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Factors and Practices that Influence Livestock Distribution

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INTRODUCTION

Reducing the impact of livestock on water quality, aquatic and riparian habitat, and biodiversity is a continuing goal for livestock producers, natural resource managers, and conservation groups. Livestock's environmental impact is frequently determined by livestock distribution. While fences are usually an effective tool for controlling livestock distribution and reducing impacts on riparian zones or other critical areas, manipulation of grazing patterns can also reduce adverse effects from livestock. Another helpful practice is the use of grazing to manipulate vegetation to meet management goals. An awareness of livestock needs and management is crucial for livestock producers, land managers, community watershed groups, environmental interest groups, and policy makers. By understanding the factors that influence where animals graze, rest, and drink, livestock can be redistributed in a predictable and effective manner so that they do not have undesirable effects in grazed watersheds.

In this publication we describe pasture and animal management knowledge and practices that can be used to alter livestock distribution and to attract livestock away from environmentally critical areas or into areas targeted for grazing. While basic livestock distribution practices have changed little in the last 50 years, new research suggests ways to fine tune and combine these management techniques that will improve their effectiveness. The practices derive from basic and applied research in animal behavior and landscape ecology, and they involve changes in pasture management or changes in livestock management. Instead of documenting these practices with extensive literature citations, the reader is directed to a few comprehensive reviews and recent reports on the factors and practices that influence livestock distribution (Bailey et al. 1996; Bailey 2004).

DAILY ACTIVITIES INFLUENCE DISTRIBUTION

Each day grazing animals must decide where to graze, ruminate, rest, and drink. Large herbivore activity and use patterns in different areas of a grazing unit, pasture, or habitat are based on the kind of resources found there. Both abiotic and biotic factors influence the way livestock use rangelands (Bailey et al. 1996). Abiotic factors include slope, distance to water (horizontal and vertical), weather, and barriers. Biotic factors include forage quality, forage quantity, and secondary compounds. With the exception of weather, abiotic factors usually remain somewhat constant while biotic factors may change due to forage growth, senescence, and grazing. Riparian zones often receive heavy use because they provide water, shade, thermal cover, and a productive source of high-quality forage. Animal cognitive abilities to select foraging areas, such as spatial memory, also influence grazing distribution (Bailey et al. 1996).

Stock water is the primary focal point around which the daily feeding and resting activities are centered. The water source and surrounding areas used for grazing, rest, and thermoregulation define a ***camp*** that may be used for a few days to several weeks. In large allotments several camps may constitute the ***home range*** for the herd. A camp is made up of several *feeding sites* (fig. 1). Animals rarely use the same feeding site for more than 2 consecutive days.

When grazing animals become familiar with a landscape they retain information about the location of focal points such as water, shade, and feeding sites. Relying on spatial memory, grazing animals can exercise feeding site preferences in order to maximize nutrient intake, minimize travel effort, and maintain thermal comfort (fig. 2). Researchers believe that grazing animals integrate information about abiotic and biotic factors in long-term memory (Bailey et al. 1996; Bailey 2005). This information provides the basis for ranking feeding sites when deciding where to graze next. The individual animal's daily selection of a feeding site can then be modified by weather conditions, social interactions, and herding (see fig. 2). Sites that have been recently grazed may be ranked lower in the daily selection process, resulting in a feedback loop that prevents repeated use of the same feeding site.

Feeding sites are a collection of vegetation *patches* in a contiguous area that animals graze during a foraging bout. A feeding site may contain one or more plant communities (vegetation types). A patch might be a single bunchgrass, a shrub, or a nutritionally similar area within a plant community. *Foraging bouts* are defined by a change in behavior from grazing to resting, ruminating, or traveling. Beef cows commonly have a morning foraging bout of around 4 hours in length and a second afternoon or evening foraging bout of similar length.

The daily activity patterns of most ungulates are centered on watering and resting during midday. On average, a cow spends about one-third of its day grazing, one-third ruminating, and one-third resting. Typically, cows start the day just before sunrise with a grazing bout. At midday, cows usually travel to water to

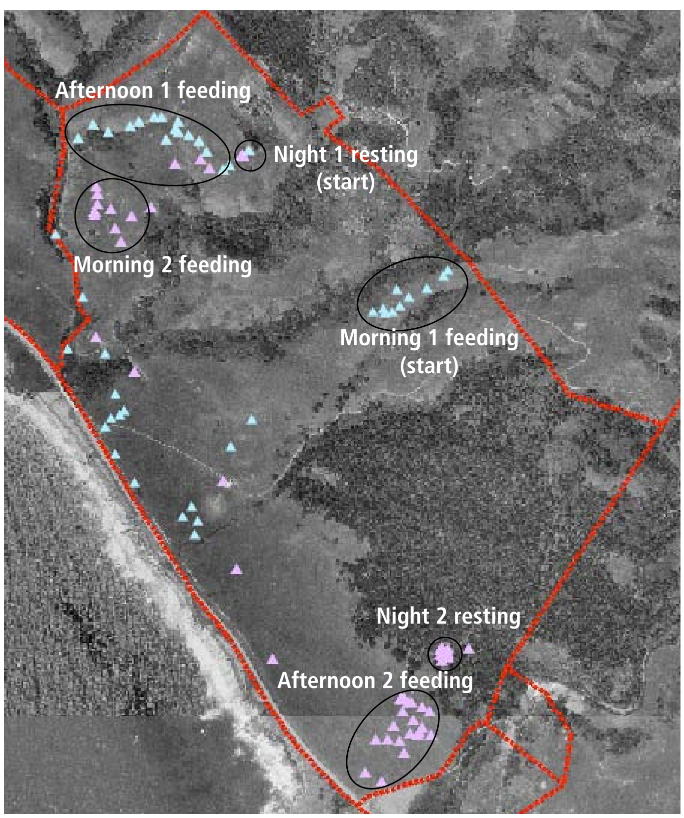

Figure 1. Positions of one cow during morning and afternoon feeding and night resting, from August 7, 2004 at 6:30 AM (morning feeding 1) to 4:00 AM on August 9, 2004 (night rest) on a 1,000-acre (400-ha) coastal pasture in San Luis Obispo County, California. The cow was equipped with a GPS collar that recorded its position every 15 minutes. Graphic by Melvin George; photo courtesy USGS.

RIPARIAN ZONES AND LIVESTOCK DISTRIBUTION

Riparian zones are attractive to grazing animals because they are a source of high-quality water and, in gentle terrain, they are often a source of dense, high-quality forage. Because soil water remains available there longer than in adjacent uplands, riparian areas have a longer green season. This results in corridors of high-quality forage surrounded by lower-quality upland forage as the growing season progresses. Riparian zones also offer shade during hot weather and often serve as a refuge from insects.

Forage and browse quantity and quality greatly influence livestock's use of riparian areas. As upland forage quality decreases, use shifts to the riparian area where quality and quantity of forage is greater. Shrub use may increase as riparian herbaceous plants decline in quality even further. During a wet year, cattle tend to use uplands longer before shifting to riparian zones, while in a drought year they use the riparian zones sooner and longer, perhaps also increasing shrub utilization sooner. Shrub utilization is lowest when herbaceous vegetation is lush and very palatable and greater when herbaceous vegetation is coarse and mature or when it is too short (< 3 inches). When the height of herbaceous vegetation is below three-fourths inch, cattle cannot physically graze it and are forced to feed on another species or an otherwise less-preferred herbaceous species and/or shrubs.

If the turn-out location directs cattle to the riparian zone, that is where they will

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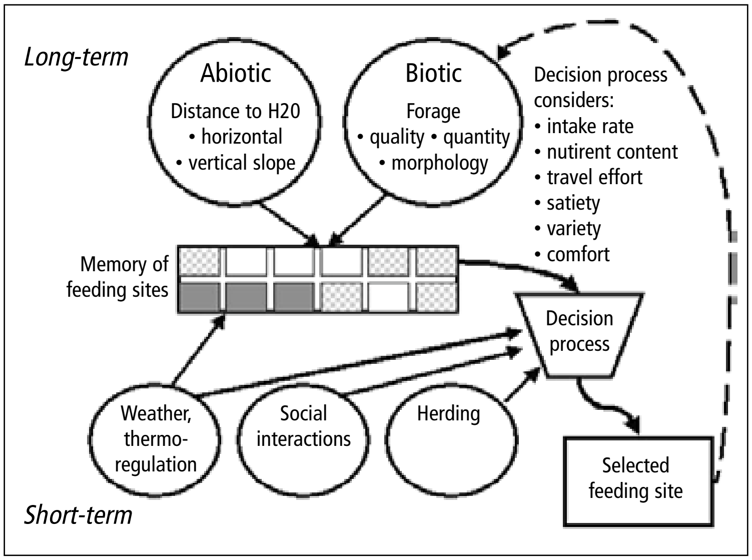

Figure 2. Effect of management on feeding site selection. Animals rate individual feeding sites based on abiotic and biotic factors. Daily feeding site selection is based on these relative ratings in an effort to maximize nutrient intake, minimize travel effort, and maintain thermal comfort. The interaction between the desire to maintain satiety and seek out variety is also important (Provenza et al. 2003). The individual animal's selection of a feeding site can then be modified by weather conditions, social interactions, and herding. Through a feedback loop, the grazing of selected sites affects the sites' biotic characteristics (forage quantity and quality). For the memory of feeding sites, white boxes represent good ratings (e.g., riparian areas in the summer), cross-hatched boxes represent intermediate ratings (e.g., moderate-sloped uplands in the summer), and solid gray boxes represent poor ratings (e.g., high and steep uplands in the summer).

