diversity on rangelands and provide enhanced opportunities for site renovation. Semiarid rangeland grasses will be adapted for use in lawns to reduce water requirements. New techniques will allow development of critical seed identification procedures, an improved understanding of genome relationships in breeding populations, and provide the opportunity to mark specific genes thus facilitating enhanced gene transfers.

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Rangeland Pests and Poisonous Plant Research

Lead Location—Logan, UT
Linked locations—Bozeman, MT; Albany, CA; Temple, TX

The mission of the USDA-ARS Poisonous Plant Research Laboratory, Logan, Utah, is to investigate poisonous plants, their toxins and teratogens, and their mode of action; identify conditions under which poisoning occurs; and, from the information gained, develop methods to prevent or moderate livestock poisoning. Major investigations include: determining the mechanism(s) by which toxic plants cause injury to grazing animals and developing procedures for better diagnosis of naturally occurring plant intoxications; determining the toxic and reproductive process in livestock from ingestion of poisonous range plants, such as locoweed, ponderosa pine needles, broom snakeweed, and seleniferous forage; isolating and identifying teratogenic and toxic compounds from poisonous plants, such as ponderosa pine needles, broom snakeweed, and certain mustards; measuring toxins within poisonous plants as influenced by soils, sites, environmental conditions, plant parts, and stage of growth; and determining grazing behavior and conditions under which livestock consume poisonous plants such as locoweed, pine needles, broom snakeweed, and larkspur.

Pine Needle-Induced Abortion in Cattle: Ponderosa pine needles (PN) induce premature parturition or abortion in cattle when ingested during the latter stages of pregnancy. Estimated losses range from $6 to $20 million annually. Currently, the only method of prevention is avoidance of pastures having ponderosa pine growing in them. Efforts are being made to isolate and characterize the abortifacient compound in the pine needles. Bioassay techniques are being developed to aid in the isolation of the abortifacient material-mechanism by which pine needles elicit the premature birth or abortion. Grazing studies are currently being conducted to determine the conditions under which cows will graze pine needles in sufficient quantities to cause abortions.

Larkspur Poisoning in Cattle: Larkspur kills more cattle on mountain rangelands in the western U.S. than any other cause. Over 1,000 cattle die annually from larkspur poisoning in the intermountain Forest Service Region, and similar losses occur in the Rocky Mountain and Northern Regions.

A group of structurally similar alkaloids in larkspur have recently been implicated in causing the acute toxicity. Research is currently underway to identify environmental and site factors that influence the biosynthesis and accumulation of these toxic alkaloids in an effort to measure and predict the potential toxicity of a given larkspur population. Research is also underway to identify the mechanism of action of these alkaloids and develop antidotes.

Consumption of larkspur increases and toxicity decreases as the plant matures. The most dangerous time is when cattle start to eat larkspur during the bud and flower stages while the alkaloid levels are still sufficiently high to harm them. The overall objective of this research is to combine the information on grazing behavior and toxicity of the plant to predict the risk of grazing infested areas.

Livestock death from poisonous plants, ARS, Logan, Utah.

Several management practices are also being evaluated to reduce the incidence of loss. These include mineral supplements, grazing larkspur with sheep before cattle turn-in, training cattle to avoid eating larkspur by conditioned food aversion, and herbicide control. Recent research has shown that intravenous injection of the drug physostigmine will rapidly reverse acute larkspur poisoning in cattle. This drug appears promising for field treatment of intoxicated cattle.

Locoweed Poisoning: Locoweed poisoning is the most widespread poisonous plant problem in the western U.S. and can occur in almost all rangeland plant communities. The locoweed toxin, swainsonine, inhibits an essential enzyme in glycoprotein metabolism, resulting in metabolic dysfunctions. There are multiple symptoms of locoweed poisoning: neurological disturbances such as depression, abnormal behavior, impaired vision and loss of motor control; reduced fertility in both males and females, birth defects, abortion, small and weak offspring, and lack of maternal-infant bonding; difficulty in prehending food and emaciation.

