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Stocking Rate: The Most Important Tool in the Toolbox

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Successful grazing management integrates animals, forages, and other resources to market valuable products at a profit. Grazing management relies on several principles and practices established through experience and scientific research. Stocking rate—the number of animals allotted to an area for a given length of time—is one of the most important grazing management factors a rancher can manipulate, regardless of the grazing system employed, vegetation type, or kind and class of livestock produced. Of all the management tools, stocking rate has the largest impact on animal performance and forage resources, because it directly influences

- animal productivity
- forage production
- forage quality
- long-term plant species composition
- plant physiology
- profitability of the operation.

Therefore, a proper stocking rate is vital to maintain grazing operations under changing conditions, optimize forage and animal performance, and sustain renewable land resources over the long term (Figure 1). Many factors affect stocking rate, including but not limited to animal species, acres of land useable for grazing, rainfall, forage species and productivity, topography, water distribution, and class of livestock (e.g., lactating, growing, etc.).

Two general considerations in establishing an appropriate stocking rate are animal performance and the forage resource. Effective managers will balance animal and forage production over the long term rather than attempting to maximize either factor alone (Ohlenbusch and Watson 1994). With that in mind, setting an appropriate stocking rate consists of determining (1) how much forage is required by the type and class of animals raised (forage demand), (2) how much forage is produced during the year and how much of this is available for livestock consumption (available forage), and (3) how long animals will be using the area under consideration (duration of grazing).

Forage demand

The basis for measuring forage demand is the *animal unit* (AU), which is defined as the amount of forage required to maintain a 1000-pound cow with a calf. The most widely accepted studies have established that an AU requires on average 2.6 percent of the body weight in dry forage daily (26 pounds per day for a 1000-pound cow). An *animal unit month* (AUM) is the average dry weight of forage required by a lactating 1000-pound cow and her calf for one month, or about 780 pounds (Figure 2).

Naturally, not all kinds of livestock have the same forage demand as a 1000-pound lactating cow. Also,

Figure 1. A proper stocking rate is important for sustainable grazing management and will ensure optimal animal and forage production over the long term.

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Figure 2. An animal unit (AU) is considered to be one 1000-lb cow with calf. This lactating cow requires 26 pounds (or 2.6 percent of her body weight) of dry matter each day in order to maintain her body condition and raise her calf.

forage demand varies within a species depending on its class, i.e., its growth (e.g., stockers), lactation, and maintenance (e.g., dry cows). For this reason, *animal unit equivalents* (AUE) can be determined to evaluate forage demand and grazing pressure of animals in relation to the AU. For cow herds with animals having a different average weight than an AU, every 100 pounds of animal weight generally equals 0.1 animal units. For example, an 1100-pound cow and calf pair would be 1.1 AU. Table 1 summarizes the daily dry-matter intake of animals expressed as percentage of their body weight.

Here are two examples:

(1) A 1200-pound horse consumes 3 percent of its body weight (36 pounds) of forage on a dry-weight basis each day; divide the forage demand of the horse (36 pounds) by the forage demand of an AU (26 pounds) to get an animal unit equivalent of 1.39.

(2) A 125-pound sheep consumes 2 percent of its body weight (2.5 pounds) of forage a day on a dry-weight basis; the AUE of this sheep is 0.1 (2.5 pounds divided by 26 pounds).

Forage production

The next consideration in determining stocking rate is the amount of forage produced that is available to grazing animals. Climate (temperature and precipitation), soil fertility and texture, and vegetation management largely affect total forage production for an area. Total production of available forage can be estimated by using a simple clipping procedure (adapted from Brence and Sheley 2003).

Table 1. Daily forage demand of common Hawai‘i range animals expressed as percent of body weight.

	Daily dry matter intake (% body weight)	
Animal	Non-lactating	Lactating
Cattle	2.0	2.6
Sheep	1.7	4.0
Goat	1.7	4.0
Horse	2.0	3.5

Components and definitions

Animal unit (AU): (1) a lactating 1000-pound cow with a calf; (2) any combination of animals with a forage demand of 26 pounds of dry matter per day.