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RIPARIAN ZONES AND LIVESTOCK DISTRIBUTION
(continued)

go and stay. In large pastures, changing the turn-out point may change the timing of use in riparian zones and meadows. This might facilitate the development of an internal pasture rotation that could be alternated each year. It might also help reduce the actual grazing period for an area of critical concern by turning cattle onto the pasture at a point far removed from the area of concern.

During winter, if the riparian zone acts as a cold air drainage or pocket, cattle tend to minimize use. Cattle often leave narrow valley and canyon bottoms late in the season when cold air accumulates in the riparian zone; they also leave those areas when late-summer or early-fall rains improve the palatability of the forage on adjacent slopes. Conversely, cold air drainage in flat, broad valleys is not prohibitive; late in the season, cattle are often drawn to a riparian area because it contains the only remaining succulent vegetation.

drink, rest, and ruminate. As evening approaches, cows begin a new feeding bout, often in a new location (see fig. 1). The daily activity pattern changes depending on conditions. In the summer, beef cows in the central Sierra Nevada foothills grazed for a total of 8.2 hours, with 6.3 hours occurring during daylight (Harris 2001). Cows rested for 14.5 hours, with 8.7 hours occurring during daylight. During the winter of 1999, when forage was adequate, cows grazed for about 9.3 hours (5.3 hours during daylight) and rested for 13.2 hours. In 1998, when forage was scarce, the grazing time was extended to 12.8 hours (8.4 hours during daylight) and resting time decreased to 10.6 hours (1 hour in daylight). In a study near Burns, Oregon, Ganskopp (2001) found that beef cows grazed for about 11 hours from mid-June to mid-July and rested for about 10.1 hours.

The time spent grazing depends on forage quality, thermal balance, and forage availability. Animals reduce grazing time as digestibility of forage declines and as passage time of forage through the digestive tract increases. When daytime temperatures are within the thermal comfort zone, most grazing will occur during daylight hours. During hot periods, cattle reduce afternoon grazing and increase evening grazing. Cattle limit evening grazing and increase afternoon grazing when winter temperatures are below their thermal comfort zone. When the forage supply is limited, animals compensate by increasing grazing time. However, if the forage supply is severely limited animals may give up foraging to reduce the energy expenditure of travel.

Starting from a watering site, the distance covered by an animal on any given day is determined partly by rate of food passage through the digestive tract, rate of forage harvest, grazing velocity, and hunger. During the early summer, beef cows in the Sierra Nevada foothills with only one stock watering site ended their afternoon or evening feeding bout near a ridgetop to take advantage of cooling breezes (Harris 2001). The following morning, the herd grazed away from the night resting site until midmorning when they sought a shady resting site to ruminate and digest the food ingested during the morning feeding bout (fig. 3). In the early afternoon the herd traveled toward the watering point, drank, and traveled a short distance to shade. In the mid- to late afternoon the animals grazed away from the shade and water toward a night resting site.

Daily movement patterns are influenced by forage quantity and quality. Patches of high-quality forage surrounded by forage of lower quality may be visited daily (fig. 4). This

Figure 3. Beef cattle resting in the shade of an oak tree. Photo by Melvin George.

Figure 4. Seasonal riparian patches surrounded by dry annual herbaceous plants in an oak woodland in California's Sierra Nevada foothills. Photo by Norm Harris.

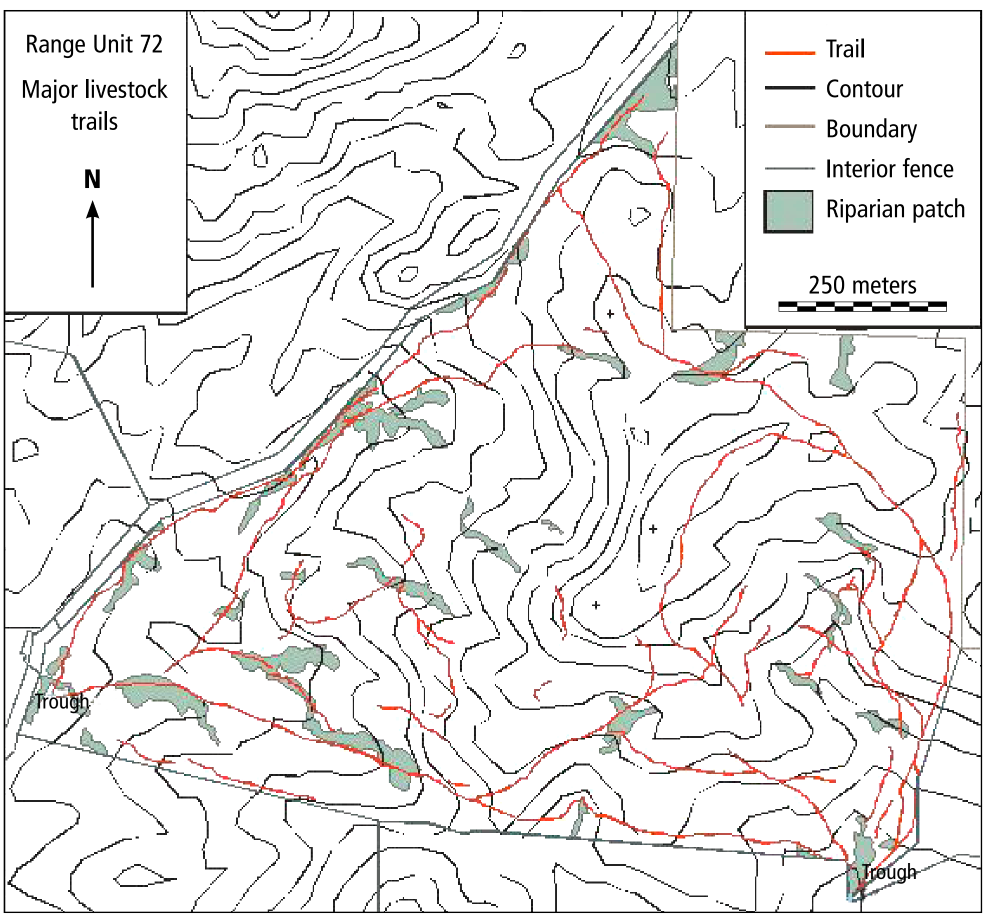


Figure 5. Using a well-established trail system, beef cows make a daily circuit visiting high-quality seasonal riparian patches surrounded by dry grass (example in fig. 4) in a 200-acre (80-ha) annual rangeland pasture at the San Joaquin Experimental Range in Madera County, California.

may increase daily travel if patches are dispersed, and may result in heavy grazing of high-quality patches. Early summer studies at the San Joaquin Experimental Range (Harris 2001) showed that beef cows make daily visits to a series of high-quality seasonal wetland patches surrounded by dry lower-quality forage (fig. 5).

ABIOTIC FACTORS THAT INFLUENCE DISTRIBUTION

Slope and Water Strongly Control Livestock Distribution

Slope and distance to water have a strong effect on livestock distribution. When a mixture of gentle and steep terrain exists, cattle typically congregate on the gentler terrain, preferring slopes of 10 percent or less. As slope and horizontal distance to water increase, grazing use often decreases (tables 1 and 2). In gentler topography, horizontal distance to water has a stronger influence on grazing capacity than vertical distance to water. In rough topography, the relationships between grazing use and distance to water may differ from those observed in gentle terrain. In northeastern Oregon researchers found that cattle preferred areas within 200 yards (183 m) of water and avoided areas greater than 656 yards (600 m) from water in mountainous terrain (Gillen et al. 1984). In another Oregon study cattle avoided areas further than 1 mile from water but vertical distance appeared to be more important than horizontal distance to water. Cows did not graze at elevations that were 260 feet (79 m) above water (Roath and Krueger 1982).

Cattle may preferentially use feeding sites nearest the stock water source (fig. 6). However, as these near-feeding sites are depleted, livestock will travel to more distant and steeper feeding sites. The size of a camp is largely controlled by the distance cattle will travel for water. While cattle have been known to travel up to 2 miles (3.2 km) for water during drought conditions, under normal conditions forage utilization begins to decline on gentle terrain at distances of about 0.5 mile (0.8 km) from water. Under normal conditions a camp may be defined as the collection of feeding sites within 0.5 mile to 1 mile (0.8 to 1.6 km) of water. Under drought conditions a camp might include more distant feeding sites.

The physiological state of the animal also influences use of rugged terrain. The greater water requirement of lactating cows and the behavioral requirements of caring for a calf can limit use of rugged terrain (Bailey et al. 2001). Nonlactating cows in Montana traveled higher from water and in some cases used steeper slopes than lactating cows. A study in Oregon found that cows whose calves have been weaned graze further from riparian areas than cows that are nursing calves (DelCurto et al. 2005).

Table 1. Approximate reductions in cattle grazing capacity for different slope percentages

Slope (%)	Reduction in grazing capacity (%)
0–10	0
11–30	30
31–60	60
> 60	100

Source: Holechek 1988.