Locoweed is not addictive, rather, livestock graze it because it is relatively more palatable and higher in nutrition and digestibility than associated species. Locoweed grow on specific soil sites; thus moving livestock to noninfested sites is one management practice that can be used to prevent poisoning. Locoweed-free pastures could be created by spraying with rangeland herbicides. Periodic retreatment will be necessary because of the large seed bank in the soil that will germinate and establish when conditions are favorable.

Selenium Toxicity in Livestock: Selenium is taken up by plants from the soil. Forage containing excessive amounts of selenium (Se) can cause various toxic effects in livestock. Some plants, such as certain species of Astragalus, have the ability to accumulate high levels of selenium. These are known as Se indicator plants. Some grasses, shrubs, and crop plants accumulate Se at levels that render them toxic to livestock.

Acute Se poisoning is uncommon and usually results from ingestion of excessive amounts of Se indicator plants. These plants are all relatively unpalatable and are grazed only under extreme conditions.

Chronic poisoning has been described to occur in two forms: alkali disease and blind staggers. Alkali disease results from prolonged ingestion of non-indicator forages such as certain grasses, crops, and shrubs. It is characterized in livestock by rough hair coat, hair loss, emaciation, hoof lesions, and overgrown feet. Investigations are continuing to further describe selenium poisoning in livestock. The effects of seleniferous forages on reproduction in livestock are being investigated.

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Water flow measuring weir on experimental watershed, Boise, Idaho.

Rangeland Hydrology

Lead location—Boise, ID
Linked locations—Tucson, AZ; Bushland, TX; Ft. Collins, CO

In 1959, the United States Congress appropriated funds to the USDA, Agricultural Research Service to initiate rangeland watershed research in a geographical area associated with winter precipitation (snow and rain), frozen soils, and snowmelt runoff. The project headquarters were located at Boise, Idaho, and the 90 square mile Reynolds Creek Watershed about 50 miles southwest of Boise was chosen as the experimental watershed and field research headquarters. Reynolds Creek is the only experimental watershed in the world which provides an uninterrupted and realistic hydrologic and climatic record representative of the Intermountain West and Northwest rangelands. Elevations vary from 3,600 feet at the outlet to 7,390 at the summit. Plant communities typical of the Great Basin Desert are found at the lower and middle elevations. Mountain brush and forest vegetation is typical of the higher elevations. Annual precipitation varies from 10 inches at the outlet to over 40 inches at the summit where 75 percent occurs as snow. Annual water yields vary from less than 1 inch at the lower elevations to over 23 inches at the higher elevations. Annual sediment yield averages 0.25 ton per acre of which 97 percent originates from snowmelt or rain-on-snow events.

The USDA-ARS Northwest National Watershed Research Center's research objectives are to acquire a predictive understanding of rangeland hydrologic processes to better assess the impacts of land use, alternative management strategies, and global change. The research program focuses on developing and modifying watershed-level hydrologic predictive techniques that account for temporal and spatial variability and that improve water supply and flood forecasting and the use of water on rangeland. The effort is concerned with adapting, validating, and applying modeling technology to the management and research of rangeland ecosystems. Some ongoing research programs include: soil freeze and thaw processes and their relationship to runoff and erosion; characterization of the spatial and temporal variability of precipitation and runoff and development of linkages with natural resource and climate models: evaluation of the evapotranspiration processes at the rangeland plant community level; evaluation of optimal seedbed conditions for range plant establishment; and development of a real-time, watershed-level water supply and flood forecasting models that account for the spatial and temporal variability of snow accumulation and melt associated with rangelands.

Insect enemy of leafy spurge.

> Scientists have recently shown that future, higher carbon dioxide levels will increase photosynthesis, often without increasing water use. . .

Future research will investigate the potential impacts of global change and the increasing demands on our rangeland resources. The ability to understand the effects of global change on precipitation and streamflow is critical to sustaining agriculture. Competitive demands for rangeland resources by livestock, wildlife, recreation, mineral exploration, and off-site water users far exceed the available supply. Future research will address these concerns by: developing models that can accommodate the spatially and temporally variable processes that could be impacted by global change; quantifying the impacts of livestock and other uses on habitat and water quality in riparian areas and developing decision support systems that bring together expert information, resource models, remote sensing, and other technology into a readily useable package for use by resource managers.

