Forage Production and Carrying Capacity:
Guidelines for Setting a Proper Stocking Rate

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The most important decision for successful range management is setting a proper stocking rate. The stocking rate affects rangeland health and productivity, livestock production, and economic returns. Because of its importance, much rangeland research has focused on answering the question, "what is the proper stocking rate?" However, like many important questions in life, it is not easily answered. The objectives of this paper are to explore the concept of "proper" stocking and offer some tools for setting an initial stocking rate.

WHAT IS STOCKING RATE?

The number of animals a piece of land can support on a long-term basis without causing damage to the range resource is the *carrying capacity* (or grazing capacity) of the land. *Stocking rate* is the number of animals a land manager places or maintains on a piece of land over a specified period of time. Thus, carrying capacity is set by mother nature, through soil and climate characteristics; stocking rate is set by humans, through livestock or wildlife management.

The currency by which stocking rates are designated is the *animal unit* (AU). An AU is 1,000 pounds of grazing animal. In other words, a 1,000 lb cow equals one AU, a 1,200 lb horse is 1.2 AUs, and a 150 lb mule deer equals .15 of an AU.

Stocking rate is often stated as the # of AUs/acre/year or acres/AU/year. This AU concept is useful most grazing animals eat 2% of their body weight each day. Thus, the term *animal unit month* (AUM) is the amount of forage an AU can eat in a month (about 600 pounds). A stocking rate can also be expressed as a number of AUMs per acre. The terms AU and AUM are widely used in range management, but there is not universal agreement on the quantities each term expresses. Thus, one must be cautious when discussing AUMs with a stranger - semantic arguments often ensue**.**

Table 1. Average animal unit equivalents (AUE) and average amount eaten per day for several common range herbivores.

Kind/class Mature Animal	AUE	Daily Intake (lb of DM)
Cow (1000 lb), dry	.92	23
Cow with calf	1.00	25
Bull	1.35	34
Horse	1.25	32
Sheep	.20	5
Goat	.15	3.8
Deer, white-tailed	.15	3.8
Deer, mule	.20	5
Elk	.60	15
Pronghorn	.20	5
Bison	1	25
Sheep, bighorn	.20	5
Yearlings of any species have an AUE about 60% of their mature equivalent		

WHAT IS THE "PROPER" STOCKING RATE FROM A RANGE ECOSYSTEM POINT OF VIEW?

To maintain a healthy and productive range ecosystem the stocking rate should not exceed the carrying capacity of the land. Stocking rates less than or equal to carrying capacity generally result in limited soil erosion,

decreased invasion by weedy plants, and drought resistant vegetation. Moderate stocking rates set at or below carrying capacity often lead to improvement of degraded rangeland. Thus, setting an appropriate stocking rate represents an often overlooked range improvement technology.

Proper stocking can also be defined as the level of grazing that does not impair the ability of plants to recover from grazing and provides sufficient residue for soil maintenance. The proportion of individual plants that should be utilized depends on timing and amount of precipitation and the grazing resistance of the major forage plants (Table 2).

Table 2. Utilization guidelines for selected range types in North America (more complete list in Holechek 1988).

Average Annual Precip. (in.)	% Use of Major Forage Plants	Range Type
4-8	23-35	Salt desert shrublands
8-12	30-40	Sagebrush grasslands
12-20	30-40	Intermountain bunchgrass
16-50	30-40	Mountain shrublands

WHAT IS A "PROPER" STOCKING RATE FROM AN ANIMAL POINT OF VIEW?

Overstocking results in lower individual animal performance (weaning weights, conception rates, wool production, etc.). During the growing season, ample green forage is usually available and animals on overstocked ranges may produce as well as animals on moderately or lightly stocked range (Fig. 1). However, as the season progresses, animals on heavily grazed ranges often lose weight while those on moderate or lightly grazed ranges maintain or gain weight.

Decreased animal production observed at high stocking rates occurs for several reasons. As the amount of land and forage allocated to each animal decreases the animal has less forage to choose from and diet quality decreases. At high stocking rates animals may not be able to meet daily dry matter requirements and searching for adequate forage increases energy requirements. Also, the consumption of toxic plants is more common on heavily than lightly stocked pastures so death or weight losses often occur.

