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HAND APPLICATION OF HERBICIDE PELLETS TO CONTROL SMALL JUNIPER AND PINYON TREES

N. E. WEST and N. S. VAN PELT

Juniper trees, with or without pinyon pines, are increasingly common on the mountains, foothills and plateaus of the Intermountain region. Once mainly confined to steep, often fireproof slopes, the small, stout trees are becoming more abundant on the deeper valley soils and more level terrain characteristic of sagebrush-grass ranges.

The spread of pinyon-juniper trees hampers livestock movement and reduces forage yields on spring, fall and some winter ranges. As trees grow and stands become more dense, forage plants are competed out of the interspaces and soil erosion may increase dramatically. In the 1950s and 1960s, infested sites were chained or cabled and seeded with introduced grasses. Increased costs and environmental concerns subsequently reduced the feasibility of these practices.

Saplings have regrown and re-invaded many areas that were not thoroughly cleared, yet roads, fences and stockwater facilities there are probably still in good repair.

Areas treated to control these trees depreciate, just like other ranch assets. Tree growth reduces the options for renovation and makes control more expensive.

The Utah Agricultural Experiment Station funded 5 years of research to learn what can be done to control “weed” trees in previously chained areas. We identified methods that work well on a variety of sites, do not require the licensing of applicators or involve stringent restrictions, and require a low investment and occasional labor.

Before removing any trees, ranchers should consider whether the trees have value as fence posts, fence stays or pinyon Christmas trees. Stands that include well-formed pinyon trees that may be suitable for Christmas trees should be evaluated by an Extension forester or potential buyer.

Trees can be killed by aerial application of herbicides, a tree-crusher
drum or hand-cutting, but these methods are costly, difficult, hazardous to workers and harmful to grasses and forage shrubs. Conditions favorable for clean burns are difficult to achieve, although burning has been successful on some previously chained areas. Large-scale sawing is feasible only when there is enough firewood to be marketed. A small (40-horsepower) farm tractor with loader can be used to uproot sparse sapling junipers on accessible sites with somewhat moist soils, but it is a slow process.

In comparison, hand application of herbicide is flexible, quick and can be done almost any time of the year. Applicators can also select trees that should remain to provide animal shelter or for other purposes.

Ranchers in eastern California and Oregon have applied Tordon by hand on scattered western juniper stands at a cost of $10-$20 per acre on productive sites with fewer than 70 to 100 trees an acre. Repeated applications and the proper calibration of doses to the site and size of trees have opened thickets for reseeding. Treating sites before trees have killed grasses may mean that reseeding will not be necessary.

Previously chained sites may have from 25 trees to more than 400 trees per acre. A common manageable density is 100 to 150 trees per acre, which means trees cover 4 to 5 percent of the ground, although roots occupy a much larger area. About two-thirds of the trees on many sites are junipers, but the composition varies with environmental conditions and history of the site. Removing some trees by chaining often meant an acceleration in the growth of remaining trees.

This study concerned the feasibility of tree defoliation using herbicides that can be applied on foot or from horseback. Experiments involved thousands of trees in Tooele and Carbon counties during 1984-88, a period when annual rain-
Forage production will start to increase 30–32 months following herbicide application.

Fall was somewhat greater than normal. The herbicide was tebuthiuron (Spike, then sold as Graslan "Brush Bullets") applied according to label recommendations. More than 90 percent of the treated juniper and pinyon trees were defoliated after 36 months. Some trees were defoliated 24 months after treatment.

Effective Control is Possible

We found that applying herbicide according to label recommendations provided effective control on sites in central and eastern Utah. The herbicide may affect other vegetation on shallow soils with a hardpan, however.

Trees taller than 6 feet were no harder to kill than shorter trees when the amount of herbicide was calibrated to stem height. Solid herbicide can be applied beneath the trees, or herbicide granules can be spread at the edge of the crown: an ounce of active ingredient should be adequate to kill even the largest trees.

Forage production will start to increase 30–32 months following application, or after about 36 inches of precipitation have fallen on the soil. There were initially some differences in how the types and sizes of trees responded to treatment; these differences became less significant with time. Applying particles in a cluster at the stem base was the most effective method, and one which minimized damage to shrubs and grasses.

Spike contained in a pail or canister was applied under the foliage or from the top; the amounts were based on a tree’s height. The rates recommended on Spike 20P containers are adequate but less than one "click" of the applicator (one-fourth ounce) should work on trees less than 3 feet tall. A quarter ounce is adequate for trees 4 to 5 feet tall.

The second phase of the research involved hand-application on 22 acres of old chaining on private land in eastern Tooele County. The area was subdivided with colored markers and the trees in each strip were counted; we then recorded the time required to treat each tree, the number of pounds of herbicide applied and the number of trees missed during the first application. Thirty percent of the land was covered with sagebrush and bitterbrush, which made it difficult to walk.

It took 8 hours to treat the 22-acre area, and 11 percent of the trees were missed (usually seedlings or those trees growing close to each other).

It took about 25 minutes, or 15 to 20 seconds per tree, to treat an acre thoroughly. Less than 1.5 pounds of Spike was required per acre.

The herbicide was carried in a shoulder bag, but a saddle bag on a horse would make it even easier. Each treated tree was then marked with spray paint.

A motivated worker can treat about 20 acres a day on foot. The best width of a swath to treat in one pass seems to be 50 to 75 feet. A brisk, systematic travel pattern is more efficient than trying to find every last tree or hunting for untreated trees that lie outside the swath.

One 5-pound Spike dispenser should be adequate to treat about 3 acres; a larger area can be treated if trees are smaller. Carefully apply herbicide where it will be most effective. Simply scattering herbicide in the general direction of the tree is wasteful and will delay grass recovery or prevent early reseeding.

Determine Economic Feasibility

Since it will be possible to treat only a fraction of the tree-invaded land on a ranch or allotment in a year, a 5- to 10-year treatment plan should be developed. These areas to be treated first should include the most productive and responsive sites. Other sites that should be treated first are scattered clumps in otherwise treeless
range, and the lower, leading front of the main pinyon-juniper belt, which is usually found at higher elevations.

Contact the Soil Conservation Service or USU Extension advisor to estimate how much forage production might increase following treatment. It might be best to treat a few acres or to visit a demonstration area before developing a treatment plan.

Costs depend on the number of trees and average height of trees to be removed. Rough estimates of the number of trees tend to be low, often by a factor of two. As a guide, at a density of 125 trees per acre, trees will be spaced about 20 feet apart.

Given the drawbacks and high costs of other methods of tree removal and the complex regulations governing broad-scale pesticide use, treating individual trees may be the best method for ranchers. The benefits from this type of treatment will gradually increase on favorable sites. Spike is registered, well-tested and widely available in Utah. It may be possible to use smaller amounts of herbicides such as Velpar and Reclaim, but these herbicides may have to be tested to be registered for use in this region.

Labor and application cost more than the herbicide. Based on prices during spring 1988, it cost about $3.50 for herbicide to control 25 trees an acre. Ordering herbicide in bulk can reduce herbicide cost by about $2 a pound.

To decide whether treatment will be cost effective, ranchers should know 1) average stand height, 2) cost per acre for labor and herbicide, 3) site productivity (low, moderate or high), 4) AUM value, and 5) the number of trees per acre. Once the first four factors are known, the economic break-even points for projects offering the highest returns can be determined by considering tree density.

A computer program developed in New Mexico estimates the economic feasibility of treatment and could be adapted to reflect Utah prices and conditions. For more information, contact either the authors of this article or the USU Extension range specialist, Utah State University, Logan, Utah 84322-5230.

ABOUT THE AUTHORS

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N. S. Van Pelt was formerly a graduate research assistant and is now public lands protection planner with the Nature Conservancy, Salt Lake City, Utah.
Dieback is the term used to describe the widespread death of a plant species. In forest ecosystems, diebacks have been attributed to pathogens such as diseases or insects, although industrial pollution in Europe and in the eastern U.S. have also been identified as contributing factors. These findings indicate that dieback is a much more complex phenomenon than a simple relationship between aging plants and infectious organisms.

Dieback of shrub stands in the Great Basin has been observed since 1982. Although these shrubs may appear to be part of a barren landscape, they are often the principal food for livestock and wildlife during the winter months when other forage is scarce. Shrubs are often the dominant plants in many communities, even those that have not been disturbed.

According to one estimate, one million acres of shrublands in Utah have been affected by shrub dieback (Nelson et al. 1988). The important species involved include sagebrush (*Artemisia tridentata*), budsage (*Artemisia spinescens*), shadscale (*Atriplex confertifolia*), four-winged saltbush (*Atriplex canescens*) and winterfat (*Ceratoides lanata*). The most dramatic and extensive dieback affected shadscale and four-winged saltbush; in some valleys, nearly all these shrubs were eliminated.

**A Natural But Irregular Phenomenon**

Ranchers and land managers were anxious to learn whether livestock grazing was related to shrub dieback. However, since shrub dieback has also occurred on lands that had not been grazed for 30 to 50 years, such as those associated with the U.S. Air Force Eagle Firing Range and U.S. Army Dugway Proving Ground, livestock grazing does not appear to be a factor in dieback. Shrub dieback, similar to forest dieback, appears to be a natural phenomenon associated with Great Basin shrub-grass ecosystems. Dieback does not occur on a regular cycle, but it probably has occurred several times during the past 70 to 80 years.