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Climate Research

Lead location—Temple, TX
Linked locations—Tucson, AZ; Bushland, TX; Ft. Colins, CO

Carbon dioxide levels in the Earth's atmosphere have been increasing since prehistoric times. Currently the the atmospheric carbon dioxide level climbs almost 2 ppm every year. Levels of other trace gases such as methane, nitrous oxides and chloroflourocarbons are also increasing. This chemical change in the composition of the atmosphere is believed to be of critical importance because these gases may trap more and more heat.

Scientists have recently shown that future, higher carbon dioxide levels will increase photosynthesis, often without increasing water use, and thereby improve the productivity of many plant species. USDA-ARS scientists at the Grassland Protection Research Unit at Temple, TX suspect that the carbon dioxide increases during ancient and more recent times have already improved productivity of many kinds of plants, perhaps at the expense of other plants, and may even have influenced important characteristics of plant communities, like species composition. It is important to test this hypothesis because an understanding of the carbon dioxide fertilization effect on plants and whole ecosystems may help explain how rangeland vegetation types formed, why they are changing today, and how the continuing, rapid increases in carbon dioxide will influence ecosystem processes and the productivity and use of rangelands in the future.

Most plants use one of two principal kinds of photosynthesis, termed "C3" and "C4" photosynthesis. C3 plants are the most abundant and include the trees, almost all of the shrubs and most of the forbs, and the cool-season grasses. Warm-season grasses are C4 plants. Recent research has shown that increased carbon dioxide above the current level increases rates of photosynthesis and consequent productivity of the C3 plants more than the C4 plants. Rising carbon dioxide reduces transpiration of water by both C3 and C4 plants, allowing them to use less of the available water to produce the same amount of growth or to be more productive while using the same amount of soil water. This is especially important for arid areas.

To determine whether C3 grasses respond significantly to changing atmospheric carbon dioxide over the range of prehistorical and more recent increases, oats were grown in a special chamber over a gradient of carbon dioxide from well below levels of the geological past, to the current level. Photosynthetic rates tripled over the entire range, and almost half of that increase occurred over the rise in carbon dioxide experienced during the last 200 years. Forage production increased to the same extent. Response of wild mustard, a C3 broadleaf plant was even more impressive. Low carbon dioxide content would favor C4 plants like the warm-season grasses, which grow equally well at low and high carbon dioxide levels. Productivity of a C4 bunchgrass, little bluestem, did not improve when grown at increasing carbon dioxide levels. Woody brush species like creosotebush, mesquite, sagebrush, junipers, snakeweeds, and others that have increased in abundance on many rangelands are C3 plants. This poses the possibility that they have benefitted from the historical increases in atmospheric carbon dioxide, while the C4 warm-season grasses they replaced in the Desert Grasslands and southern Great Plains have not. Increasing carbon dioxide may have played a role in brush encroachment by shifting the competitive balance between the two kinds of plants.

Current and future experiments will compare the effects of historical carbon dioxide increases on growth, competitive ability, and "resource use efficiency" of C3 shrubs and C4 grasses, and determine whether the C3 grasses of rangelands have been favored. Differences among plants in the effects of carbon dioxide level on their ability to use resources like water, nitrogen, and sunlight efficiently may explain how atmospheric change has altered the balance between C3 and C4 grasses and between perennial and annual C3 grasses such as cheatgrass. Competition between different kinds of plants leading to replacement of one by another is only one example of an ecosystem process that may be changing in response to increasing atmospheric carbon dioxide. Other important processes that may be affected are nut-

Plant physiologist Marshall Haferkamp inspects improved forages for row spacing, Fort Keogh, Mont.

rient cycling and nitrogen fixation. The high probability that the changing atmosphere has influenced rangeland ecosystems and will continue to do so makes it necessary that we understand the mechanisms. Otherwise, we may not be able to adjust to the ways these effects are manifested in a practical sense.