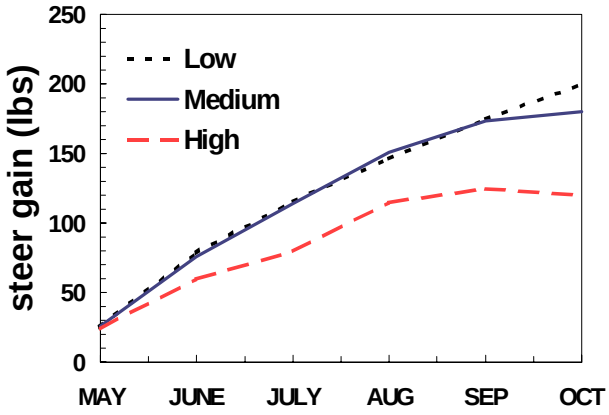


Fig. 1. Weight gains by steers in summer under different stocking rates (from Launchbaugh 1957).

Low stocking rates favor high individual animal performance. However, profits in livestock systems are not made on how much individual animals weigh, they are based on how many pounds of animal can be produced per acre. As stocking rate increases the number of pound gained per animal decreases. On the other hand, when the number of animals on a piece of land is increased the pounds of gain produced per acre increases. At very high stocking rates, however, individual animal performance is severely limited and increasing the number of AUs will decrease gain per acre (Fig. 2). An optimal stocking rate for livestock production is somewhere above the maximum production per animal and below the maximum number of pounds produced per acre.

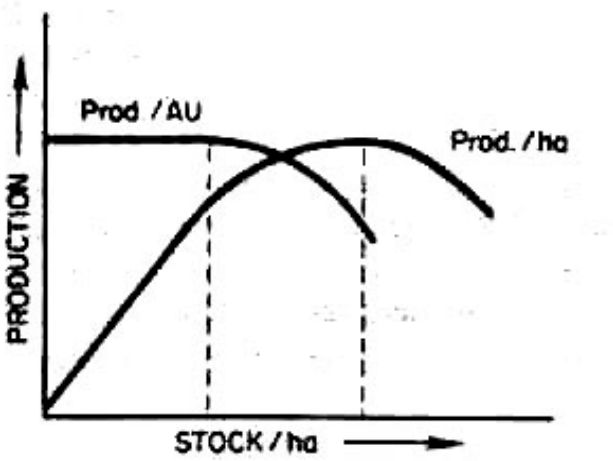
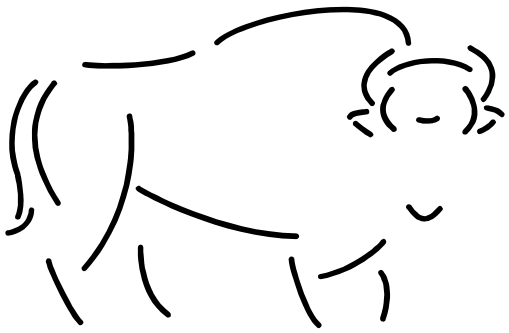


Figure 2. Effects of increasing stocking rate on pounds of production/animal and production/area of land (from Conner 1991).

Most stocking rate studies reveal that the economically optimal stocking rate is moderate, not heavy. A commonly held misconception about ranching is that the profit motives of ranchers lead to overgrazing of privately owned rangelands. In fact, the opposite is true. Ranchers that are profit-motivated and have the information necessary to evaluate the production effects of various stocking rates would actually select a stocking rate below the carrying capacity of the land. Overgrazing, therefore occurs due to ignorance or optimism about range production, not aggressive economic goals



GETTING A "BALL PARK" FIGURE FOR HOW MANY ANIMALS TO GRAZE

The virtues of a moderate stocking rate can be extolled on the basis of ecosystem stability, or animal health and production. However, that still leaves us with the question "how many animals should be grazed?" Next, I will outline a general four-step method for determining roughly how many animals a piece of land can sustain. In reality, most land managers set stocking rate based on knowledge of historic production rates. These experience-based decisions result in proper stocking provided the manager: 1) is not overly optimistic about the prospects of rain; 2) has a way to evaluate and remember previous year's production; and, 3) recognizes the signs of overgrazing.