A theory of natural dieback proposed by Mueller-Dombois (1988)
attributes its start to predisposing factors such as stands of old, even-aged plants, which often grow on marginal soils. Shadscale, one of the shrubs affected by dieback, evolved the ability to colonize areas that were once beneath the surface of Pleistocene lakes, such as glacial Lake Bonneville, during the last 12,000 years (Stutz and Sanderson 1983). As a result, shadscale may be only marginally adapted to these sites.

Disturbances of the ecosystem by abiotic factors, such as recurring climatic extremes (e.g., drought or above-normal precipitation) or abnormal fluctuations in temperature may also have a role. These factors may weaken plants and make them more susceptible to lethal agents, including diseases and insects, which are often present in low numbers in healthy plant communities. These agents can then increase, spread quickly and ultimately kill an entire stand.

Although shrub dieback in the Great Basin is not as well documented and has not been studied as thoroughly as forest dieback, several historical accounts are consistent with dieback. Photographs taken by H. L. Shantz near Modena, Utah, in 1913 and 1915 show large areas of dead sagebrush. It is not known when these sagebrush plants died. Because sagebrush wood decomposes slowly and many of the branches are still connected to the shrubs, dieback probably occurred within 10 years of the date the photographs were taken. These areas were relocated and photographed again by R. M. Turner in 1968 and by Rogers (1982) in 1977. The later photographs show that sagebrush had become reestablished on the sites by 1968. Although Shantz believed that competition from galleta grass (*Hilaria jamesii*) killed sagebrush, Rogers (1982) disagreed with this hypothesis and noted that galleta grass cover has changed very little in the area. Young sagebrush are growing with the galleta grass in the photos taken in 1968 and 1977.

**The Role of Climate**

There is another explanation consistent with the natural dieback theory. Climatological records for Modena indicate that the years from 1901 to 1904, several years before Shantz first photographed the area, were characterized by drought. Precipitation was above normal from summer 1904 until winter 1908 (Fig. 1). These precipitation patterns may have made the shrubs more susceptible to an outbreak of disease or insect damage.

Drought has been implicated in shrub death several times at the Desert Experimental Range in west central Utah. Severe reductions in shadscale abundance were noted during drought periods of 1933-34, 1942-43, 1949-52, 1954-55, 1970-71 and 1975-76 (Blaisdel and Holmgren 1984, Nelson et al. 1988) and when green rabbitbrush (*Chrysothamnus viscidiflorus*) was abundant during the late 1950s (Ellison 1960).

However, the current wave of shrub dieback is probably not due to drought. Climatic records indicate that the Great Basin received above-normal precipitation for several years (Fig. 2). High precipitation, particularly in valleys, which are often closed systems for water movement, may have temporarily waterlogged the root-zone of the shrubs, which could have limited the oxygen that
Temporary waterlogging of the rootzone of shrubs could limit the oxygen that shrubs need for survival.

**Figure 1.** Departure from normal precipitation for Modena, Utah, from 1901-1987. Normal precipitation is the 87-year mean of annual precipitation and the broken lines indicate ± 1 S.D. of the mean.

**Figure 2.** Departure from normal precipitation for Grantsville, Utah, from 1901-1987. Normal precipitation is the 87-year mean of annual precipitation and the broken lines indicate ± 1 S.D. of the mean.
FIGURE 3. False color infrared image of the Puddle Valley study area and the expanded study area. Areas of predicted shadscale dieback are blue.

FIGURE 4. Shrub dieback "front" showing a healthy stand of shadscale (2,025 live and 400 dead shrubs/ha) in the background and on affected stand (ratio is reversed) in the foreground, Puddle Valley, Utah.
Wet soil over deeper, frozen soil layers may explain patchy dieback areas.

shrubs needed to survive. Some shrubs, such as greasewood (Sarcobatus vermiculatus), seem to be adapted to waterlogging, but sagebrush and possibly shadscale are sensitive to these conditions (Lunt, Letey and Clark 1973, Ganskopp 1986). Dieback initiated in wet areas may then have spread to drier sites.

In 1987, we studied Great Basin shrub dieback in Puddle Valley, Utah, which is located about 50 miles west of Salt Lake City. Shrub dieback is severe in this area and the water tends to stand following snowmelt during years characterized by above-normal precipitation. We employed remote sensing (Pyke and Price 1989) and examined the relationship between vegetation succession and hydrology (Dobrowolski and Ewing 1989).

Satellite Images Employed
LANDSAT satellite images were studied to determine whether they could be used to monitor subtle changes in vegetation that might be associated with climatic changes, and to thereby determine the extent of dieback. Satellite imagery has been used to monitor dramatic changes in vegetation such as deforestation or desertification (Rasool 1985). Climatic change is likely to cause subtler gains or losses in plant species, changes more similar to those associated with natural diebacks.

We utilized two imagery techniques. One involved the classification of the image into classes of vegetation; one vegetation class was associated with known areas of shadscale dieback. Spectral classes which occurred in areas of dieback more often than normal were used to identify and map areas affected by shadscale dieback (Fig. 3). We conducted ground surveys to determine the accuracy of our predictions. Our predictions were correct 70 percent of the time. We estimate that shadscale dieback affects 30 percent of the land in Puddle Valley, about 10,700 acres.

The second imagery technique, the change detection method, utilized one image taken before dieback occurred and one following dieback. Values of the post-dieback image were then “subtracted” from the pre-dieback image. Those areas in which spectral classes changed should theoretically be areas of potential dieback. However, the amount and composition of annual plants in semiarid regions may change annually, which can make it more difficult to interpret data from this technique. So far, we have not successfully used this technique to map areas in which dieback has occurred.

We are studying the vegetation dynamics and hydrology in a valley bottom where severe shadscale dieback (1,200–2,000 shrubs/acre) occurs in a circular pattern 5–6 miles in diameter. In this portion of the valley, the dieback has affected all shadscale communities to the eastern border of their distribution. On the western slope of the valley, a distinct (750 foot) dieback “front” separates healthy shadscale from affected areas.

Waterlogging and Dieback
Field research in Puddle Valley is now attempting to determine whether shrub dieback is continuing and the extent of recent changes in vegetation. We are also trying to learn whether an oxygen deficiency resulting from temporary waterlogging of the root-zone triggered the dieback.

Permanent transect and permanent plots have been established across the valley and through areas of severe and moderate dieback as well as healthy shrub communities to study vegetation dynamics. During the early autumn of 1987 and 1988, we carefully surveyed the vegetation in these plots. The analysis of this data and of environmental characteristics (soils, topography, salinity) indicated the relationship between vegetation structure, environment,
dieback patterns and succession. Comparing how vegetation changes along the permanent transect indicates short-term changes in vegetation dynamics within dieback areas.

Shrub dieback in Puddle Valley is patchy (Fig. 4) and seems to be concentrated in the valley bottom. Undesirable plants such as Halogoton (Halogoton glomeratus) and cheatgrass (Bromus tectorum) have invaded areas where shadscale has died. The continued dieback of shadscale may portend the loss of all older shrubs. Shadscale seedlings are growing in areas of greatest shrub density prior to the dieback and where cheatgrass cover is less than 70 percent.

Soils influence the fate of temporary surface moisture from rainfall or snowmelt in salt desert basins such as Puddle Valley. Factors such as texture, permeability and salinity affect the amount and timing of moisture infiltration and storage in the root zone. The reduced permeability of soils in Great Basin desert valleys often means soils are waterlogged following spring snowmelt (G. Kidd, Bureau of Land Management, personal communication). Waterlogging may also occur from melting snow over partially thawed soil or over a duripan.

To determine whether soil oxygen levels are reduced in waterlogged soils during spring snowmelt, we placed soil sensors at various depths to continuously monitor freezing depth and root-zone moisture levels. We also constructed experimental water containment ponds to measure soil moisture and oxygen levels after applying known amounts of water. Oxygen levels in both experiments are determined with a platinum microelecctrode (Armstrong and Wright 1976).

During 1988, soil moisture levels were greater in dieback areas of the valley bottom than in the valley margin. Soils in the valley bottom tended to be more finely-textured, and have greater water-holding capacity but poorer permeability than soils in the valley margin. During snowmelt in 1989, however, surface soil moisture levels remained elevated at the valley margin, probably because temperatures were lower at these higher elevations, thus delaying and extending snowmelt. The persistence of wet surface conditions over deeper, frozen soil layers on the valley margin may explain patchy dieback areas in these regions, in spite of the more permeable soils.

Studies of the dieback front show no strong relationship between healthy or affected shrubs and environmental characteristics. Stutz and Sanderson (1983) found genetically diverse shadscale populations across the shoreline of Pleistocene Lake Bonneville. We are now determining whether genetic differences among mature shrubs in Puddle Valley may explain differences in survival along these dieback fronts.

ABOUT THE AUTHORS

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LITERATURE CITED


palatable forbs provide valuable forage for both wildlife and domestic livestock but have almost been eliminated on many rangelands of the western U.S. The seeds of forbs are utilized by upland game and nongame birds. Forbs that fix atmospheric nitrogen provide nitrogen for themselves and other plants when roots and shoots decompose. This nitrogen is especially important on semiarid rangelands where it is usually too expensive to apply fertilizers.

Alfalfa (Medicago sativa and M. falcata), biennial sweet clovers (Melilotus officinalis and M. alba), sainfoin (Onobrychis vicifolia) and cicer milkvetch (Astragalus cicer) are some nitrogen-fixing forbs commonly used to seed rangelands in the Intermountain West. However, all these forbs have been introduced from other parts of the world. Herbaceous legumes native to the Intermountain West and apparently is adapted to diverse sites. However, seed is now harvested from wildland stands, which means supplies are erratic and expensive, thus limiting use of sweetvetch in revegetation; these problems could be solved by commercial seed production. This study evaluated 11 populations of sweetvetch (Fig. 1) to determine if there was sufficient genetic variability to facilitate improvement through breeding and selection.