Table 2. Approximate reductions in cattle grazing capacity as distance from water increases

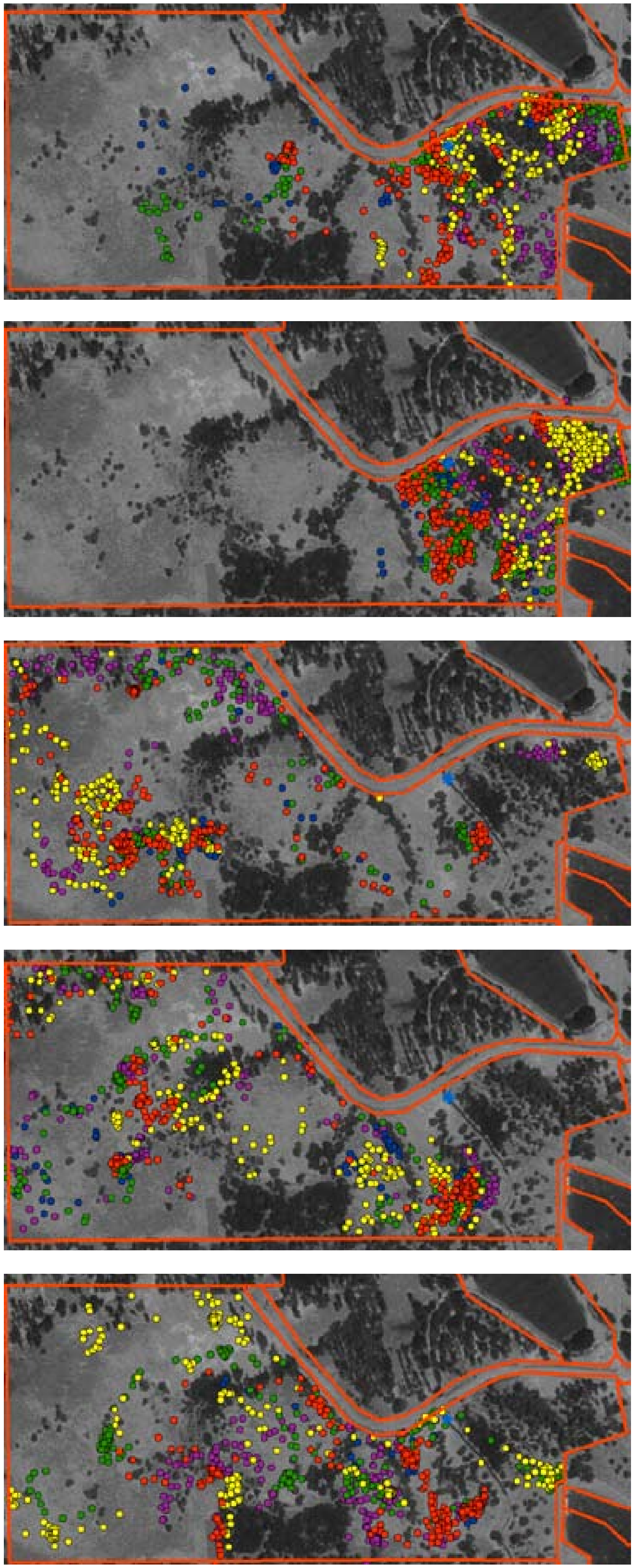
Distance from water (mi)	Distance from water (km)	Reduction in grazing capacity (%)
0–1	0–1.6	0
1–2	1.6–3.2	50
> 2	> 3.2	100

Source: Holechek 1988.

Figure 6. Increased distribution of beef cows (March 23–25) after depleting feeding sites on gentle slopes near stock water during the previous 2 days (March 21–22) in a 50-acre (20-ha) annual rangeland pasture at UC Sierra Foothill Research and Extension Center. Images by Melvin George; photo courtesy USGS.

Key

- Stock water
- Cow 1
- Cow 2
- Cow 3
- Cow 4
- Cow 5



March 21

March 22

March 23

March 24

March 25

Table 3. Approximate daily water requirements (gal) for beef cattle

Class of animal	Temperature (°F)					
	40°	50°	60°	70°	80°	90°
1,100-lb lactating cow	11.4	12.6	14.5	16.9	17.9	16.2
1,100-lb dry cow	6.0	6.5	7.4	8.7	10.0	14.5
1,400-lb bull	8.0	8.6	9.9	11.7	13.4	19.0
600-lb growing heifer, steer, or bull	5.3	5.8	6.6	7.8	8.9	12.7

Source: National Research Council 2000.
Note: 1 lb = 0.454 kg; 40°F = 4.4°C; 50°F = 10.0°C; 60°F = 15.6°C; 70°F = 21.1°C; 80°F = 26.7°C; 90°F = 32.2°C.

GIS/GPS TRACKING TECHNOLOGY

Animals with GPS collars (figs. 7 and 8) can be tracked on a 24-hour basis. The commercially available collars used in these studies come with an inherent accuracy of about 20 to 25 yards (23 m) but, with differential correction, position errors are reduced to around 5 to 10 yards (5 to 10 m) most of the time. Location fixes (latitude/longitude) can be recorded at intervals of every 5 minutes to 6 hours. Collars also record air temperature as well as vertical and horizontal head movements. Head movements can be used to estimate grazing and resting time between location fixes. Disposable or rechargeable batteries power the collars. Collar memory and battery power is sufficient to collect up to 5,000 locations. The position, along with the temperature and head movement data, can be downloaded and mapped in a geographic information system (GIS). GIS technology provides powerful tools to analyze and summarize the data collected from the GPS collars. Positions can be mapped on aerial photographs or digital elevation models (digital topographic maps) for visualization and analysis. Several of the figures in this publication were produced using GIS software. GPS collars and GIS technology have become integral components of livestock grazing distribution research.

Water is the most critical component of livestock habitat. Sufficient water must be available for the number and type of animals, given the current and expected climatic conditions. Ambient temperature, activity, and lactation status can all affect water requirements (table 3). Availability of water can limit the season of use of pastures in arid regions. For example, water from snowmelt may provide sufficient water for spring grazing, while in the summer there may be inadequate water after intermittent water sources dry out. The presence of snow during the fall and winter may reduce the amount of water that livestock must drink. In Montana, a cow tracked with a GPS collar did not visit any water sources for 6 consecutive days in January when snow was available. In California's annual rangelands, water content of forages may be high enough in early spring so that cattle make little use of stock water sources. In rough terrain in northeastern California, cows tracked with GPS collars occasionally traveled nearly 2 miles (3.2 km) from preferred summer feeding sites to stock water, drinking only once in 2 days.

Fences and Barriers

Barriers impede travel and constrain animal distribution. Steep terrain, rocky surfaces, and thickets of woody plants are common obstacles to animal movement. Canals with steep sides and deep water bodies also limit animal access. In steep terrain, roads, retired railroad beds, trails, utility or pipeline rights-of-way, topographic benches, and ridgetops can aid cattle distribution and help alleviate pressure on gentler slopes and riparian zones. Trail development and access roads improve distribution on steeper slopes or facilitate access past slopes that may be barriers preventing access to gentler terrain with available forage. However, improving access will not overcome the effects of poor water distribution.

Figure 7. Placing a GPS collar on a beef cow at the UC Sierra Foothill Research and Extension Center. Photo by Melvin George.

Figure 8. Beef cow equipped with a GPS collar grazing in north-central Montana. Photo by Derek Bailey.

Table 4. Relative preference indices (RPI) of California annual rangeland sites for grazing during daylight hours

Range site	Summer 1997	Summer 1998	Winter 1998	Winter 1999
swales	4.17	9.49	1.48	3.08
north gentle slope	0.85	0.49	0.67	1.04
south gentle slope	0.66	0.82	1.22	1.06
north open rolling slope	2.16	0.33	1.15	0.22
south open rolling slope	0.97	0.31	1.53	0.99
north brushy rolling slope	0.66	0.14	0.33	0.65
south brushy rolling slope	0.32	0.22	0.50	0.56
north brushy steep slope	0.00	0.00	0.00	0.00
south brushy steep slope	0.83	0.27	0.36	0.75
steep rocky bluff	1.15	0.00	0.26	0.57

Source: Harris 2001.

Note: An RPI of 0.00 indicates no preference and the site with the highest RPI is most preferred. Swales are preferred in summer because they remain green after the uplands have dried.

BIOTIC FACTORS

Forage Quantity and Quality

Livestock are attracted to vegetation patches and plant communities where they can rapidly fill their rumens with high-quality forage. Consequently, grazing animals spend more time in patches and plant communities that are higher in forage quantity and quality (table 4). In north-central Wyoming, researchers found that cattle spent only about 20 percent of their time in a plant community with a standing crop of 150 kilograms per hectare (134 lb/acre) that encompassed 82 percent of the total pasture area, whereas they spent about 80 percent of their time in two plant communities with standing crops of 382 kilograms per hectare (341 lb/acre) and 730 kilograms per hectare (652 lb/acre) constituting only 18 percent of the pasture (Smith et al. 1992). Studies in Colorado and Wyoming have shown that cattle prefer plant communities with greater protein levels (Senft et al. 1985; Pinchak et al. 1991). Oregon researchers have found that riparian areas and meadows often provide 1.5 to 6 times greater quantities of forage with similar or sometimes slightly greater crude protein concentrations than found in uplands, which may help explain why cattle spend a disproportionate amount of time in riparian areas.

When forage is abundant and of high quality, the time livestock spend grazing is reduced. As forage quality decreases, intake rates decline and grazing time increases. Species composition, stage of plant maturity, and leaf to stem ratios strongly influence intake by grazing animals. Large, easily accessible forage patches of high quality lead to higher intake rates and faster grazing times. When small, high-quality patches are dispersed in large areas of low forage quality, grazing time usually increases.