FOUR-PART PROCEDURE FOR SETTING BASIC STOCKING RATE

Calculate total usable forage. The first step to determining how many animals a piece of land can carry is to get an idea of how much forage the land produces. To set stocking rate at the end of the growing season one must estimate the ungrazed standing crop. To set stocking rate at the beginning of the growing season one must predict the peak amount of forage that will be produced during the season. These predictions should be based on historic production data and probabilities of receiving significant precipitation. However, in reality, predictions on the weather and forage production are seldom more than educated guesses.

Estimates of biomass can be obtained by mapping the management area into units of land that are about equally productive. Most commonly, these units are range sites or habitat types that differ in soil type and productivity. Once these units are recognized, surveys of each unit can be made to estimate production per acre. These biomass surveys can take many forms: 1) mowing or clipping very small areas; 2) referring to picture guides to visually estimate amount of forage; or, 3) referring to site guides (i.e., those produced by the Natural Resource Conservation Service) to estimate the average productivity of the site

based on precipitation. These biomass surveys should account for only the vegetation likely to be consumed by livestock or wildlife.

Estimates of forage production on each site can be multiplied by the acres of each site on the management unit to obtain the total amount of forage available. Amount of usable forage equals total available forage multiplied by the percent allowable utilization (Table 2). For example, if a person owns 1,000 acres of land in the shortgrass prairie that produces 700 lb/acre of forage the total amount of usable forage on the management unit equals 315,000 pounds (1,000 acres * 700 lbs/acre * 45%).

Adjust total usable forage. The amount of forage usable by livestock and wildlife depends on pasture characteristics such as distance from water and topography. Areas of a pasture that are more than 2 miles from water are essentially unusable. The forage in areas 1 to 2 miles from water is generally considered only 50% accessible (Table 3 in Holechek 1988). Very rough or steep topography can also decrease the amount of forage accessibility (Table 4 in Holechek 1988). Thus, the amount of usable forage must be adjusted downward to account for pasture characteristics.

The amount of forage available for one species (livestock or wildlife) must also take into account the amount of forage used by other species on the range. For example, if stocking rates for bison are being set the usable forage must be reduced by the amount of forage that deer and other wildlife (including insects) will consume. These amounts can be estimated if the number of other deer (or other herbivores) is known, otherwise the manager is forced (once again) to make a good guess.

Calculate forage demand. To calculate forage demand one must know the average weight of the animals in a herd or flock and the number of days in the planned grazing period. The amount of forage each animal will eat daily can be estimated by multiplying the average body weight times 2.5%. When forage is green and growing, animals can consume as much as 3.5% of body weight and in the dormant season intake generally falls to about 1.5%. A yearly average of 2.5% is usually acceptable. Studies comparing calculated forage demand with actual long-term stocking rates reveal that using the figure of 2% of body weight results in excessive stocking rate estimates. Therefore, calculating forage demand as 2.5% of body weight results in a stocking rate closer to proper stocking. This higher figure accounts for rejection of some usable forage by the animal, use of forage by wildlife, and some trampling of plants.

For example, a big old range cow that weighs 1200 pounds requires 30 pounds of forage per day (1200 lbs * 2.5%). If cattle are grazed year-round, each cow would require 10,950 pounds (30 lbs * 365 days) of forage per year.

Horses and rabbits are common range herbivores that ferment forage in an enlarged cecum rather than a rumen. This digestive morphology is less efficient than the rumen but it allows for greater consumption. Therefore, non-ruminants are estimated to consume about 3% of body weight per day.

Calculate stocking rate. The number of livestock that can be grazed on the management unit surveyed for the desired grazing period equals the pounds of usable forage divided by the forage demand. For example, 315,000 lbs of usable forage divided by 10,950 pounds of forage demand equals 29 bison cows that can graze on the management unit year-round.