Seedling Establishment Characteristics

The drought hardness of seedlings often determines seedling emergence and establishment. In the Intermountain West soil moisture is usually adequate for germination, but dry conditions can severely impair growth during early summer. Seedling growth for the 11 populations at different moisture levels was
Shoot weight of one of the populations remained constant as less water was applied.

*Sites of original collection

FIGURE 1. Sites of origin of the 11 populations of sweetvetch evaluated in this study.

FIGURE 2. Seedling shoot weight of the 11 sweetvetch populations growing at three water levels in the greenhouse.
evaluated in a greenhouse experiment.

Plants started from seeds were placed under a greenhouse line-source sprinkler system fitted with a nozzle that traversed along a central line; the farther plants were located from the central line, the less water was applied (Johnson et al. 1982). Ten plants from each population were grown at equal intervals along the irrigation gradient for 38 days. Surviving plants were combined into three groups based on the total amount of water applied. The three groups represented abundant water (plants 1 through 3), adequate water (plants 4 through 7) and limited water (plants 8 through 10); total water applied in the groups was 8.7, 3.5 and 0.4 cm, respectively.

Sweetvetch shoot mass decreased as less water was applied, and there were significant differences among the populations in shoot weight (Fig. 2). Shoots in population 5 were the heaviest with abundant water, while shoots of population 6 were heaviest with limited water. Shoot weight of population 1 remained relatively constant as less irrigation water was applied; the shoot weights of other populations, such as population 11, declined markedly when less water was applied.

Successful seedling establishment requires quick germination and the rapid initiation of root development. The seedling root must quickly explore a large soil volume and penetrate the soil profile as deeply as possible to facilitate water uptake as the soil profile dries. Consequently, total seedling root length should be related to successful establishment in rangeland environments. Total root length differed among the sweetvetch populations. Population 5

![Graph showing total seedling root length of the 11 sweetvetch populations growing at three water levels in the greenhouse.](image-url)
There was enough genetic diversity to assure adaptation to a wide array of sites.

Mature Plant Characteristics

Seeds from each sweetvetch population were germinated, grown in a greenhouse and transplanted (1 m apart) at the USU Evans Experimental Farm near Logan, Utah, to evaluate forage yield, nitrogen fixation, seed yield and seed weight.

Sweetvetch produced substantial amounts of forage during the spring but produced little forage during the summer and fall. Similar to the results of the greenhouse study, population 5 produced the most forage in June (Table 1). Forage yield in the sweetvetch populations varied by more than 400 percent, an indication that there is ample genetic variation to improve forage production. Average crude protein content, an indication of forage quality, was about 16 percent for all sweetvetch populations harvested in June.

Sweetvetch populations differed in their ability to fix nitrogen: populations 5, 3 and 4 fixed the most nitrogen (Table 1). Levels of nitrogen fixation varied more than tenfold among the 11 sweetvetch accessions.

Seed production is also an important attribute. Seed was harvested from the field plants in the second growing season. Seed yields varied considerably; populations 8 and 10 produced hardly any seed, while population 5 produced almost 9 g of seed per plant (Table 1).

Seed weight has been positively associated with germination rate and seedling vigor in several plant species, and this attribute is often used to screen for seedling vigor in several forage grasses. Seed weight varied considerably among the 11 sweetvetch populations (Table 1) and was heaviest in population 5 and lightest in population 10.

Regrowth may be important for fall forage production, and rhizome development would be important in erosion control and resistance to grazing. Seven of the 11 sweetvetch populations exhibited regrowth and populations 7, 9 and 10 produced rhizomes.

Future Potential

Because sweetvetch produces substantial amounts of forage during spring and can fix nitrogen, it would probably do well on nitrogen-limited rangelands. Population 5 from Orem, Utah, had one of the highest seedling shoot weights and greatest root lengths in the greenhouse study. It yielded the most forage, fixed the most nitrogen, and had the highest seed yield and seed weight in the field study. This population would be an excellent candidate for commercial seed production. There was enough genetic diversity among the sweetvetch populations to assure adaptation to a wide array of sites and to facilitate improvement through breeding and selection.

ACKNOWLEDGEMENTS

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ABOUT THE AUTHORS

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M. D. Rumbaugh is a research geneticist with the USDA-ARS and an adjunct professor in the Plant Science Department at USU. His research concerns the breeding of range forbs.

B. Z. Richardson is a retired research forester with the USDA-Forest Service.
TABLE 1. Forage yield, nitrogen fixation, seed yield, and seed weight of 25 seeds from sweetvetch plants.

<table>
<thead>
<tr>
<th>Population (g/plant)</th>
<th>N-fixation* (µ moles/h/plant)</th>
<th>Seed yield (g/plant)</th>
<th>Seed weight (mg/25 seeds)</th>
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<tbody>
<tr>
<td>5 168a**</td>
<td>5 97a</td>
<td>5 9.0a</td>
<td>5 278a</td>
</tr>
<tr>
<td>4 126ab</td>
<td>3 90a</td>
<td>6 5.8ab</td>
<td>7 272ab</td>
</tr>
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<td>7 122ab</td>
<td>4 81ab</td>
<td>1 4.3bc</td>
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</tr>
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<td>6 120ab</td>
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<td>6 260abc</td>
</tr>
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<td>3 117bc</td>
<td>6 38bc</td>
<td>9 3.3bc</td>
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<td>9 41d</td>
<td>10 10c</td>
<td>8 0.1c</td>
<td>10 149g</td>
</tr>
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</table>

*Nitrogen-fixation was estimated by acetylene reduction.
**Means in each column followed by the same letter are not significantly different at the 0.05 probability level.

LITERATURE CITED


NO TRESPASSING
LOSSES ON PRIVATE LAND DUE TO BIG-GAME ANIMALS

D. B. NIELSEN and K. McBride

Wildlife are often the focus of important and controversial issues in Utah. Many people are concerned about the well-being of big-game. Many agriculturists with land close to big-game ranges view big-game animals as a nuisance and/or a threat to their livelihood and occasionally destroy them to protect their property. Many private landowners believe that their traditional property rights are being ignored and/or threatened. These differences threaten the continued widespread cooperation among the Division of Wildlife Resources (DWR), sportsmen and private landowners.

This case study was conducted to determine the location and extent of big-game damage to agriculture. It was not possible to conduct a statewide survey because there was no list of agriculturists who had received damage. For this reason, the results of this study cannot be used to estimate state-wide losses and may or may not be representative of losses in other counties.

Potential respondents were identified from lists of farmers or ranchers who had reported big-game damage. The DWR provided a list of all farmers and ranchers who had received big-game damage payments from the state in the previous 5 years (1981-1986). The Farm Bureau also provided a list of members who had reported damage. Those interviewed were asked to identify neighbors or associates who also suffered damage. Sampling only operators reporting damage made it impossible to extrapolate to a statewide estimate of damages.

The lists of names were used to identify seven counties with the greatest number of damage reports. Weber and Morgan counties were eliminated because similar studies
Almost three-fourths of those surveyed said DWR payments did not compensate for big-game damage.

had been conducted there. The counties selected for this study were Cache, Utah, Emery, Rich, Uintah, Sanpete and Box Elder. Only operators with damage to agricultural operations were included.

**State Compensation**

DWR is commissioned by Utah state law to assist agricultural operators who sustain damage. This assistance can involve: (a) damage payments and (b) big-game fencing. A landowner must show that damage has been sustained from big-game animals to receive a damage payment. Various methods can be used to determine the extent of the damage, and the operator is compensated accordingly. The maximum damage payment is $2,000 per operation annually, which many operators believe is inadequate. Some individuals contend that damages from big-game animals are not widespread or serious because not all of the funds available to pay damages were used. Several respondents said the damage payments were not worth the hassle they encountered in making claims for damage compensation.

The DWR will provide tall posts and wire for operators to install around the perimeter of a stackyard or field where damage is frequent. No gates or corner posts are provided, and there is no provision for installation. Many operators believe that installation is time-consuming and costly. One operator reported that it cost more than $10,000 in labor and equipment to erect a DWR-provided electric fence.

Yearly compensation (fences and damage payments from the DWR) reported by respondents are shown in Table 1. Of the 42 operators who said they had received damage payments from the DWR, 26 percent indicated that the payments adequately covered the losses. Almost three-fourths of those surveyed said the payments were inadequate and did not cover damage.

**Other Income**

Some private landowners derive some income from big-game. Some

<table>
<thead>
<tr>
<th>TABLE 1. Yearly assistance from the DWR to operators claiming big-game damage.</th>
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<tr>
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<tr>
<td><strong>Table</strong>: Yearly assistance from the DWR to operators claiming big-game damage.</td>
</tr>
<tr>
<td><strong>Table</strong>: DWR big-game fence <strong>24,512.95</strong></td>
</tr>
<tr>
<td><strong>Table</strong>: Damage payments <strong>23,209.40</strong></td>
</tr>
<tr>
<td><strong>Table</strong>: Total combined <strong>47,722.35</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 2. Private income derived annually from big-game sources.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Table</strong>: Operations participating  <strong>2</strong></td>
</tr>
<tr>
<td><strong>Table</strong>: Permits sold <strong>24</strong></td>
</tr>
<tr>
<td><strong>Table</strong>: $/permit <strong>60.71</strong></td>
</tr>
<tr>
<td><strong>Table</strong>: Total <strong>1,457.04</strong></td>
</tr>
</tbody>
</table>
sell private trespass permits to hunters or lease land to private hunting clubs. Club fees are used to maintain the herd and fences and lease the land. Revenues derived from big-game are shown in Table 2. Few of the landowners surveyed derived income from big-game animals.