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Remote Sensing and Geographic Information Systems Research

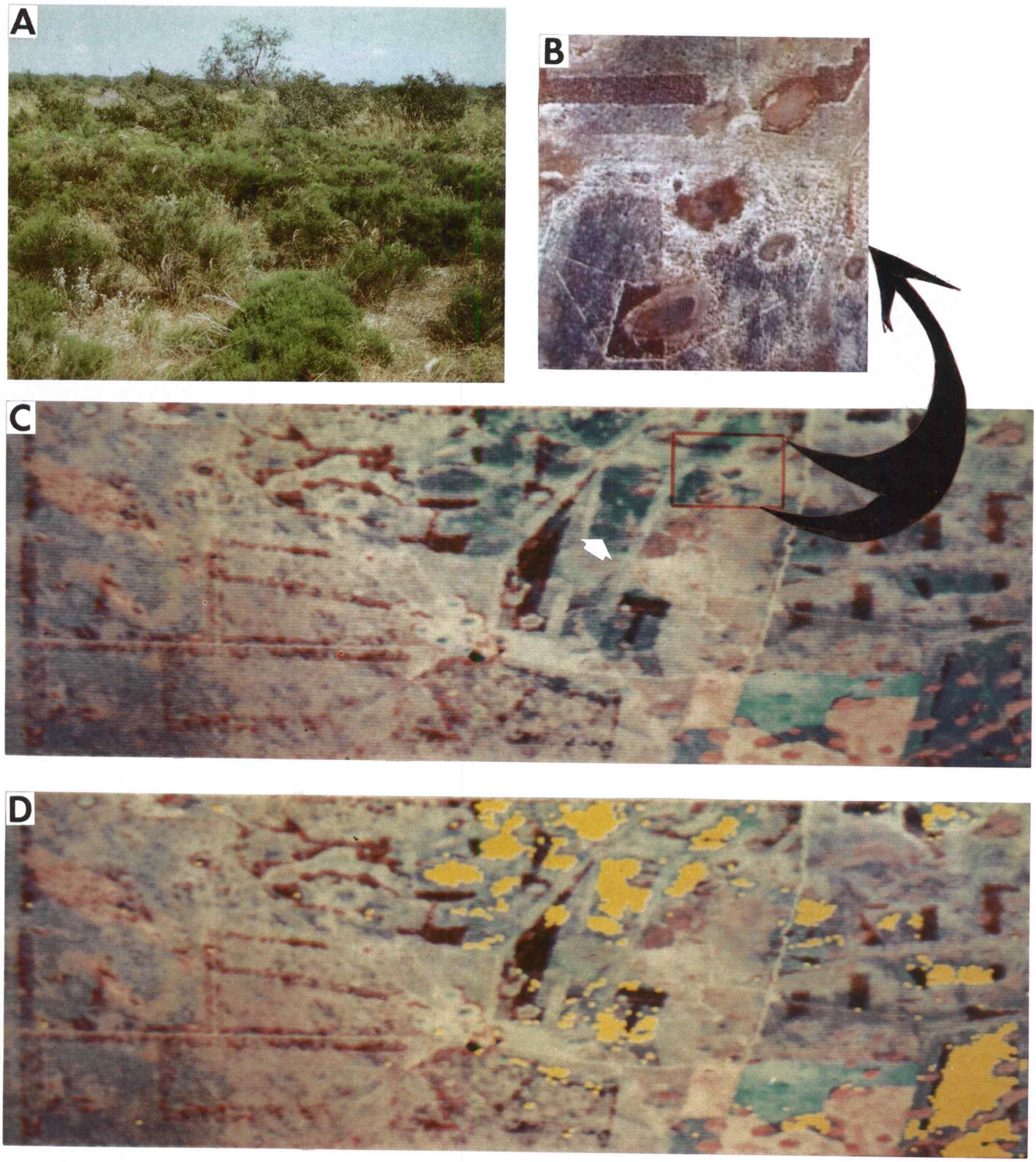
Lead Location—Weslaco, TX

Rangelands are too extensive and inaccessible to closely monitor using traditional ground survey techniques. Remote sensing and geographic information systems (GIS) are two technologies that can be used with limited ground sampling to produce timely and low-cost information about specific rangeland resources. The Remote Sensing Research Unit, USDA-ARS, Weslaco, TX, is involved in evaluating how remote sensing and GIS technologies can be used to address a myriad of agricultural problems.