Available forage: the amount of herbaceous and/or woody material available for grazing.

Carrying capacity: the maximum long-term stocking rate that can be sustained without detrimental effects on the land resource.

Forage demand: the amount of forage required to sustain a grazing animal over a specified period of time.

Grazing pressure: the ratio of forage demand to amount of available forage at a given point in time.

Stock density: the number of animals per unit of area of land at a given point in time.

Stocking rate: the number of animal units per unit area over a given period of time.

Materials needed:

Hoop or frame of known area	Clippers
Scale that measures in grams	Paper bags

Figure 3. Simple tools such as a gram scale, clippers, paper bags, and a hoop of known area (a 1.2 sq ft area hoop is shown) are all that are needed to determine the amount of forage available for grazing.

Table 2. Sampling hoop sizes and formulas for converting grams of forage sampled to pounds per acre.

Circumference (inches)	Hoop area (square feet)	Conversion formula
131.8	9.6	grams × 10 = lb/acre
93.2	4.8	grams × 20 = lb/acre
65.9	2.4	grams × 40 = lb/acre
46.6	1.2	grams × 80 = lb/acre

Table 3. Percent dry matter of common Hawai‘i forages.

Species	Fall	Winter	Spring	Summer	Avg.
Kikuyugrass	21	26	31	25	25
Pangolagrass	21	23	23	23	22
Guineagrass	25	24	26	23	24
Signal grass	27	24	27	24	26
Californiagrass	24	17	21	21	21

For more species, see www.ctahr.hawaii.edu/ctahr2001/InfoCenter/Forages/grasses.html.

A sampling hoop or frame can be purchased from various online sources. Alternatively, a circular hoop can easily be fashioned from sturdy wire or cable (Figure 3). The size of hoop to use depends on the nature of the area being sampled. Forage production varies between and within pastures, so efforts to estimate total forage production should attempt to represent this variation as much as is reasonable. Sites that have many forage species or that are sparsely vegetated require larger hoops (e.g., 2.4–4.8 sq ft area) to capture and reflect this variation in the collected samples. Alternatively, taking more samples with a smaller hoop can also increase the accuracy of the estimates. Sites that are more uniformly vegetated do not need as large a hoop (e.g., a 1.2 sq ft area hoop will suffice). Table 2 lists dimensions and conversion factors for different sized sampling hoops.

Step 1: Weigh empty bags.

Record the weight (in grams) of an empty sampling bag (be sure to use the same kind of bag for all samples) (Figure 3).

Step 2: Toss hoop and clip forage.

Choose an area that is generally representative of the whole pasture to be surveyed (i.e., similar soil, vegetation, topography). Randomly toss the hoop and let it lay flat on the ground. Clip all vegetation within the hoop to the ground or to the root mat layer (Figure 3). Discard weeds, soil, roots, or other materials that are not forage species, and place the remaining forage in the bag. Repeat this process until you have at least four samples. More samples give a more reliable estimate of forage production.

Step 3: Weigh clippings and adjust for dry matter content.

Weigh the bags containing the clipped forage and record the weight in grams (Figure 3). Subtract the weight of the bag from each sample to get the actual weight of forage. Calculate the average wet weight of the samples for the pasture. Dry weight values are more useful for determining forage production and in setting a stocking rate because plant tissue water content varies widely, and the dry portion represents the nutritionally important material. To convert the production average to a dry matter basis, multiply by the appropriate percentage in Table 3.

Step 4: Determine pounds per acre.

Lastly, convert the average dry weight per hoop to pounds per acre by multiplying by the appropriate conversion factor in Table 2. This will give the average forage production in pounds per acre on a dry-weight basis, which is necessary for determining the appropriate stocking rate. See Example 1.

Proper utilization

Plants, especially grasses, have a certain tolerance to grazing, but if herbage removal exceeds a critical point, most plants will lose vigor, produce less, and eventually die (Heady and Child 1994). In a general sense, proper utilization is the maximum point of forage harvest that will not lead to range deterioration or decreased animal performance. Leaving sufficient leaf area allows plants to recharge depleted energy stores in response to grazing and thus maintain desirable range productivity and composition.