Palatability and preference are terms commonly used to describe animal acceptance of a forage source. Palatability refers to those factors inherent to a plant species that elicit a selective response in the animal. Palatability is a dynamic plant characteristic that changes throughout the annual plant growth cycle. Preference is a behavioral function which involves proportional choice of one plant species from among two or more species or one plant part from among two or more parts. The preference status of a particular plant species is largely dependent upon its inherent abundance, its morpho-phenological characteristics, the array of species on offer, and the species of animal in question. As with palatability, preference is also dynamic and changes with seasonal forage availability and weather conditions.

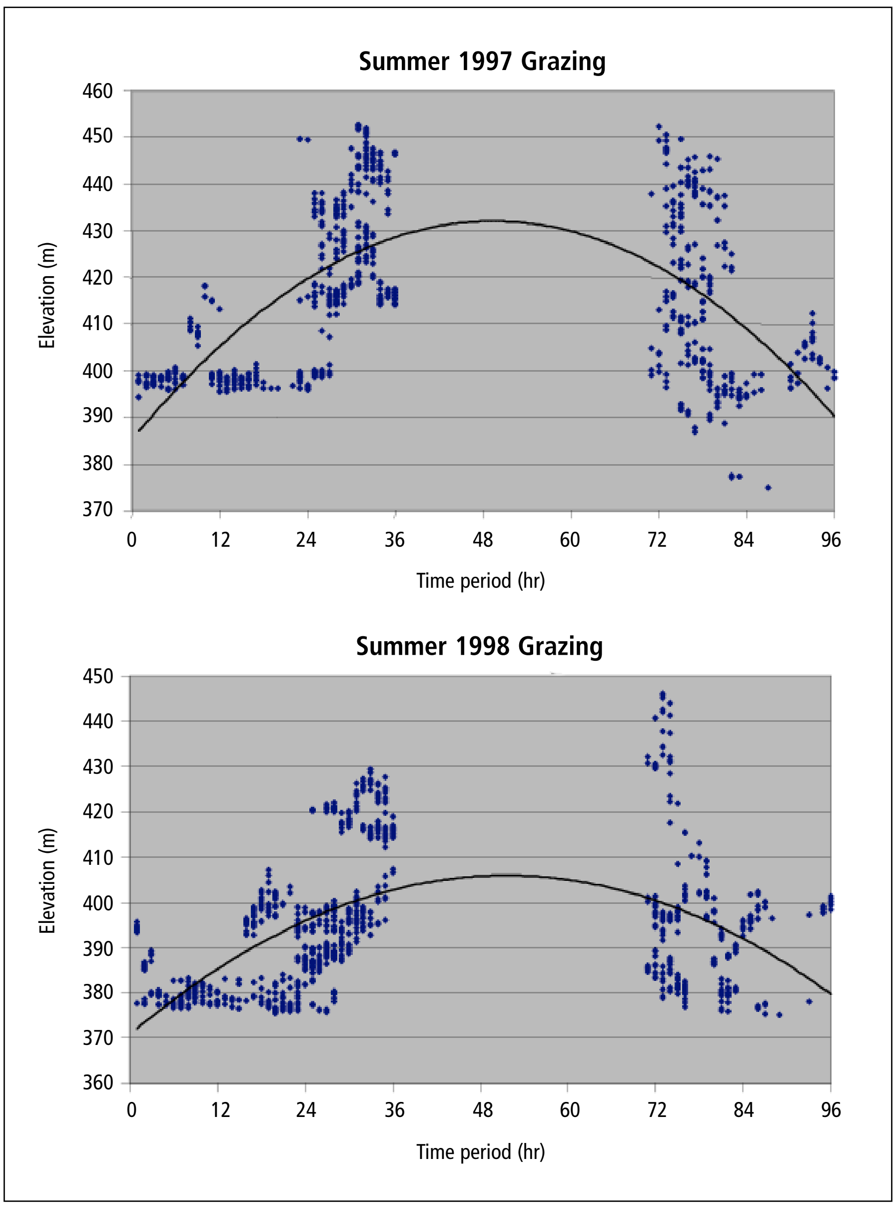
In addition to having high intake rates, herbivores select diets more nutritious than those that researchers can collect by hand. Studies have shown that grazing animals eat a diverse array of plant species but they have also shown that the bulk of a meal contains fewer than 10 species and often fewer than 5 species (Provenza 2003). It is believed that grazing animals balance their intake of the available plant species and plant parts in response to post-ingestive feedback from nutrients and toxins present in plants. The presence of secondary plant products, such as tannins, alkaloids, and glycosides, may reduce intake of a particular forage (Provenza 2003); conversely, the presence of nutrients that are lacking in the diet, such as energy or protein, may stimulate intake.

Thermoregulation

The need of grazing animals to maintain their body temperature within a thermal neutral zone strongly influences livestock distribution. National Research Council (2000) reports that the thermal neutral zone for a beef cow is from 59° to 77°F (15° to 25°C). Rangeland with trees, shrubs, and variable terrain provides livestock opportunities to seek out sites with more favorable climatic conditions so that body temperature can be maintained. Microsite characteristics, such as the presence or absence of shade and wind, affect where animals rest and can affect where they graze. In California, cows spent about 8 hours per day under shade trees during sunny summer days and then grazed up the elevation gradient in the late afternoon and evening toward higher-elevation ridges where there was greater night air movement (Harris 2001) (fig. 9). During the winter, these cows avoided shade trees and grazed warmer southern exposures. During cold, windy periods cattle seek shelter from the wind. In Montana and Colorado, cattle sought out protected microsites within a pasture to avoid high wind speeds combined with low temperatures. During cold, nonwindy periods, cattle tend to use south slopes because of the warmer environment (Prescott et al. 1994). Relative humidity has also been found to influence preference for location. In one study, both cows and yearlings preferred zones where the relative mean humidity was 60 to 70 percent regardless of temperature (Bryant 1982).

Researchers have found that cattle spend more time grazing and less time standing on warm days than on cold days. They also graze and ruminate longer following changes in atmospheric pressure. Daily travel distances are inversely related to average daily wind speeds. The net result for cattle is reduced energy

Figure 9. Grazing positions plotted every 15 minutes along an elevation gradient (100 m = 328 ft), showing that beef cows at the San Joaquin Experimental Range in Madera County, California, grazed uphill in the late afternoon and early evening and then downhill the following morning starting at about 6:00 AM.



expenditures during periods of weather stress, according to researchers. They also found that daily grazing time increases with increased ambient temperatures and decreases with increased thermal stress.

Pest Avoidance

If face flies are a problem, cattle tend to select upland or open areas with more wind for resting. In a study that provided cattle with access to open pasture, open canopied forest, and closed canopied forest, cattle selected the open pasture more during a drought year than a wet year. Flies were a problem during the drought year, and the cattle may have found more relief in the open pasture. During the hot part of a wet year, when fly problems were not as bad, cattle preferred the open canopied forest. The closed canopied forest was used very little in either year.

Memory and Learning

As defined earlier in simple terms, a camp is a set of feeding sites that share common water and resting points. In reality, a camp may have multiple feeding, watering, and resting locations. Large grazing allotments may contain a single camp or multiple camps depending on their size and the distribution of watering and resting sites. The location of these sites is part of herd memory passed on from mother to offspring, resulting in repeated use of favored feeding, watering, and resting sites over the years. This learned behavior can be difficult to change. Keeping the same turn-out points (unloading locations or pasture entry points) will reinforce this learned behavior. Changing turn-out points and persistent herding can modify these behaviors by encouraging changes in preferred feeding, watering, and resting sites. To be effective, however, these practices need to be applied consistently and repeatedly. Placement of an attractant such as a supplement site can reinforce herding practices. These same practices might be used to train a naïve herd that does not have knowledge of the terrain nor of spatial relationships of water and feeding sites.

Inexperienced cattle have less predictable behavior in a pasture than do cattle that traditionally use an area. In theory, it might be possible to behaviorally bond inexperienced cattle to a new area which had been previously underused, provided that water, forage, shade, and salt are available there. For this to be successful, the livestock must be handled so they disperse to upland slopes when turned onto the pasture, avoiding initial concentration on riparian bottoms.

PRACTICES THAT MODIFY BEHAVIOR IN GRAZING ANIMALS

Application of existing and improved management techniques can alter livestock distribution patterns and improve the sustainability of range livestock production. Most of the practices and strategies currently used to improve grazing distribution have been known for over 50 years. Grazing behavior modification can be accomplished by changing the pasture or by changing the animal.

Changing the Pasture

Water Development

Cattle and other large herbivores are central-place foragers with the central place or home place centered on water. Consequently, proper placement of stock water can often reduce the impact of livestock on riparian areas and other critical resources. Horizontal and vertical distance from water strongly influences the selection of feeding sites by beef cattle (Bailey et al. 1996). Utilization of an area usually decreases with distance to water, resulting in overuse near stock water and underuse at distances from stock water (see table 2). Vertical distance to water is important in steep terrain.