MANAGING STOCKING RATES WITH VARIABLE RAINFALL

One of the greatest challenges to setting a “proper” stocking rate is that precipitation and forage availability vary immensely from year to year. Management strategies to address a variable forage supply can be either fixed or flexible. Fixed stocking strategies are based on the reality that precipitation on rangelands varies from year to year in an abnormal pattern creating a situation in which most years have below average precipitation. Research in southern Idaho exemplifies this property; annual precipitation and forage production in

the last 43 yrs were below average in 63% of the years. Meeting animal forage demand while maintaining a fairly stable herd size requires that stocking rates be set at least 10% below the rate that would yield proper use in an average year. Flexible stocking practices are generally accomplished by keeping, buying, or leasing extra animals in years of above average forage production. Conversely, strategies such as heavy culling or early weaning can be used to reduce the nutritive demand in years of low forage production. The costs associated with retaining, buying, or selling animals limit the economic feasibility of highly flexible approaches. Therefore, a combination of fixed and flexible stocking strategies will usually maximize economic returns of most livestock operations.

WAYS TO DECREASE STOCKING RATE WITHOUT SELLING ANIMALS

Decreasing animal numbers is not the only way to rectify an excessive stocking rate. Improving animal distribution makes forage more available to animals. Dividing large pastures into smaller pastures or adding water sources improve the distribution of animals across the landscape. Changing the breed, age or species of animal can also result in a decreased grazing pressure. Young animals make better use of rough terrain, so if yearlings, rather than mature animals, are grazed the amount of usable forage may be increased in areas of great topographic relief. Grazing multiple species (i.e., sheep, goats, and cattle) also increases the amount of usable forage since different species prefer different types of forage. Some breeds of animals may even make better use of particular vegetation types than others. For example, longhorns have long been noted for their ability to survive on low quality forage. Selecting animals that can make the best use of the forage available results in improved animal distribution and a greater amount of available forage.

MIXED SPECIES GRAZING

Most rangelands are not grazed by a single species; they are grazed by a combination of species. This multi-species grazing is often called “common use” and is well-documented as a way to make greater use of grazing resources. Grazing animals differ in the kinds of plants they prefer and dietary choices they make. A manager must have a working notion of the kinds of plants grazing animals select to make decisions about which animals are most suited for the grazing resources or how much forage is available for specific animals (Table 3).

Table 3. Forage selection by large herbivores in North America (a summary of Table 11.7 in Holechek et al. 1989)

Species	Grass (%)	Forbs (%)	Browse (%)
Cattle	61	18	21
Sheep	48	31	21
Goat	33	12	65
Horse	80	9	11
Bison	92	6	2
Moose	1	3	96
Bighorn Sheep	73	14	13
Elk	73	8	19
Mule Deer	8	43	49
Pronghorn Antelope	16	40	44

When animals select substantially different diets, they can often graze the same area of range with complimentary effects. For example, in the foothills of Idaho, cattle prefer mostly grass and they graze these areas mostly in the spring. In the fall and winter, deer and elk move into these foothill regions and primarily eat shrubs such as bitterbrush and sagebrush. If the stocking rate of these lands is set for cattle, no reduction is necessary for the amount of forage used by elk and deer because they do not consume the forages used by cattle. One added benefit of this multi-species grazing is that the removal of herbaceous forage by cattle in the spring improves the vigor and biomass production of

the winter browse species used by deer and elk. In turn, the use of browse by wild ungulates improves grass production for cattle.

In the case above, little dietary overlap occurs between the cattle and the wild ungulates, therefore grazing capacity is additive when both groups of animals graze the same range. However, if dietary overlap between animals is substantial, such as between cattle and bison, then the presence of both species must be accounted for in forage demand estimates.

There are equations, worksheets, and computer models that improve stocking rate estimates in multi-species situations. However, caution must be used when interpreting diet "rules-of-thumb" such as those given in Table 3. The caution is that animals are very flexible in their diet selection. For example, cattle generally prefer grass and may select diets as high as 86% grass. However, if grass becomes limited they may select diets as high as 74% browse. Increased dietary overlap between species is often, therefore, observed in periods of limited forage availability. Furthermore, diet overlap does not necessarily indicate that animals are competing for forage. If there is enough forage to go around, animals don't compete for forage even if they are selecting very similar diets.

SUMMARY

Stocking rate is critically important to the health of the range and the economic viability of the ranching enterprise. Since a proper stocking rate is not easily determined with field techniques there is no substitute for long-term experience and careful monitoring of ranges and ranches. The success of range managers most directly depends on their success in setting the illusive "proper" stocking rate.

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