**Damage Costs**

Damage to crops, orchards and range in the state were categorized as follows:

1. Unharvested or field crops
2. Feed or harvested crops
3. Orchards
4. Range or rangeland.

This report considered three major types of damage:

1. Annual crop damage—physical damage that affects this year’s crop, which adversely affects income for only 1 year.
2. Permanent crop damage—physical damage that also adversely affects subsequent years’ costs or revenues. Permanent damage usually affects perennial crops such as alfalfa and orchards.
3. Nuisance cost—costs incurred as a result of the presence of big-game in the area, i.e., costs of implementing and maintaining methods to prevent depredation.

**Annual Damage**

In orchards, deer tend to browse on buds that make up the next fruit crop. Loss of fruit represents a direct loss of revenue to the orchardist. In addition, variable costs increase due to increased pruning and general tree care required to overcome the damage. Actual damage in orchards was identified in order to ascertain the extent of losses.

**Permanent Damage**

Permanent damage to alfalfa means the loss of revenue during the time required to reestablish the crop, usually 1 year; a tree requires 2 to 12 years. For this reason, orchardists may incur greater losses than farmers.

Grazing by big-game may be beneficial or harmful to forage production for livestock. Heavy grazing can change the composition of range plants. This study did not determine whether big-game grazing actually changed range plant composition, but relied on producers’ perceptions of how big-game grazing affected the forage availability.
Many respondents thought the DWR was allowing increases in the number of big-game in order to accommodate recreationists.

Nuisance Costs
There are nuisance costs associated with big-game damage as producers try to prevent damage by building tall fences, scaring animals away from crops or feeding away from crops.

Big-game may consume or destroy harvested crops such as hay or silage. They may climb in mangers and contaminate feed. There are also costs associated with repairing fences and the inconvenience associated with opening and closing gates to prevent damage.

This study examined only the damage costs farmers and ranchers incurred. It did not consider whether or not resources were allocated efficiently between agriculture and wildlife or the marginal social benefits or tradeoffs between these uses.

Field Damage
The respondents grew a total of 5,683 acres of field crops, of which 3,717 acres (approximately 65 percent) were alfalfa. Corn, barley and others (grass hay and wheat, etc.) made up the remaining 1,966 acres. In total, approximately 4,809 acres were devoted to perennial crops.

Operators estimated that deer were responsible for more than 72 percent of the damage to field crops. More than 27 percent of the damage was caused by elk. Respondents did not attribute measurable damage to field crops to any other type of big-game.

Estimated damages are shown in Table 3. In total, annual damage to field crops was more than $95,000, an average of almost $3,000 per operation, or $30.92 per acre per year (32 of the 52 operators interviewed reported field crop damage).

Losses of Harvested Crops
There were 19,932 tons of feed stored, of which approximately 72 percent (14,377 tons) was alfalfa, 11 percent (2,115 tons) was corn silage and 18 percent (3,500 tons) was mostly grass-type hays. Of this total, 301 tons (approximately 1.5 percent) were consumed by big-game and 302 tons (approximately 1.5 percent) were spoiled by big-game (32 operators estimated direct feed losses and 20 operators estimated spoilage losses). Thus, big-game consumed an average of 9.42 tons in the 32 operations reporting this type of loss. Big-game also spoiled an average of 15.1 tons of stored feed in each of the 20 operations reporting these losses. Approximately 69 percent of the feed damage was attributable to deer and approximately 31 percent was attributable to elk. Although some operators expressed concern over damage caused by antelope

<table>
<thead>
<tr>
<th>Total</th>
<th>Loss per</th>
<th>Loss per</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>loss</td>
<td>operation</td>
</tr>
<tr>
<td>Field crops</td>
<td>$95,339</td>
<td>32</td>
</tr>
<tr>
<td>Stored feed</td>
<td>44,445</td>
<td>39</td>
</tr>
<tr>
<td>Orchards</td>
<td>97,075</td>
<td>15</td>
</tr>
<tr>
<td>Range</td>
<td>10,635</td>
<td>14</td>
</tr>
<tr>
<td>Fence</td>
<td>7,488</td>
<td>27</td>
</tr>
<tr>
<td>Build big-game</td>
<td>8,155</td>
<td>29</td>
</tr>
</tbody>
</table>
and moose, none estimated damage attributable to these animals. As shown in Table 3, these losses were equivalent to approximately $2.23 per ton of feed initially stored.

Orchard Damage
Most of the orchardists interviewed were in Box Elder and Utah counties. Fifteen operators reported damage to orchards. Much of the damage in Box Elder County involved peaches, and much of the damage in Utah County involved apples and cherries. Estimated losses include other nuisance costs.

In total, annual losses in orchards due to big-game were almost $98,000, or an average of approximately $217 per acre (Table 3). Approximately 89 percent of the loss involved apples, 6 percent involved cherries and 6 percent involved peaches. Permanent damage was reported on 171 acres, which represents about 14 acres per operation per year. Ninety-three percent of this damage involved apples and 6 percent involved peaches.

In the winter of 1983–84, deer caused so much damage in a 10-acre peach orchard in North Willard, Box Elder County, Utah, that all trees had to be removed and replaced. The orchardist estimated that it would take 4 to 5 years for the orchard to become fully productive again. The orchard previously produced about 200 bushels per year, which could be sold for an average of $10 per bushel, for a gross revenue of $2,000 per acre per year.

Gross Revenue Loss
Table 4 shows the loss of gross revenue, and/or potential gross revenue, in two ways. In scenario 1, the loss of gross revenue is calculated in 1983 for the next 5 years; this means that future losses in gross revenue must be discounted to their present value. Scenario 2 assumed that the losses will be evaluated at the end of the big-game damage cycle, or year five (1988). The orchardist is paid 5 percent annually on the losses.

Net Revenue Analysis
The previous analysis concerned losses in gross revenue from a peach orchard. Permanent big-game damage can also be determined according to losses in net revenue. Costs were broken down into three categories to determine losses in net revenue:

1. One-time costs. This includes replacement trees, special ground

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**TABLE 4. Potential revenue loss per acre due to permanent big-game damage over a 5-year period.***

<table>
<thead>
<tr>
<th>Year</th>
<th>Scenario 1 1983–84</th>
<th>Scenario 2 1987–88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual or potential gross revenue loss</td>
<td>$10,000.00</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Interest rate used</td>
<td>5.00%</td>
<td>5.00%</td>
</tr>
<tr>
<td>Number of years the orchard has not produced revenue</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Total loss in gross revenue</td>
<td>$9,091.90</td>
<td>$11,051.26</td>
</tr>
</tbody>
</table>

*Scenario 1 concerns damages when damage first occurred; scenario 2 concerns total losses at the end of the damage period.*
M
ost respondents said damages were higher than payments.

preparation costs required to replace an orchard and other costs not normally incurred in a productive orchard.

2. Nondeferred costs. This includes pruning, irrigation and fixed costs, etc., incurred in any orchard, whether newly planted or mature and productive.

3. Deferred costs. This includes harvesting and other costs incurred only when the orchard is productive.

Net revenue is normally figured by subtracting costs from gross revenue. However, gross revenue is actually negative when permanent damage occurs, so additional costs during the nonproductive cycle should be added to rather than subtracted from potential gross revenue. One-time costs were added only to the first year's loss of gross revenue, so the annuity calculations must be modified accordingly. Nondeferred costs may be ignored because they do not generally have any substantial effect on losses. Deferred costs are subtracted from the potential loss in gross revenue because they are not incurred during the nonproductive cycle. Net revenue can replace gross revenue in Table 4 to calculate net loss to permanent big-game damage. The interest rate in the example is one that an orchardist could earn by placing the money in a passbook savings account. Other interest rates, e.g., rates for operating capital, could be used.

Damage to Rangelands

There are no provisions for compensation for big-game use of or damage to private range. Utah law limits payments to "cultivated crops from or upon cleared or planted land" (Utah Code 1987-88). Colorado, unlike Utah and most other states, allows damage payments for depredation on private rangelands (Tully and Greene 1981). In this study, "damage" refers to any big-game activity on rangeland that requires the rancher to alter management practices in any way.

Of the 75,970 acres of rangelands, damage was reported on 66,610 acres, 88 percent of the total. Most of the damage was caused by deer (66 percent) and elk (32 percent). As shown in Table 3, losses were equal to $2.80 per acre.

Fencing

Table 3 also shows fencing costs related to big-game damage (excluding fencing provided by the DWR). Average losses were $277 per operation per year.

Operators spent an average of $281 to build big-game fences with materials supplied by the DWR (Table 3). Big-game fences are generally used to protect stackyards and orchards, which are generally small enough and have relatively high values. On the other hand, it may not be feasible to fence an orchard. For example, an orchardist in Utah County with an orchard in the foothills near Utah Lake found it was uneconomical to construct a fence because rocks required that post holes be blasted out and cemented in. Thirty-one of the 42 operators who had received damage payments from the DWR thought these payments were inadequate. Most of these respondents said damages were higher than payments, and even some who said payment was adequate were dissatisfied with how the DWR assessed damage and settled damage claims.