Remote sensing is the measurement or acquisition of information about an object or phenomenon without physical contact. Common remote sensing tools include aerial photography, airborne video, and satellite imagery. Aerial black-and-white, natural color, and color-infrared photography have been used to classify, and monitor rangelands. Color-infrared photographs have been particularly useful for mapping plant communities, distinguishing noxious plant species, documenting response to drought and overgrazing, and delineating wildlife habitats. Aerial photographs provide higher resolution (most detailed information) than any other remote sensing technique but, each photograph must be manually interpreted.

Commercially available airborne video imaging systems are a relatively new development in remote sensing. These systems can record black-and-white, natural color, or color-infrared images. They have the advantages of near-real-time availability of the imagery and the relative low cost of image acquisition and display. Video imaging systems also have wider spectral sensitivity in the infrared spectrum than photographic film and the use of narrowband filters can aid in feature discrimination. Video imagery can be easily digitized and processed in the same manner as satellite data. Although video has lower resolution than film, it is ample to detect differences among many rangeland variables such as plant communities and species, phytomass levels, grazing intensity, and burned areas.

The use of satellite data for range research has been limited, primarily due to the cost of the data. In the past, LANDSAT and SPOT satellite images have been used to estimate green forage biomass, determine foliar cover percentages, detect stress and physical change, and map or classify vegetation. The resolution of satellite imagery is less than that of video or photographs. The smallest picture element recorded on the LANDSAT Thematic Mapper sensor is approximately 98 square feet. The French SPOT satellite can record black-and-white images with a ground resolution of 66 square feet. The lower resolution of satellite images produces a less distinct image than video or photographs; however, satellite images cover much larger areas (LANDSAT 115 mile and SPOT 37 miles swath width). Satellite images are stored as digital values and require image processing software and hardware to analyze and display the images. The advantage is that auto-



Depicts: (A) false broomweed infestation on south Texas rangeland; (B) aerial color-infrared video image of area delineated on SPOT satellite image (C) showing the dark-gray signature of false broomweed; and (D) computer classification of false broomweed areas (yellow overlay).

Superior gaining Angus × Hereford and Brahman Hereford steers, Woodward, Okla.

mated computer analysis techniques make it possible to analyze large areas, while the disadvantages are the more costly data and image processing hardware and software.

Geographic information system technology is a relatively new tool that originated within the computer-aided cartographic field. GIS allow accurate entry, placement, and labeling of map features (themes) such as pasture fences, topgraphy, vegetation, soil, water sources, and green biomass within a spatial-coordinate system (electronic mapping). Themes can be used separately or in combination to place new fences, identify optimum water point locations, and identify specific areas to receive various chemical treatments. GIS technology will let range managers tailor specific management strategies to specific sites and reduce the investment required by broad management approaches.

Remote sensing and GIS technologies are unique in their ability to portray data as a picture. While many will scoff at the usefulness of "pretty pictures", anyone who has used this medium will tell you that the information in the images can contribute much to our understanding and perception of the rangeland resource. Digital GIS maps and remote sensing images also allow for rigorous statistical analysis and the combination of data in many ways never thought possible. Research at the remote sensing lab will continue to focus on the development of tools that integrate remote sensing and GIS technology for on-ranch management. The initial investment required to obtain and use these imaging and mapping tools can be substantial, but the return is an information source that can be used to solve many problems encountered by range managers in developing sound management strategies. [*J.H. Everitt, Research Leader, Remote Sensing Research Unit, 2413 E. Highway 83, Weslaco, Texas 78596 TEL 312-968-5533*]

Other Groups not Included in this Article

Intermountain Systems Research
Principal location—Boise, ID
Linked locations—Dubois, ID; Logan, UT

Small grazer kangaroo mouse.