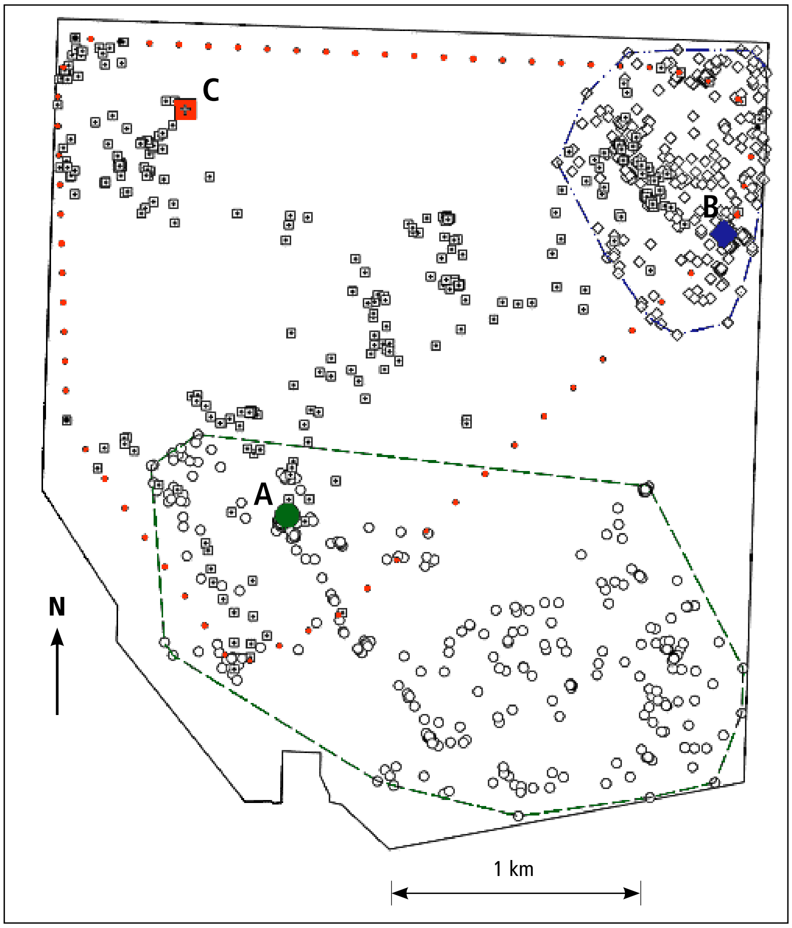
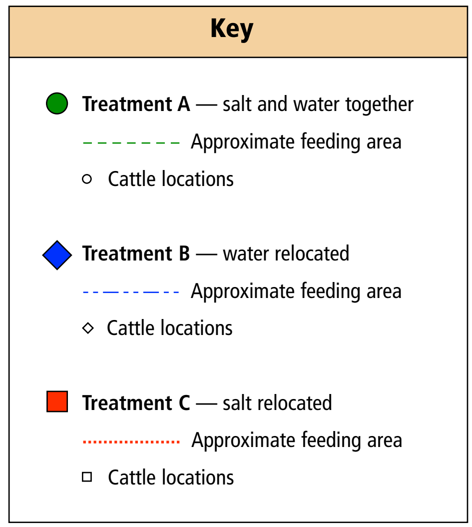


Figure 10. GPS positions for one cow as the location of water and salt changed in a pasture near Burns, Oregon. In Treatment A, salt and water were provided at Location A and the cow grazed within the area of the green dashed line. In Treatment B, when the water was relocated to Location B, the cow abruptly shifted to the new water location and did not return to Location A for salt. When the salt was relocated from Location A to Location C (Treatment C), the cow used the salt but preferred to stay near the water at Location A, resulting in travel between Location A and C.



Generally, cattle should not have to travel more than a mile to water in gentle terrain and 0.25 to 0.5 miles (0.4 to 0.8 km) in steep terrain (see table 1). Development of new stock water in areas that are further than 0.5 mile (0.8 km) from stock water usually increases forage use nearby and improves uniformity of grazing. Additionally, it usually results in an increase in carrying capacity for the pasture. Using GPS technology, Ganskopp (2001) documented the abrupt change in grazing patterns when the location of stockwater was changed (fig. 10). With several strategically placed stock water troughs in a pasture, alternately filling and emptying troughs can result in a grazing rotation that provides for rest periods (troughs empty) between grazing periods (troughs full).

Water development has been useful for reducing livestock impact on riparian areas (Bailey 2004). Some studies have shown a significant reduction in use of streams when off-stream water troughs are provided, especially early in the summer grazing season when forage is plentiful (DelCurto et al. 2005). Miner et al. (1992) found that cattle prefer off-stream water during winter, presumably due to warmer stock water temperatures. Studies have also shown continued preference for streams in riparian zones when alternative water sources required negotiation of steep slopes. Researchers in eastern Oregon have found that development of stock water away from riparian areas decreases livestock use of riparian areas (Bailey 2004).

The water requirements of beef cattle vary with air temperature and physiological state. Dry or bred cows require 6 to 15 gallons (23 to 57 l) of water per day (see table 3). Lactating cows require 10 to 20 gallons (37.9 to 75.7 l) per day. In large pastures where cattle travel long distances to water, they tend to go as a herd; this results in a large demand for water during a short period of time. Sneva et al. (1975) found that if water is readily available, cattle water twice. They also found that when water is restricted, cow milk production decreases, resulting in reduced calf gains. During hot summer days on

California's foothill rangelands, cattle generally drink only once daily, coming to stock water as a herd usually between noon and 2 PM. A study in Montana, however, observed cattle coming to water sooner, usually between 10 AM and noon.

Water quality can influence stock water use (Boyles et al. 1988; Miner et al. 1992; Willms et al. 2002). Researchers in Montana found that the ideal drinking water temperature for livestock is from 40° to 65°F (4.4° to 18.3°C), and that steers having access to cool drinking water gained 0.3 to 0.4 pounds more per day than those drinking warm water (Boyles et al. 1988). Observations in Oregon, Montana, and Alberta suggest that cattle prefer to drink from a trough rather than a pond. Cows that drink out of reservoirs or ponds churn up the sediments as they move into the water to get a drink. Many times the second cow to drink will travel farther out, if possible, to get a cleaner drink of water. When drinking from a tank, however, the sediments are not resuspended each time a cow comes to drink. Cattle drinking from a tank rarely deposit urine and manure in the tank compared with those drinking in the reservoir, which usually make a deposit before leaving the water source (Willms et al. 2002). Researchers in Alberta reported a 23 percent increase in weight gains over a 71-day period for yearling steers that drank well water versus those that drank from a dugout.

Fences

Fences have been the method of choice for protecting environmentally sensitive areas. While fencing can be used to protect areas from grazing, they can also be used to control pasture size, shape, and heterogeneity. Smaller, more uniform pastures lend themselves to more uniform distribution and reduced patch grazing. In larger, heterogeneous pastures cattle tend to select the more productive sites and avoid the less productive sites (Bailey et al. 1996). By grazing productive sites more often, cattle are able to spend more time in areas where there are greater quantities of higher-quality forage. Strategic placement of fences can reduce feeding site choices and concentrate grazing in the remaining feed sites. For example, cattle are more likely to graze slopes uniformly if gentle terrain is not available within the pasture. If riparian areas are fenced separately from uplands, both types can be grazed more uniformly. It has been suggested that reduced pasture size along with reduced distance to water may be responsible for the alleged benefits of intensive, time-controlled, rotation grazing systems.

Fencing facilitates control of the seasonal use of an area. In mountain rangelands, upland forage quality is usually higher early in the summer but declines as the summer progresses and soils dry. Riparian forage remains higher in quality as the summer progresses because soil moisture remains available. Researchers have found that cattle make greater use of the upland vegetation early in the summer but often shift to the riparian forage as the uplands dry and forage quality declines. Installation of fences that separate uplands from riparian areas allows managers to graze areas more uniformly throughout the year. Pastures can be established that enclose similar types of forage that grow and senesce at similar rates. Stock density can be used as a tool for achieving uniform use within a pasture (Senock et al. 1993). Increases in stock density are achieved by subdividing pastures into smaller units. However, topography and distance to water remain strong influences on grazing patterns. Hart et al. (1993) found that pasture size and distance to water have a greater effect on cattle foraging activity than grazing systems (continuous versus rotational). These researchers suggest that rotational grazing systems are unlikely to improve animal performance over continuous grazing unless pasture size and distance to water are reduced below previous levels.

Roads and Trails

Steep slopes, dense vegetation, and rocks often act as barriers to cattle movements, reducing access to some feeding sites. Roads, trails, and utility rights-of-way can aid cattle in circumventing barriers and improving distribution (Roath and Krueger 1982). However,

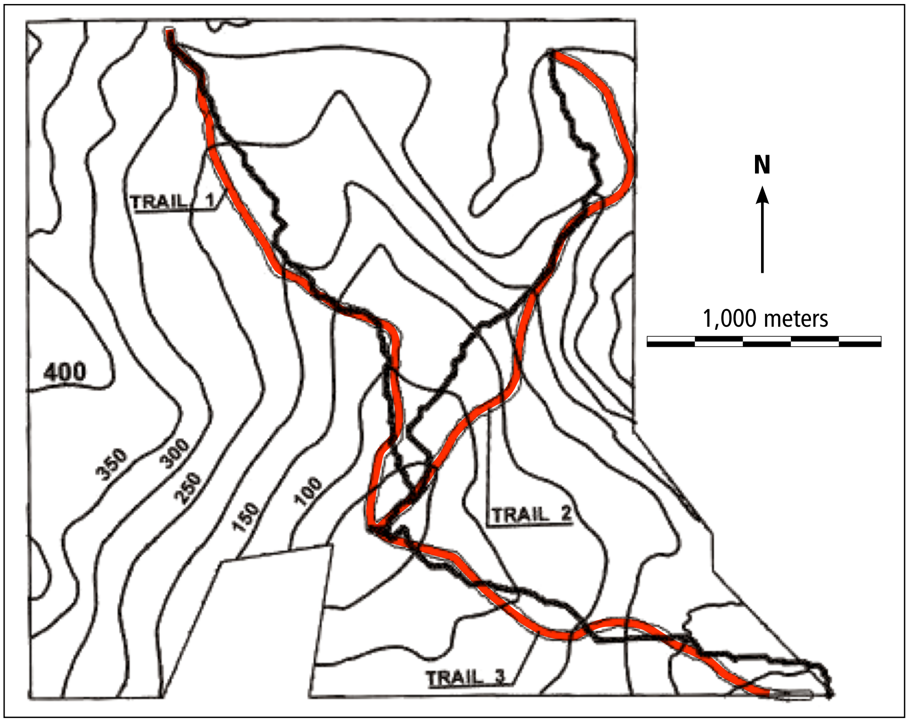


Figure 11. Comparison of simulated least-effort routes (heavy black line) and actual beef cattle trails (red line) on the Northern Great Basin Experimental Range near Burns, Oregon.