Many questioned the methods used to prevent damage, e.g., gates were not usually included with fences provided by the DWR. Fences also made it inconvenient to enter protected areas and move equip-
ment, particularly around barnyards. Some indicated that the type of fencing provided by the DWR was not suitable for their operation. One person purchased fencing materials to keep elk out of his haystack without DWR assistance. Most indicated that damage generally subsided after a fence was erected. However, some respondents indicated that deer climbed through or under fences.

Fee Hunting

Only three of the 51 operators interviewed indicated that they had ever provided private trespass permits or leased land to hunting clubs: two had sold permits only a few times and one regularly leased land to a hunting club for a nominal fee. The other operators indicated that they did not want to sell trespass permits or lease land to hunting clubs. Some of the operators, including some in southern Cache County, had land near big-game winter range and had few, if any, big-game on their land during hunting seasons. Some were upset because a hunting club had recently excluded them from hunting on traditional hunting sites.

This particular hunting club catered to “out of state” hunters and charged a substantial fee for hunting rights. Landowners believed that hunting clubs caused the elk herd to increase in size, which put more pressure on their cropland and private range for big-game winter feed. If so, these landowners incurred higher expenses due to the hunting club.

Population

Many operators believed that the DWR policies are causing or allowing big-game population to increase in order to accommodate demand by recreationists, and feel that private

Trespassing

This survey did not attempt to estimate costs to private landowners resulting from trespass. However, many respondents mentioned trespass-related costs. One farmer indicated that it required three men on horseback 10 hours daily during the deer hunting season to prevent fence damage and to keep hunters from shooting cattle. One farmer reported damage to a tractor and another said trespassers had destroyed Indian petroglyphs. From leaving gates open to more serious damage, trespassers can affect agricultural producers. Because a large portion of damage is probably caused by hunters, big-game thereby are linked with damage caused by trespassers. Even though only a few hunters are probably responsible for most of the damage, trespassing is still a major concern of the respondents.
Big-game spoiled as many tons of feed as they consumed.

Landowners absorb much of the cost associated with this increase because they involuntarily feed big-game during most of the winter. Operators who depend on public rangelands believe that increasing wildlife populations are affecting grazing policies and will cause government agencies to reduce livestock grazing to accommodate the extra wildlife.

Losses

Results of this study indicate that losses involve more than the feed or crops consumed by big-game. Operators incurred substantial costs in constructing and maintaining their own fences and in constructing and maintaining fences provided by the DWR. Big-game spoiled as many tons of feed as they consumed. Operators reported minimal trampling losses (three operators reported $1,004 in losses annually), although many more respondents indicated that this was a problem but were unable to estimate the costs. There are probably similar costs associated with big-game.

Damage may be greatest in orchards because trees can generally provide a source of feed year-round, fruit is a high-value and vulnerable crop and the time required for an orchard to mature increases potential revenue losses. The average damage in this study was almost $10,500 annually. Permanent damage was reported on 171 acres. In one orchard, estimated damage caused losses of $9,000 per acre. In 1986, 625,000 acres of hay (470,000 acres of alfalfa) grown in Utah yielded 2,135,000 tons of hay (1,833,000 tons of alfalfa hay) (Utah Department of Agriculture 1987). It is not surprising that unharvested crops and feed, which include a high percentage of hay, accounted for a major portion of the losses.

Big-game can consume and contaminate crops and feed. Trampling and other nuisance costs increased costs by more than $10,000 per year. Operators spent almost $5,000 to build and maintain big-game fences provided by the DWR. Nuisance costs and fence maintenance contributed almost $10,000 to indirect feed costs per year, which is more than 20 percent of the cost of damage to feed.

Damage to rangeland is more difficult to measure. Deer grazing may have beneficial effects on plant composition (Austin et al. 1986). However, it takes a considerable length of time for the overgrazing by big-game to change plant composition from shrubby plants to the grassy plants preferred by domestic livestock. In the meantime, farmers would incur considerable costs to prevent damage by big-game.

Many of the livestock producers interviewed considered big-game to be native to rangeland and did not want to remove them. They did feel threatened by what they perceived as attempts by the DWR to increase the number of wildlife and possible cuts in grazing permits.

Remuneration

This study did not attempt to assign responsibility for the damages. It was assumed that the state owned and was responsible for wildlife. Data were collected to determine whether remuneration covered the losses.

Results clearly showed that remuneration did not fully compensate the operators for their losses. The mean damage loss was about $5,100, while the mean compensation was less than $600. Some people derived benefits from the
presence of big-game on land. The operators interviewed in this study who pay for the maintenance of wildlife received few, if any, of these benefits.

Many of the operators who received fencing material from the DWR said that the damage had been substantially reduced. However, in some cases, it was too expensive to erect and/or maintain big-game fences, even when the materials were provided by the DWR.

Further Research
Additional research is required to better understand the problems that big-game inflict on agricultural producers. More information is needed on total losses and the long-term benefits and costs of big-game fencing, as well as the utility of current damage payments. Problems associated with trespassing also merit additional research.

Cooperation Advised
Losses are a small portion of total farm income, but these losses can have a substantial effect on profit margins, which are usually small in agricultural production. In some cases, losses attributable to big-game can mean the difference between profit or loss.

It may be difficult to estimate damage on some field crops or on rangeland. Nonetheless, “perceived” damages indicate landowners’ anxieties about and interest in policies regarding wildlife and damage payments. Damage is affected by those rules and policies that direct wildlife management. Even though landowners who are affected by big-game do not represent a large portion of residents, their actions have a major impact on wildlife. Cooperation between those responsible for wildlife programs and the landowners affected by these programs is essential if both wildlife and private landowners are to reap the benefits available from the land of the state. More sensitivity and understanding by state agencies toward landowners could help ease tensions on this volatile subject. Landowners should also be better informed about the possible advantages associated with big-game. Both agricultural production and big-game management could be enhanced by greater cooperation.

ABOUT THE AUTHORS
Darwin B. Nielsen is a professor of Agricultural Economics at USU. His research interests concern range and ranch economics of beef cattle and sheep production, and the economic impacts of federal government regulation on the range livestock industry.

K. McBride earned his MS degree in Agricultural Economics at USU and is now employed by the Utah Agricultural Statistics Service.

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INCREASING PROFITS ON CATTLE RANCHES IN UTAH

R. E. BANNER

Budgets for Utah cattle developed from extensive surveys and interviews conducted in 1977 (Capps and Workman 1982) serve as a valuable benchmark for analyzing the profitability of Utah cattle ranches over time. These budgets are a comprehensive source of information on ranch sizes, land and livestock inventories, management practices and production levels that can be used to estimate and evaluate current costs and returns.

Utah cattle ranches continue to be caught in a cost-price squeeze. U.S. Department of Agriculture price index reports on prices received and paid by farmers indicate that average operating costs on Utah cattle ranches increased approximately 72 percent from 1977 to 1988 while average livestock prices increased by only 48 percent (USDA 1977-1988). These price indices also indicate that crop production costs increased by 77 percent during this period. Figure 1 compares prices received and paid by farmers with 1977 levels, when average net return (cash costs basis) per cow on Utah cattle ranches was -$10.98.

This disparity in prices received and paid has been offset to some degree by an increase in livestock production levels. Average weaned calf crop has increased from around 70 percent in 1977 (Banner 1981, Capps and Workman 1982) to 75 percent in 1986 (Dickie 1986). The Utah Department of Agriculture (1988) assumed an 85 percent weaned calf crop for southern Utah cattle ranches in 1987. Average weaning weights have remained relatively constant at 450 pounds for steer calves and 420 pounds for heifers. Average cow replacement rates may have increased slightly from 13 percent to 15 percent, which increased annual cull cow sales but reduced heifer calf sales.

Failure of livestock prices to keep pace with production costs has meant a decline in average net returns per cow (cash costs basis). Even with increased calf production and cull cow sales in recent years (an increase in livestock sales of almost 15 percent over 1977 levels), average net returns to cash costs have remained negative and show a nominal decline (see Fig. 2). Under these conditions, it is exceedingly difficult to improve profitability solely by increasing production efficiency. In 1986 it would have required a 95-percent weaned calf crop, 450-pound steers and 420-pound heifers to break even given calf prices and production costs. Reducing production costs offers the greatest opportunity for improving profits on Utah cattle ranches.

Feed Costs

Feed costs account for 46 percent of the production costs of U.S. beef cow herds (Fitzgerald 1989). Based on Utah ranch budget production costs indexed up to current price levels, Utah ranchers spent an average of $241 per cow in 1988, of which $178 (74 percent) was related to feed. Obviously, substantial savings are possible if feed costs can be reduced and production levels can be maintained. A 10 percent reduction in feed-related costs would improve profitability by almost $18 per cow. If feed costs were reduced by 50 percent, cash costs per cow would be reduced by $89 and net returns to cash costs would be $62 per cow (Fig. 3). If production levels could be improved simultaneously, profitability would be even greater.

Most feed-related costs on Utah ranches involve the production and harvest of forages and feed grains. Costs associated with the ownership and operation of farm machinery (repairs, maintenance, fuel, interest, insurance, labor, parts and supplies) account for more than 50 percent of cash costs. Seed and fertilizer add 10 percent to these costs, which means...
Approximately 60 percent of the annual feed-related costs are incurred to support the cow herd during the winter.

**FIGURE 1.** Trends in livestock price and production cost indices for Utah cattle ranches (1977–1988).

**FIGURE 2.** Average costs, returns and net revenue per cow for Utah cattle ranches in 1977, 1986, 1987 and 1988 (cash cost basis).