Tall Grass Prairie Systems Research
Principal location—To be determined
Mixed Species Systems Research
Lead location—Dubois, ID
Linked locations—Las Cruces, NM; Miles City, MT
South-Central Family Farm Research
Lead location—Booneville, AR

Summary and future research

Rangelands are the largest of the terrestrial ecosystems. These lands are a primary source of food, fuel, fiber, and quality water supply. They are the front line defense against soil erosion, ecosystem instability and degradation, and inadequate supplies of quality water. Periodic drought, atmospheric change, and increased public interest require innovative management strategies that will improve the stewardship of public and privately owned rangelands. These strategies are needed to improve the ecological stability and productivity of rangeland plants and maintain the diversity of rangeland ecosystems. The strategies must be efficient for energy and water use and nutrient production.

At the White House Conference on Science and Economic Research Related to Global Change, April 1990, President Bush stated that, "Global stewardship will become a dominant scientific, economic, and environmental issue of the 21st century." The President concluded that "Global stewardship is not a fixed state, but a process of change in which environmental and economic values are brought into balance to meet human needs and to expand human prospects."

Development of rangeland ecosystem management strategies that can be used effectively by Federal agencies as well as by private landowners requires detailed understanding of ecosystem structure and function. Our ability to become wise stewards will determine the contribution of these resources to the Nation's economy and security. Several factors must be incorporated into our thinking. The global environment is experiencing significant changes, developed and developing nations have become more competitive, and we have become more aware of the relationship between the quality of life and national security and the productivity and resiliency of our natural resources.

We must pay more attention to management of rangeland, particularly to the fragile riparian landscapes, public and private grazing lands, and to those lands that are vulnerable to invasion by plant and animal pests that diminish our already-limited energy, nutrient, and water resources. Managers at all levels must have the tools that provide integrated knowledge of complex terrestrial systems with large and varied data bases in useable format for rapid, efficient, and accurate decision making.

Understanding the stability and resiliency of rangeland ecosystems and the transfer of this knowledge to more intensely managed systems will only be possible through in-depth investigation of the complete ecosystem. The objectives of this research are divided into three parts:

Managing Ecologically Complex, Natural Rangeland Ecosystems— Research will be started to understand the genetic diversity of key rangeland plants and the relationship of ecological processes basic to: (1) selecting and improving germplasm of certain grass, legume, and shrub species; (2) developing cultivars with enhanced seed viability, establishment characteristics, and stress tolerance; and (3) developing and releasing appropriate varieties of grasses, legumes, and shrubs for use on rangelands, including germplasm adapted to fragile land and riparian areas.

Maintaining and Restoring Rangeland Biodiversity—Research to improve biodiversity on rangeland will have four elements: (1) develop technologies for evaluating how water and temperature stress affect productivity and reproduction of grasses, legumes, and shrubs; (2) evaluate regeneration requirements and competitive ability of natural and introduced plant species at both the individual plant and plant community level; (3) develop technologies for improving success of field regeneration of desirable plant species; and (4) devise successional concepts and strategies for managing complex, multiple-resource-based natural rangeland ecosystems.

Plant/Soil Microbial Interactions Controlling Vegetation Dynamics— Research will be started to identify, describe and manipulate plant/soil microbial populations that benefit rangeland vegetation structure and resiliency to herbivory and to global and regional change. Specific markers will be developed to monitor ecosystem stresses that can be attributed to either natural or human activity.

Three specific objectives for increased research emphasis are:

Riparian Ecology and Management—Measure the impact of grazing animals and the influence of alternative management strategies on the condition of riparian areas and their effect on the hydrology and water quality.

Impact of Large Grazing Animals—Determine the impact of large herbivores on range condition and successional dynamics and improve production of high-quality forage for livestock and wildlife and the yield of high-quality water for domestic and industrial use.

Decision Support Systems— Develop and test decision-support systems that improve multiple-use management of rangeland ecosystems to ensure the stability and quality of soil, plant, and water resources. Systems could incorporate the use of geographic information systems (GIS) and remote-sensing technologies to evaluate alternative management strategies.