Contour lines represent increments of 50 units of effort and were derived from a geospatial model of energy expenditure (Ganskopp et al. 2000). Values range from 0 at the water source where the trails converge to a maximum of 461 near the northwest corner of the pasture.

barriers cannot overcome the effects of poor water distribution. Forage improvement by burning or fertilizing in combination with water and trails can improve livestock distribution. Ganskopp et al. (2000) analyzed the location of cattle paths in an extensive, rugged pasture. Cows established paths that were very similar to computer-selected, least-effort routes between distant points (fig. 11).

Burning, Fertilization, Seeding

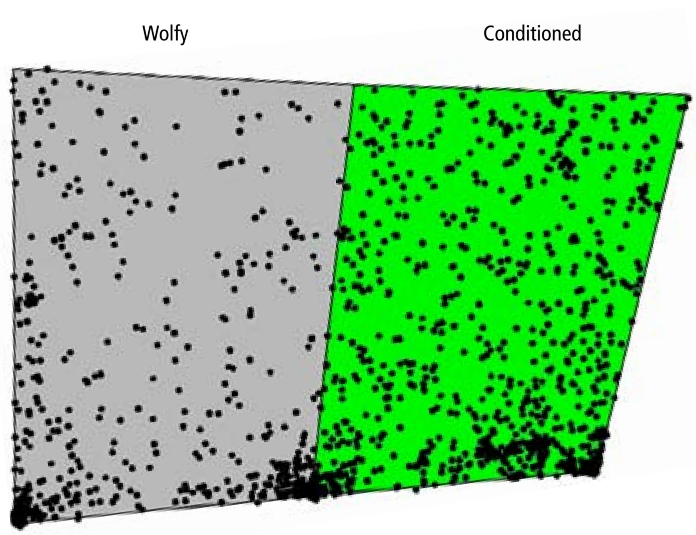
Land treatments such as burning, brush removal, weed control, seeding, and fertilization can result in changes to feeding sites that increase the rate of nutrient capture. Weed and brush control often improves the yield and accessibility of forage. Burning and fertilization can improve forage quality (Bailey 2004). Seeding with adapted species, especially legumes, can improve the quality and quantity of range forage. Improved access, in addition to improved forage quantity and quality, attract grazing animals; this results in increased grazing use.

Grazing and Mowing

Feeding sites are made up of patches. Uniform feeding sites may have only a few different patches. Heterogeneous feeding sites have greater variation in patches that may influence nutrient intake but also may provide dietary variety. Over time, patches may develop in response to differential grazing pressure. Patches containing stiff culms, abrasive seed heads, litter, and standing dead material often receive less use than patches where forage quantity and quality are greater or more accessible. Animals prefer patches, such as those that contain dense, leafy forage, where they can maximize bite size and biting rate, resulting in high intake rates. Mixing unpalatable vegetation into preferred patches increases searching and decreases bite size and biting rate; this results in increased grazing time and a decrease in the preference ranking of the patch. Ganskopp and Bohnert (2004) found that when beef cattle have a choice between ungrazed pasture containing wolfy plants and previously grazed pasture, 68 percent of grazing occurs in the previously grazed portions of pastures and 32 percent in the wolfy sectors of pastures. Foraging cattle's preference for portions of pastures that were grazed during the previous growing season suggests that utilization patterns established by livestock at landscape scales are self-sustaining (fig. 12).

Figure 12. Standing dry forage (wolfy plants) from the previous year (A) impedes grazing the following year. Pasture sectors that were grazed to reduce wolfy plants the previous year (right half of B and C) were preferred over sectors where dry wolfy plants (left half of B and C) remained. Distribution patterns (B) of three beef cows equipped with GPS collars as they grazed in a crested wheatgrass pasture supporting wolfy (left) and conditioned (grazed) forage (right) over a 7-day period on the Northern Great Basin Experimental Range near Burns, Oregon, in 2001. In this figure, 394 positions occurred in the wolfy sector and 1,000 positions occurred in the conditioned area. Photos by David Ganskopp.

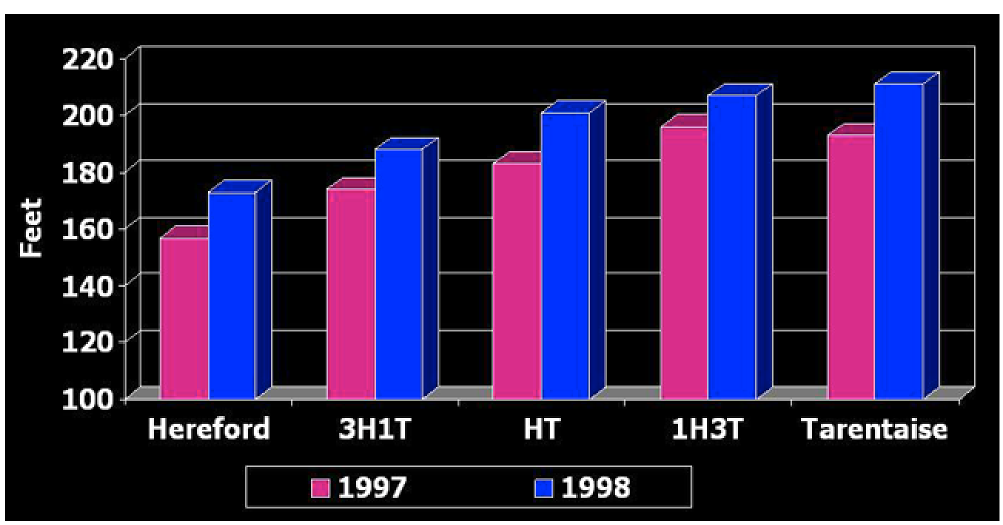
A



B

C

Figure 13. Travel comparisons (vertical distance to water) for Hereford (H), Tarentaise (T), and Hereford X Tarentaise crosses of beef cattle. Crosses of Hereford and Tarentaise cows included three-fourths Hereford and one-fourth Tarentaise (3H1T), one-half Hereford and one-half Tarentaise (HT), and one-fourth Hereford and three-fourths Tarentaise (1H3T).



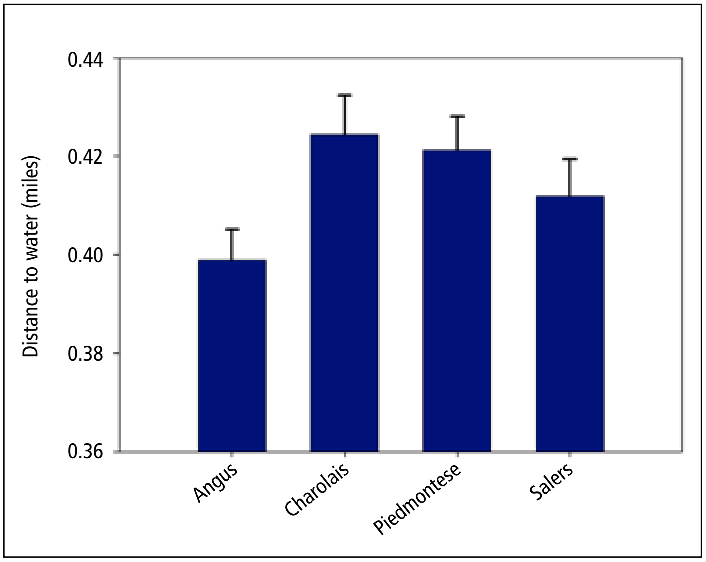


Figure 14. Travel comparisons (horizontal distance to water) of cows sired by Angus, Charolais, Piedmontese, and Salers bulls.

Changing the Animal

Breed Selection

Research in Montana suggests that grazing uniformity might be improved by selecting breeds that are developed in more rugged terrain. According to Bailey (2004), Tarentaise cattle developed in the French Alps consistently climb higher and use areas of higher elevations (greater vertical distance to water) compared with Herefords (fig. 13). Additional research compared terrain use of cows sired by Angus, Charolais, Piedmontese, and Salers bulls (fig. 14). Cows sired by Charolais and Piedmontese bulls travel further from water than cows sired by Angus bulls. Although breeds may differ in terrain use when grazed together in the same pasture, additional research is needed to verify that overall herd grazing patterns could be affected by selection. Social interactions and other factors could overwhelm any differences in terrain use that result from genetic factors such as breed.