- Cash costs/cow
- Total returns/cow*
- Net revenue/cow**

*Calf crop = 80% except 70% in 1977.
**Total returns less cash costs.
that approximately 60 percent of the annual feed-related costs are incurred to support the cow herd during the winter months, less than one-third (2-4 months) of the year.

Feed costs in Utah represent a greater proportion of annual cash costs per cow than the national average, in part because a relatively small amount of rangeland in the state is privately owned. Traditional ranch management practices and federal land management agency grazing policies mean that ranchers must often rely on more expensive harvested feeds to maintain cow herds when federally owned land is not available.

Although a considerable portion of feed costs involve maintaining cow herds, many ranchers have viewed this portion of costs as necessary and have placed more emphasis on increasing production in order to increase profits. Harvested feeds could, however, be used more efficiently if strategic production/profit objectives were established, such as increasing conception and weaning rates by shortening the breeding/calving period. Other objectives might be to increase average sale weights of calves, yearlings and cull cows or bulls, or to manage replacement heifers and young cows for growth and development as well as reproduction.

The most efficient use of range and pasture is to support the breeding herd. Ideally, these resources would provide most if not all of the feed required to maintain the cow herd. Allowing livestock to harvest forage minimizes equipment costs, and reduces other non-cash costs such as depreciation.

### Options to Consider

Ranchers must rely on good production and financial records to increase ranch profits. Production activities must be viewed as separate ranch enterprises to accurately attribute costs and returns to each enterprise. Forage and grain enterprises should be evaluated by comparing the costs of production to the market value of the crop. An evaluation of livestock enterprises involves comparing the market value of inputs (e.g., feed) whether purchased or ranch-raised, to the market value of livestock. Unless this is done, it will be difficult to identify the true cost or value of an intermediate product, such as hay or stocker calves, and more profitable alternatives may be overlooked.

Profits can be increased by increasing revenue and/or reducing costs. Increasing revenue involves adding value to products by increasing quality, quantity or both. Obviously, the greater the cost of an item, the more substantial are the potential savings in reducing the use of that item.

Strategies employed to maximize profits are similar whether or not prices are favorable (Banner 1981). Ranchers might tend to favor a more conservative approach to management if the prognosis for prices is somewhat pessimistic, and might employ a more aggressive approach if it is favorable. However, an analysis of various management strategies showed that the most profitable strategies based cow herd size on the year-long availability of range forage. To minimize losses associated with feeding hay or other harvested feeds for extended periods, the analysis indicated that breeding herds should contain fewer cows than was characteristic of most cattle ranches in Utah—returns were higher when hay was sold instead of feeding it to the beef cow herd.

### Use Less High Value Feed

Ranchers have several options to reduce their dependence on relatively expensive sources of feed and forage.

They should consider leasing or purchasing additional winter and spring range as long as the annual costs (transportation, labor, supplementary feed, fees and payments) are less than the cost of feed currently fed.
Cow herd size should be based on year-long forage availability.

Rangeland can be improved and better managed. New species and varieties of forage plants are available for winter or spring grazing. Reserving and managing some rangeland specifically for winter and spring grazing is also an option. Limited supplementation may be all that is required to meet cows' nutritional requirements.

Basing cow herd size on year-long forage availability allows ranchers to retain or purchase additional calves to utilize surplus forage and at far less expense than maintaining a breeding herd. High-value hay and grain raised on the ranch can be fed to calves or sold, depending on calf and feed prices. This approach gives ranchers more options and flexibility to control costs and increase revenue. Investments or short-term debt repayment can be appealing options for increasing revenue or decreasing costs if calf feeding does not appear to offer favorable returns.

Consider early (August) weaning. Calves gain, at best, relatively little weight late in the season when cows produce less milk and forage is mature. Early weaning allows calves to be fed high quality forage so they continue to gain weight, thus increasing their market value. Weaning calves early also allows cows to put on more weight through the fall so they enter winter in better body condition and, therefore, require less high-value supplemental feed.

Converting marginal cropland to pasture can reduce forage bottlenecks and add flexibility as well as reduce equipment costs and depreciation. Profits can often be substantially improved by increasing the percentage of weaned calves and the market weights of calves or yearlings.

Strategies developed to maximize profit for Utah cattle ranches incorporate these approaches. When long-term profitability was assessed by estimating net revenues under conditions that ranged from adverse to favorable, profit-maximizing strategies increased profit by at least three-fold over traditional strategies (Banner 1981).

ABOUT THE AUTHOR
Roger E. Banner is an assistant professor and Extension range specialist in the Range Science Department at USU.

LITERATURE CITED
Agriculture wields considerable economic clout in Utah, according to a recent study by two Experiment Station economists.

Agriculture accounts for almost 1 in 10 jobs and about 1 in 10 dollars of wages generated in Utah—$1.07 billion in wages and 60,200 jobs.

And those figures probably understate agriculture's actual effect on the state's economy, say economists W. Cris Lewis and Donald Snyder. The criteria they used to assess agriculture's economic impact were more conservative than those commonly employed in similar studies.

To determine agriculture's role in the state's economy, the economists surveyed about 2 percent of more than 12,000 agriculturally related firms that they identified in the state.

Urbanization tends to mask agriculture's economic contributions. In spite of a large percentage of rural land, Utah is among the most heavily urbanized states.

Almost 80 percent of the state's residents are in the contiguous Salt Lake City/Ogden and Provo/Orem areas.

In absolute terms, however, agriculturally related earnings and employment are greatest in the highly urbanized Wasatch Front area—almost $635 million in wages and more than 31,000 jobs.

"Our findings suggest an expanded, not diminished, role for agriculturally related industries," the economists say, noting that the processing, wholesaling and retailing of food and fiber recorded continuous growth from 1984 through 1987, a period of relatively stagnant economic growth in the state.

"Increasingly, production agriculture is only one part of a huge agri-business complex," the economists add. They measured economic activity associated with the production, processing, marketing, wholesaling, and retailing of agricultural commodities, as well as related services and support.

In view of agriculture's economic contributions, government action to support existing agricultural industries and to attract new agricultural industries is certainly warranted, the economists add.
Can nothing stop the invasion of leafy spurge? Apparently not, or at least not yet. But there have been several promising developments that should help researchers gain the upper hand against this poisonous, extremely competitive weed that threatens crops, rangelands, endangered species of plants, and habitat for wildlife as well as livestock.

One promising breakthrough involves the use of pyrolysis gas chromatography (PyGC), a technique in which heat fractures samples of the weed into its basic components. Computers then sift through this information to create a characteristic "fingerprint" of each type (accession). It now appears that there are at least three or four biotypes of the weed.

"Pyrolysis appears to be the most reliable and sensitive test capable of resolving chemical differences between accessions," says weed scientist Jack Evans, who is studying methods of controlling the weed.

The weed now infests about 5,000 acres in Utah, and threatens to spread quickly, Evans says. Leafy spurge is distributed worldwide, and in recent years has invaded several northern states, and has choked rangelands, forests and cropland in several northern states, particularly in North Dakota and Montana, where it has infested about one million acres in each state, and large acreages in Wyoming and Idaho.

Battling the weed is costly. North Dakota spends several million dollars annually to keep the weed in check. Control with herbicides is prohibitively expensive due to the need to apply concentrated solutions.

"Essentially, we have no acceptable controls," Evans says. Sheep will graze the weed at a certain stage of growth but it appears to be toxic to cattle. Several insects have been studied as potential biological controls and goats have been used to gnaw away at infestations in Montana.

Herbicides, even the most potent, are only partially effective. A major barrier to the development of effective controls is the fact that accessions of the weed are virtually indistinguishable visually and difficult to differentiate taxonomically. The effectiveness of potential controls varies among accessions.

The ability to quickly and accurately identify accessions will facilitate the development of biological and herbicidal controls effective against different biotypes.

"So far, we have not yet seen two different types of leafy spurge within a single stand," Evans says, although different types have been found in the same area.

"The results of the research here will have application in all areas of the world in which the weed is found."

Other Experiment Station researchers are employing similar methods to study the chemical characteristics of biological materials to determine the relationship between accessions of sagebrush and palatability to sheep, and to identify races of bees.

REFERENCE

Can plants control the rate at which photosynthesis increases when light intensity changes? If so, it could provide new methods of increasing crop yields.

There can be a 10-fold variation in the rate of photosynthesis among plants in the same environment. Some of this variation may reflect a plant's ability to respond to changes in the intensity of light.

Experiment Station research to learn how plants gear up for photosynthesis will help genetically alter (bioengineer) crops with higher photosynthetic rates—and higher yields.

"Although there are many factors that may limit crop yield, any biological system is ultimately limited by the photosynthetic rate," says Keith Mott, plant physiologist with the Utah Agricultural Experiment Station.

Mott's research concentrates on ribulose 1,5-biphosphate carboxylase (rubisco), an enzyme known to be a key factor in the overall rate of photosynthesis. Its activity changes within minutes following alterations in light intensity.

While there has been considerable research on the role of rubisco during periods when light intensity remains constant (steady-state photosynthesis), Mott is studying the role of rubisco immediately after light intensity increases (transient-state photosynthesis).

"The limitations on transient-state photosynthesis may be quite different than during steady-state photosynthesis," Mott says. "Under many conditions, we find that rubisco can significantly limit transient-state photosynthesis."

Mott recently developed methods to determine the enzyme's effects on photosynthetic rates during the transient state, and is now creating an in vitro photosynthetic system to determine what factors affect the enzyme's activation rate.