Individual Animal Selection

Selecting individual animals based on their grazing patterns and terrain use has the potential to improve livestock distribution (Bailey 2004). Sufficient variability appears to exist both between and within breeds for selection to change terrain use (fig. 15). Culling cattle that frequent riparian areas and selecting cattle that prefer upland slopes, higher elevations, and distances further from water can shift the herd behavior toward preference for the uplands, thereby reducing use of riparian areas. Feeding site selection and terrain use is learned behavior passed from dam to offspring. It is also potentially heritable and could be improved through sire selection. According to Bailey (2004), selecting for terrain use should not adversely affect herd performance.

Animal Age and Status

Managers have recognized that yearling steers, yearling heifers, and nonlactating cows typically use extensive pastures more evenly than cow-calf pairs (Bailey 2004). Nonlactating cows use steeper slopes and higher elevations more often than lactating cows in northern Montana during the summer. Oregon studies have suggested that producers might consider early weaning of calves to help protect riparian areas. After weaning, nonlactating cows would spend more time in the uplands and less time in riparian areas. Older cows with more knowledge of terrain may graze more uniformly than inexperienced animals such as yearlings or younger cows.

Strategic Supplementation

Most commercially available supplements fed to cattle are palatable and have the potential to lure animals to underused rangeland. Supplements weighing up to 250 pounds (113.5 kg) can be transported readily to rough terrain where cattle can be self-fed. Manufacturers often recommend placing one container for every 20 to 25 cows. When fed at this rate, large containers (250 pounds, or 113.5 kg) of low-moisture molasses blocks usually provide supplement for about 2 weeks. Montana researchers have shown that cattle spend more time and graze more forage in pasture areas where supplement is provided than in similar areas where no supplement is provided (fig. 16). Supplement is usually a more effective attractant on gentle terrain (10 to 20 percent slopes) but can also change grazing patterns in steeper terrain (15 to 30 percent slopes). Low-moisture blocks

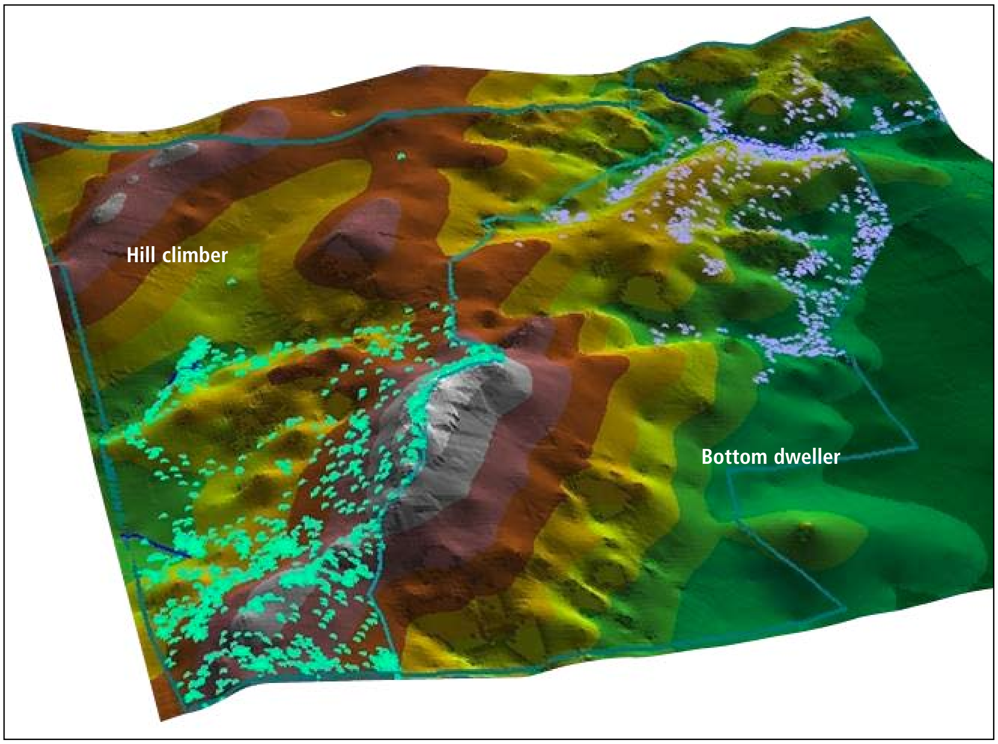


Figure 15. Positions of two cows grazing similar pastures recorded at 10-minute intervals during the same 2-week period in August. This Montana study compared hill climber cows (cows that previously preferred steeper slopes and higher elevations) and bottom dweller cows (cows that previously preferred gentle terrain near water). The differences in grazing patterns between these cows show the potential for selection to modify grazing distribution.

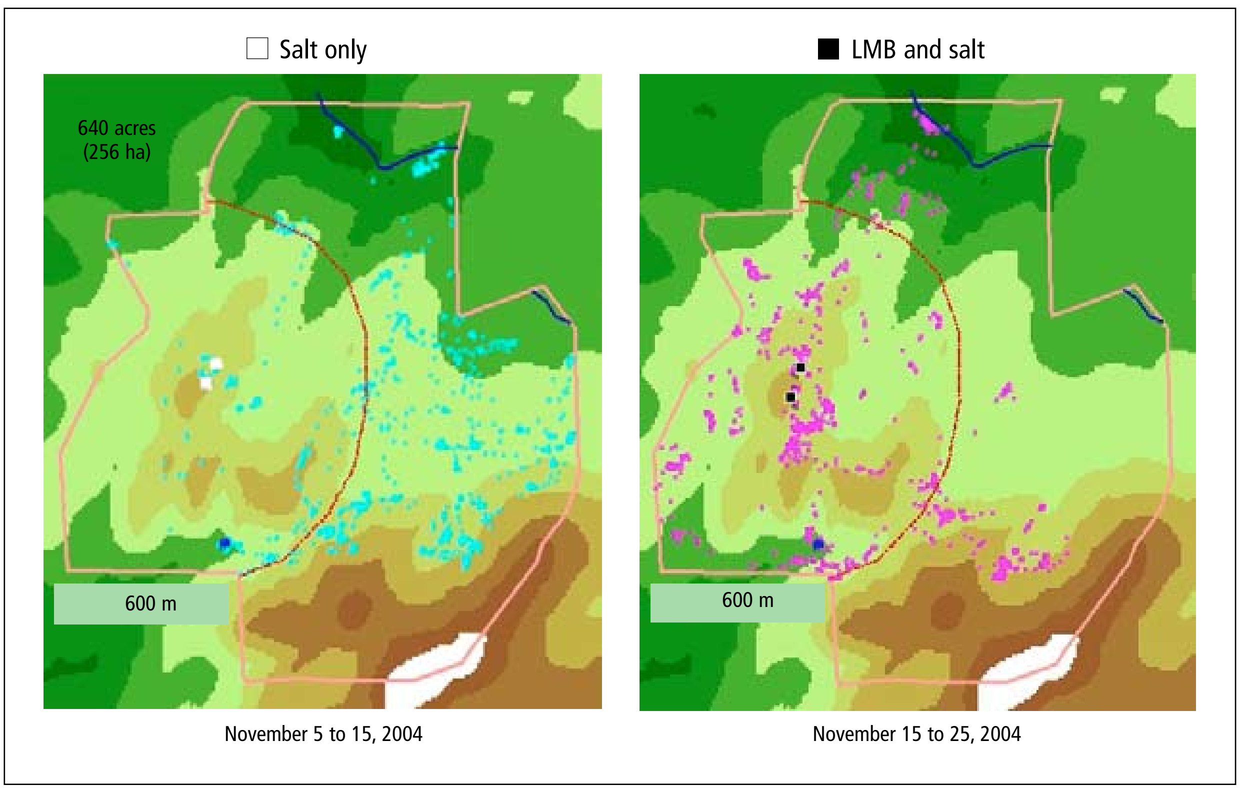


Figure 16. Grazing patterns of the same cow in a 640-acre (256-ha) pasture when only salt was available on a ridgetop, and when salt and low-moisture blocks (LMB) were available (positions recorded at 10-minute intervals). The cow spent more time within 656 yards (600 m) of a placement site when low-moisture blocks and salt were available than when only salt was available, irrespective of the order in which salt and LMB were placed, first or second.

increase grazing use of rangeland within 656 yards (600 m) of the placement sites, after which the attraction of the supplement declines rapidly (fig. 17). Studies have shown that low-moisture supplement blocks are a more effective attractant than dry mineral mixes, pressed blocks, or range supplement cakes.

Low-moisture blocks are very palatable and typically provide energy from molasses, protein, and minerals. After they become familiar with the product, cattle are willing to travel long distances and up steep slopes to consume the supplement. Cattle graze nearby areas, because the travel effort that otherwise would prevent use in the area has already been expended.

Herding

Although herding has been used to manipulate livestock distribution for centuries, its use on rangeland cattle operations has been limited. Herding requires additional labor and its effectiveness has been questioned. Some producers believe that herding cattle away from riparian areas is futile, because animals often return to streams shortly after being moved. Others have found that herding can be an effective practice, especially if applied consistently. Recent studies (Bailey 2005) have shown that herding can improve livestock distribution and reduce time spent in riparian areas in some pastures (fig. 18). If cattle are herded to upland areas where supplement is available, the herd frequently tends to stay and graze in areas within 656 yards (600 m) of placement. Apparently, herding minimizes the use of riparian areas, and supplement placement focuses cattle use on upland slopes.