Determining whether there are differences between and within species of plants and the biochemical origins of those differences could help scientists remove some important barriers to increased agricultural productivity.

For example, if two plants are exposed to light for 5 minutes, the plant that can increase its rate of photosynthesis within 1 minute will be much more efficient than a plant that takes 4 minutes to get its photosynthetic machinery in gear.

However, there may be disadvantages associated with the ability to respond quickly to a change in light intensity. "It seems possible that there could be a tradeoff between the ability to respond quickly and the maximum steady-state photosynthesis. The ability to quickly respond to fluctuating light intensities may lower the maximum photosynthetic rate," Mott says.
Poisonous Plant Research

"You are what you eat."

That aphorism applies to thousands of sheep and cattle on western rangelands who end up either dead or ill when they eat poisonous plants.

Researchers with the Experiment Station and the Poisonous Plants Research Laboratory continue to study ways to prevent these losses.

Locoweed poisoning is probably the most widespread poisonous plant problem in the western states. Researchers studied when and why cattle in the Henry Mountain winter range in Utah graze the local variety of spotted locoweed, Wahweap milkvetch. Cattle found even senescent stalks of the plant palatable, and readily grazed it. The best advice: Keep cattle off infested rangelands until other forage begins to green and grow in the spring. Infestations appear to increase in wet years.

Velvet lupine, another plant widespread on mountain rangelands in the west, probably is the poisonous plant responsible for killing the most sheep. Researchers determined how defoliation affected concentrations of total alkaloids to see if plants that had been grazed were more toxic, as would be predicted by plant defense theory.

Surprisingly, alkaloid concentration in regrowth leaves declined after defoliation, perhaps because conditions were dry. That might not be the case when more moisture is available to plants.

There's better news about Ruby Valley pointvetch, a plant from the Soviet Union introduced early during the 20th century now found in several western states. Researchers found that the plant is apparently nontoxic and has about the same nutritional value as alfalfa—it may even be a good pasture forage plant. But they caution that it shouldn't be introduced where it might infest crops or meadows where grass is harvested for hay.

REFERENCES

For more than 5 years, researchers from USU and the Universities of Idaho and Wyoming have been measuring water depletion in the Bear River Basin. What they learned will affect the future allocation of water from the Bear River.

Their results were recently published by the Experiment Station as Research Report 125.

"It (their report) may be the single most important element in implementing the amended Bear River compact," says Wally Jibson, engineer-manager with the Bear River Commission.

The study determined how much water is actually consumed by irrigated crops and is therefore not available for downstream flow, says Robert Hill, USU agricultural irrigation engineer.

Under provisions of the amended Bear River compact, which governs the distribution of water among Idaho, Utah and Wyoming, depletion must be considered in the allocation of water.

Several methods can be used to calculate depletion, but the accuracy of these methods had not been verified in areas of the Bear River Basin. The three states now use different equations based on temperature to calculate depletion, and their results often varied.

Those differences can now be resolved, thus eliminating a potentially serious impediment to water allocation.

"In one of the subbasins, the values in the literature for one of
A method of generating methane (natural gas) from the wastes of dairy manufacturing plants promises to cut costs and reduce pollution.

The system involves passing wastewater through a reactor column where bacteria convert organic matter to carbon dioxide and methane. The method is widely used in sugar and alcohol processing plants, but had not been tried with whey permeate, says Conly Hansen, food engineer with the Utah Agricultural Experiment Station.

Permeate is the byproduct of ultrafiltration, a process which employs membranes and pressure differentials to remove most of the solids in milk and whey. The increased popularity of ultrafiltration in the dairy industry, due to higher yields and other advantages, threatens to create problems disposing of millions of gallons of permeate.

Hansen's studies involve whey permeate, although his results should also apply to milk permeate.

Hansen views permeate as a potential resource. "I like to call it waste utilization instead of waste treatment since we make a useful product from wastes. It's somewhat like turning sows' ears into silk purses," Hansen says.

The system, which incorporates a sludge blanket containing a mixed culture of anaerobic bacteria, can remove more than 90 percent of the potential pollutants as permeate flows through the reactor column over a 12-hour period. The end product is treated wastewater—and natural gas.

"It's a low management, low maintenance system," Hansen says. Researchers have found that some nitrogen must be added to whey permeate and are now developing methods to limit increases in the acidity of permeate.

About 25 liters of gas, about 70 percent of which is methane, is produced from a liter of permeate.

Future research will address the economic feasibility of the system. Because most large plants process whey to recover protein and other solids, the system is likely to be used by smaller dairy manufacturing plants.

REFERENCES
Grazing practices in the Intermountain region may have to be modified to maintain the productivity of crested wheatgrass stands, according to researchers with the Utah Agricultural Experiment Station.

Results of a 3-year study indicate that heavy grazing according to "range readiness" may harm crested wheatgrass stands. The ability of crested wheatgrass to produce tillers (shoots) that successfully overwinter, a factor related to the survival and productivity of stands, was not reduced by grazing before mid-May.

Heavy grazing after mid-May, as allowed under many range readiness guidelines, led to a cumulative decline of tillers in crested wheatgrass stands.

However, moderate grazing of crested wheatgrass after mid-May may not be detrimental if the stand is allowed to recover the following year, says range scientist James Richards. "But crested wheatgrass stands can't be grazed heavily after mid-May year after year without a decline in tiller density. And when that occurs, stand productivity declines and the potential for cheatgrass and shrub invasion increases."

Millions of acres of rangelands in the Intermountain West have been seeded to crested wheatgrass. These stands are important sources of forage for livestock and big game, and are important for erosion control. The study also examined the effects of intensive grazing systems such as short-duration grazing.

"Intensive grazing systems probably are not a feasible management alternative for livestock producers in the Intermountain region. Forage or cattle production may increase slightly in the short-term, but probably at the expense of long-term stand stability. In addition, the costs of implementing and managing an intensive system would probably not be offset by the slight increases in production unless the systems could be used for longer periods of the year instead of only seasonally. The spring growing season is just too short and variable," the researchers say.

In previous studies, Experiment Station researchers found that the superior ability of crested wheatgrass to produce tillers after spring grazing largely explained why it was more tolerant of spring grazing than native perennial grasses such as bluebunch wheatgrass.

This superior tillering ability means that the native, grazing-sensitive bluebunch wheatgrass should be grazed before crested wheatgrass, reversing the grazing sequence now used by many ranchers.

"Crested wheatgrass is much less susceptible to grazing damage after mid-May than bluebunch wheatgrass," Richards says. The key is to allow only moderate grazing of crested wheatgrass or to allow less intensive grazing following a year of heavy spring grazing.

"The traditional range readiness rule-of-thumb means that bluebunch wheatgrass is grazed after mid-May, which damages plants more than earlier grazing. We need to reevaluate grazing recommendations, especially for native species," Richards says.

When crested wheatgrass was grazed before mid-May, growing points (apical meristems) were not removed and plant development was not interrupted, Richards explains.

Heavy grazing after mid-May removed growing points and impeded regrowth. Stand density eventually declined.

Stand degradation is a cumulative process. Only a few tillers may be lost the first year, but those losses increase as overgrazing continues, setting the stage for invasion by weedy shrubs and other undesirable plants, Richards explains.

Range scientists Bret Olson and James Richards report the results of their research in Research Bulletin 516, "Grazing Effects on Crested Wheatgrass Growth and Replacement in Central Utah." Copies are available from the UAES Information, Utah State University, Logan, Utah 84322-4845 for $4.00 plus postage.
Researchers Seek Probe to Detect Carriers of Deadly Sheep Disease

Researchers are searching for an accurate, quick and inexpensive test to detect carriers of Spider Lamb Syndrome (SLS), a deadly genetic disease that primarily afflicts Suffolks.

A diagnostic test to replace the costly and time-consuming progeny tests now used to detect carriers of the defective gene may be available within 2 to 5 years, says animal scientist Tom Bunch.

Currently, a ram’s progeny must be tested to determine whether he is a carrier. A ram is now considered 99 percent likely not to be a carrier (“clean” or “white”) if it sires 16 normal lambs from ewes that carry the gene.

Developing a gene probe to identify carriers would make it much easier to reduce the frequency of or eliminate the SLS gene.

SLS is associated with a variety of skeletal abnormalities, including twisting of the spine, spider-like legs and displacement of the sternum. The mutant gene causing the disease probably originated in a ram born in the 1960s whose male progeny were widely popular for their ability to sire big, tall growthy sheep.

The abnormalities associated with his progeny were not associated with a specific disease until the mid-1980s, after the gene had become widespread among Suffolks and Suffolk crosses.

In 1986, pedigrees indicated that the gene frequency approached 35 percent, which meant that about 70 percent of Suffolks may be carriers of the recessive gene. Estimated SLS-related losses exceed $30 million.

Experiment Station researchers are applying recombinant DNA technology to sift through the 50,000-100,000 genes to identify the gene that causes SLS. The technique, restriction fragment length polymorphism (RFLP) mapping, involves cleaving fragments of DNA with restriction enzymes to determine the location of the SLS gene. Once the mutant gene that causes the disease is identified, a diagnostic probe can be developed to identify carriers.

RFLP mapping has been used to discover several inherited disorders in humans. The technique promises to have widespread application in livestock production, Bunch says.

“This type of technology will have a profound effect on animal breeding. It should be possible to develop probes for genes associated with attributes such as rate of gain, reproductive ability and milk production,” Bunch says.

With these probes, the productive potential of livestock could be evaluated soon after birth. For dairy farmers, the probes that identified genes associated with milk production would mean they would no longer have to wait for lactation to assess the milk-producing ability of heifers.
Is There Enough Water for Energy Development?

Will a lack of water choke energy development projects in the Western states? Many analysts assume that only large-scale water development projects can provide the water required for energy development. Experiment Station economists came to a different conclusion when they reviewed studies of water allocations in the Upper Colorado River, Yellowstone River and Great Basins. They found little reason why energy development would require large-scale water storage facilities as long as water rights could be bought and sold.

Current methods of allocating water appear to be reasonably efficient, although steps may be necessary to protect instream flows and water quality. Furthermore, energy development apparently would have little effect on other users of water, such as agriculture.

It's essential, however, that governments don't hinder the exchange of water rights, the economists say. Full cost sharing among beneficiaries of water projects, eliminating restrictions on the transfer of stored water in public projects and water-banking would also increase the efficiency of water use. Transfer of Indian water rights for use off the reservation would decrease water costs for users and increase income for Indians.

They also note that the cost of water in energy production seldom exceeds 1 percent of variable energy production costs, so a water development project probably wouldn't give a region much of a competitive advantage in attracting energy development.

REFERENCE

USU Biotechnology Building To Be Completed This Year

USU's $4.5 million Biotechnology building is scheduled for completion in December. The building, located near the Agricultural Sciences and Biology-Natural Resources buildings, will house gene machines for sequencing DNA and proteins, a monoclonal antibody unit, and fermentation facilities for bulk growth of microorganisms.

The services will be available to researchers campuswide and will house laboratories for studying the degradation properties of whiterot fungi, research which is headed by Steven Aust, director of USU's Biotechnology Program.

The Biotechnology Program will play a significant role in understanding and applying knowledge in hazardous waste cleanup, oxygen damage to living tissue, plant disease resistance, new crop strains, animal vaccines, antiviral drugs and improved cultures for the dairy industry.
THE ECONOMIC FEASIBILITY OF IMPROVING CATTLE RANCH PRODUCTION

J. P. WORKMAN and A. DICKIE

The economic feasibility of range improvements and improved management practices should be evaluated before they are implemented. The managerial techniques of budgeting and optimization can significantly increase net returns to range livestock operations. Budgeting can be used to estimate how changes in production and use of inputs will change costs and returns. Linear programming (LP) is a computerized budgeting procedure that can be employed to estimate optimal (least cost or maximum profit) combinations and amounts of inputs and products.

We used the Computer Optimization PLANning (COPLAN) program of Child and Evans (1976) to estimate optimal herd size and resource use on a representative sample of medium-sized cattle ranches in west central Utah. We also calculated the maximum break-even investments in various ranch management and range improvement practices. Specific objectives were to:

1. Quantitatively describe the typical cattle ranch in west central Utah.
2. Develop a computerized framework to analyze the economic feasibility of ranch improvement options.
3. Calculate the net value of improved production practices.

Methods

Managers of 19 medium-sized (100-300 brood cows) ranches in west central Utah (Tooele, Juab, Millard, Utah and San Pete counties) were interviewed using the ranch survey case method (Cook and Stubbendieck 1986). Data from four previous studies conducted in the area (Capps and Workman 1980, Capps and Workman 1982, Resource Concepts 1980, King 1985) were included to increase the sample size to 115 ranches.

The COPLAN program was used to estimate the optimum herd size, resource use and product mix for ranches before and after various range improvement practices. This made it possible to calculate the added net returns to each investment (Fig. 1). Present net worth (PNW) was based on a 4 percent long-term real interest rate (Row et al. 1981) and a 20-year expected improvement life.

LP analyses of ranches commonly consider forage quantity (AUMs) but not forage quality (energy and protein) (Torell et al. 1985). In this study each source of forage was assigned a relative value for crude protein, which made it possible to consider both forage quality and cost when selecting the least-cost forage combination. Crude protein values were taken from published data (e.g., Olson 1986).

Ranch Characteristics

Data from rancher interviews were used to construct a representative 179-brood cow ranch for west central Utah. Sources of forages available to this ranch are shown in Table 1.

On the average ranch, 584 tons of hay are produced annually, which is fed from about Christmas until May 1. An average of 83 calves are weaned in November for every 100 brood cows included in the herd inventory taken the previous January 1. The brood cow replacement rate of 18 percent includes heifer calves raised on the ranch (15 percent) and purchased yearling heifers (3 percent). All weaner calves, except replacement heifers, are sold in November. The average bull-to-cow ratio is 1:33.

Improvement Options

Costs and returns of range improvements or management changes should be estimated before they are implemented. For example, a rancher might want to know how much he can afford to spend to develop private foothill range. The LP model used in this study provides a fast, inexpensive and relatively
Reducing haying costs resulted in the greatest increase in net returns.

Simple method to evaluate how a change in production would affect net return above variable costs. Table 2 shows optimum cowherd size, net return and increase in net return for the following scenarios: (1) representative ranch under current conditions, (2) a 5 percent increase in weaning weights, (3) a 3 percent increase in number of calves weaned, (4) a 20 percent reduction in the cost of producing alfalfa hay, from $54 to $43 per ton, (5) a 50 percent increase in the carrying capacity of crested wheatgrass during the first 10 percent of the grazing season, (6) making crested wheatgrass available for grazing 2 weeks earlier (April 15 instead of May 1), and (7) scenarios 5 and 6 combined.

The COPLAN optimum combined the various inputs in a manner which maximized net return over variable costs (Table 2). The constraints on the optimum solution specified full utilization of all owned sources of forage, use of all U.S. Forest Service permits and feeding hay from 84 of the 117 acres of alfalfa (1100 AUMs) from January 1 to April 15. The optimum solution for current conditions required use of only one-half of available BLM and private low meadow leases. Even so, the cow herd size increased slightly from 179 to 184 head. The optimum solution for current conditions also involved retaining all calves for sale in March as short yearlings (except 33 replacement heifers) rather than selling...
them in November as weaners and resulted in net returns above variable costs of $3,048 (Table 2).

**Values of Improved Production**

The maximum amounts that a rancher could pay for the various improvements in production were determined by present value analysis (Table 2). Present values of increased net returns were calculated at a 4 percent discount rate over the 20-year investment life. Option 4 (reducing the cost of haying) resulted in the greatest increase in net returns, followed by Option 2 (heavier weaning weights) and Option 3 (more calves weaned). Options 5 and 6 (increased carrying capacity and early spring availability of crested wheatgrass) increased net returns, but much less than Options 2, 3 and 4. Thus, a rancher could afford to pay much more for reductions in haying costs or for increased cattle production than for increased carrying capacity of spring range.

**LITERATURE CITED**


**TABLE 1.** Forage sources and amounts on a representative west central Utah ranch, 1985.

<table>
<thead>
<tr>
<th>Forage source</th>
<th>Acres</th>
<th>AUMS</th>
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<tbody>
<tr>
<td>FS permits</td>
<td>323</td>
<td></td>
</tr>
<tr>
<td>BLM permits</td>
<td>688</td>
<td></td>
</tr>
<tr>
<td>State permits</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Leased native foothill</td>
<td>876</td>
<td>109</td>
</tr>
<tr>
<td>Leased low meadow</td>
<td>311</td>
<td>138</td>
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<tr>
<td>Leased crested wheatgrass</td>
<td>256</td>
<td>75</td>
</tr>
<tr>
<td>Leased seeded pasture</td>
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<td>22</td>
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<tr>
<td>Owned native foothill</td>
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<tr>
<td>Owned low meadow</td>
<td>253</td>
<td>197</td>
</tr>
<tr>
<td>Owned crested wheatgrass</td>
<td>903</td>
<td>324</td>
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<tr>
<td>Aftermath alfalfa hay</td>
<td>117</td>
<td>177</td>
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<tr>
<td>Aftermath grass hay</td>
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<td>103</td>
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<tr>
<td>Aftermath barley/corn</td>
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<td>37</td>
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<tr>
<td>Aftermath wheat</td>
<td>51</td>
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</table>

**TABLE 2.** Changes in optimum number of brood cows and net return due to improved production practices.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</thead>
<tbody>
<tr>
<td>Current conditions</td>
<td>Weaning weight increased by 5%</td>
<td>Increase number of weaned calves by 3%</td>
<td>Decrease haying costs by 20%</td>
<td>Increase carrying capacity of crested wheatgrass by 50%</td>
<td>Crested wheatgrass available 2 weeks earlier</td>
<td>Combine options 5 and 6</td>
</tr>
<tr>
<td>Optimum number of brood cows</td>
<td>184</td>
<td>223</td>
<td>222</td>
<td>223</td>
<td>184</td>
<td>184</td>
</tr>
<tr>
<td>Net return ($)</td>
<td>3,048</td>
<td>5,824</td>
<td>5,176</td>
<td>7,589</td>
<td>3,288</td>
<td>3,603</td>
</tr>
<tr>
<td>Net increase in return over current conditions</td>
<td>——</td>
<td>2,776</td>
<td>2,128</td>
<td>4,541</td>
<td>240</td>
<td>555</td>
</tr>
<tr>
<td>Maximum affordable investment to obtain increase in net return ($)</td>
<td>——</td>
<td>37,700</td>
<td>28,900</td>
<td>61,700</td>
<td>3,260</td>
<td>7,540</td>
</tr>
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</table>

**ABOUT THE AUTHORS**

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Livestock grazing changes plant communities in ways that are often beneficial to wildlife. Much more remains to be learned about these relationships, but what has been learned indicates that livestock and wildlife can share...