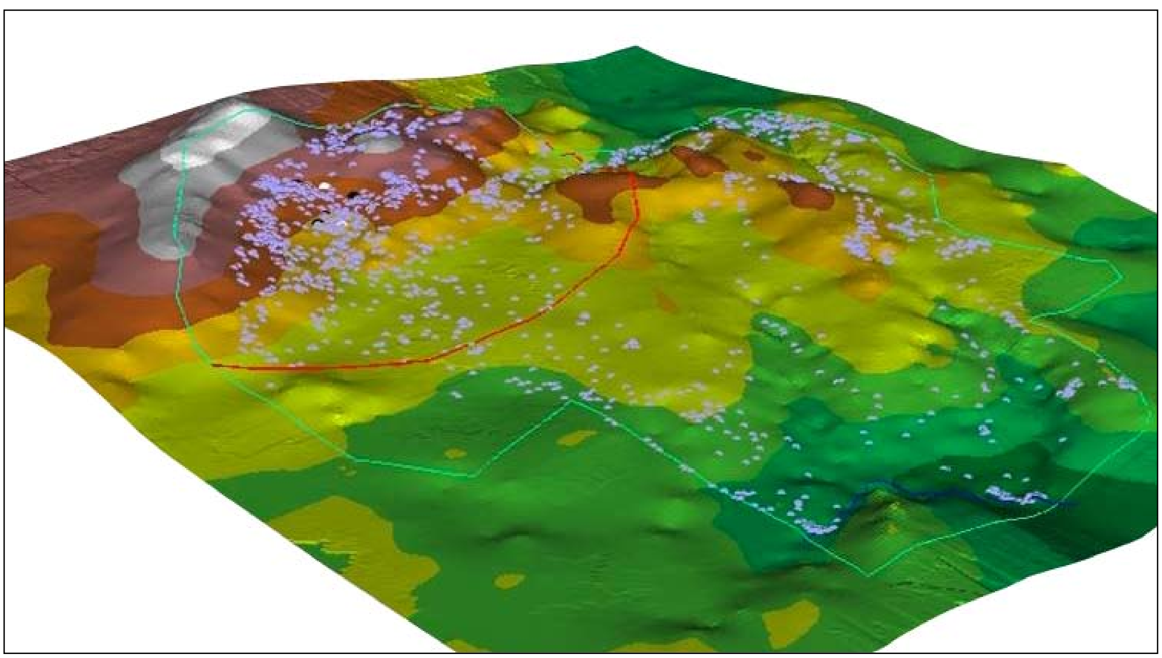


Figure 17. Example of effectiveness of low-moisture blocks for attracting cattle to graze steep and high terrain. The red line is situated at 656 yards (600 m) from the placement of low-moisture blocks. At distances greater than 656 yards (600 m) from the placement site, the effectiveness of low-moisture blocks begins to decline. Locations were recorded at 10-minute intervals for two weeks in early December. The green line shows the pasture boundary and the blue line traces a perennial stream.

Figure 18. Locations of cows that were herded to a target area (white lines) with no supplement (▲), herded to a target area with supplement (▲), and control cows that were allowed to roam freely with no herding (▲). Cattle were herded to target areas (white lines) that were within 656 yards (600 m) of the location where salt alone or low-moisture blocks with salt were placed. Brown lines represent the target areas when there was no supplement or salt during the control treatment. Black lines represent pasture fences and blue lines represent streams. When there was no herding (▲), riparian use was greater than when herding or herding with supplement was applied. These results suggest that herding and herding with supplement can effectively increase use of target areas and reduce time spent in riparian areas.

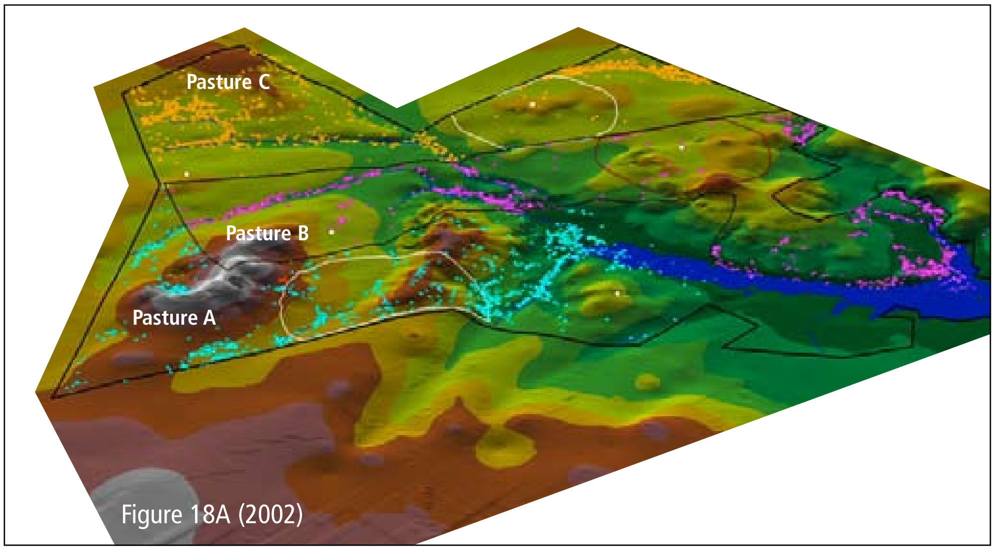
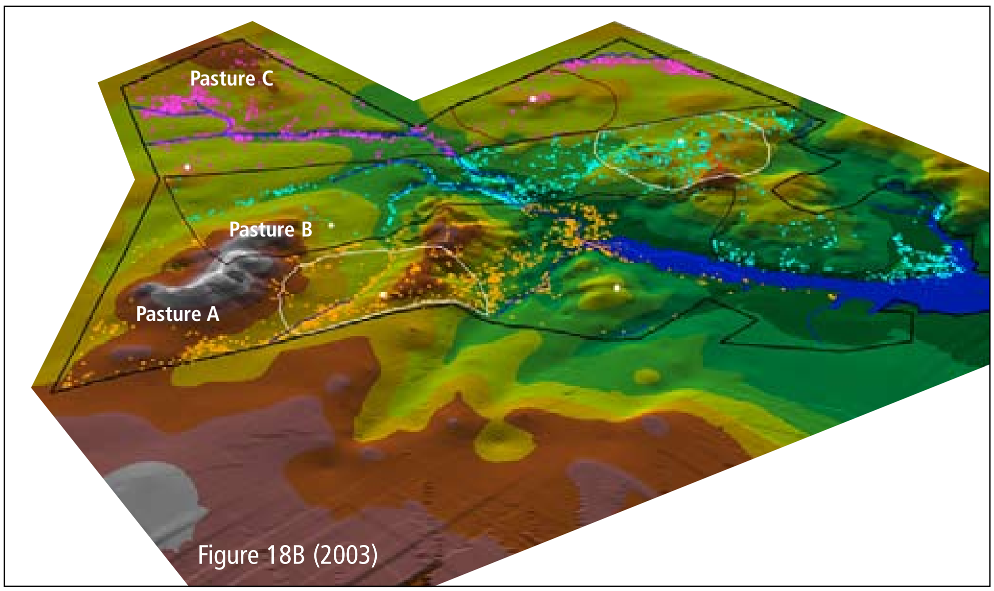


Figure 18A (2002)



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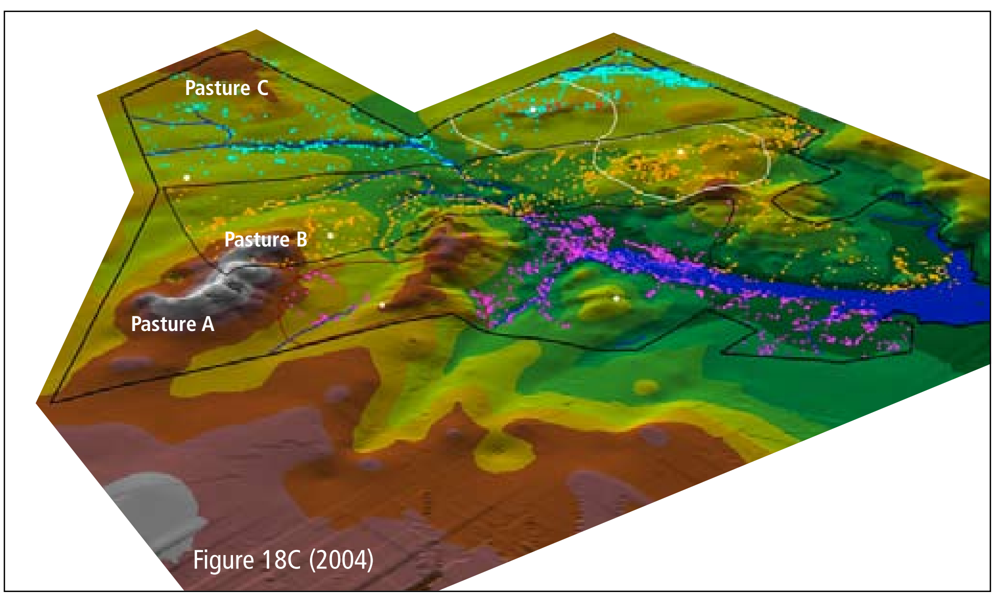

Figure 18C (2004)

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