A common rule of thumb for planning an appropriate level of pasture utilization is "take half, leave half," or a 50 percent use of annual available forage production. This degree of forage utilization includes not only herbage actually consumed by the animal but also damage to the plants caused by trampling, loafing, and losses owing to other, non-livestock factors (e.g., loss to insects or wildlife). Some experts estimate that up to approximately 25 percent of total annual forage production is lost to livestock damage and competitive uses under continuous or set-stock grazing programs (Lyons and Machen 2001). Harvest efficiency increases as the stock density is increased and the rotation interval is shortened. Evidence suggests that the grazing animal harvests as much as 40 percent of the forage (i.e., only 10 percent is lost) under high-intensity, short-duration grazing programs (Ohlenbusch and Watson 1994).

The carrying capacity of a unit of land is commonly expressed in animal unit months (AUMs). Recall that an AUM is a measure of the forage supply within the management unit, based on the amount required to support an animal unit (AU) for a month. Using the figures from Example 1, the carrying capacity of Kimo Smith's 3-acre pasture would be 16.8 AUMs (13,128 lb available forage / 780 lb / AU / month). If Kimo had 10 similar 3-acre pastures, the carrying capacity for his ranch would be approximately 168 AUMs. The value of determining the carrying capacity for the ranch, pasture, or other management unit is that it connects forage supply with forage consumption and is thus absolutely foundational to proper grazing management.

Example 1
Determining forage production

To determine the average forage production of a 3-acre pasture on his ranch, hypothetical rancher Kimo Smith clipped four forage samples from a 1.2 sq ft hoop in an ungrazed area. The entire pasture has similar soil and other characteristics. The samples are largely composed of kikuyugrass with a well established mat. Forage samples in each hoop were clipped down to the mat layer, which represents the amount of forage available for grazing. Line A gives the fresh sample weights in grams, and Line B gives the bag weight in grams.

Sample:	1	2	3	4	Total
A.	250	225	270	230	975
B.	25	25	25	25	100

C. Total wet weight of forage
(A total – B total = C), C = 875

D. Average wet weight
(C ÷ 4 = D), D = 218.8

E. Average dry weight (see Table 3)
(for kikuyugrass, E = D × 0.25), E = 54.7

F. Pounds per acre (see Table 2)
(F = E × 80), F = 4376

Kimo has thus determined that this pasture produced about 4376 pounds of usable* forage per acre on a dry-weight basis, or a total of 13,128 pounds produced in the whole pasture (4376 lb/acre × 3 acres).

*Note: in this example, the clipped material represents 30–50 percent of the total forage mass in a typical kikuyugrass pasture. If the mat was not well established, or if the pasture was composed of a forage grass that does not form a mat (e.g., guineagrass), then the vegetation inside each hoop would be clipped to the soil surface to provide an estimate of total forage mass.

Unit time

Once the carrying capacity has been determined for a particular ranch, the amount of time a group of animals spends in each pasture should be determined to complete the process of setting a stocking rate. The amount of time spent by livestock in each pasture depends largely on the grazing area itself, the type of operation, and management goals.

Stocking rates are most generally expressed as the number of animal units (AU) per unit time per unit area (usually an acre). Operations that use large pastures or grazing units will typically find basing stocking rates on months or years more useful. For example, a ranch that rotates cattle through multiple pastures may express each pasture's stocking rate as animal unit months per acre (AUM/acre) or acres per AUM. Similarly, a unit that is continuously grazed will express that area's stocking rate as animal units per acre per year (AU/acre/year). On the other hand, operations that use smaller pastures may find a shorter period more useful; for example, the number of days (D) a 3-acre pasture will support a particular number of animals (AUDs/acre). Example 2 illustrates different situations for estimating stocking rate.

Stocking rate considerations

It is the three components of stocking rate—animal numbers, grazing area, and grazing period—that managers have the most influence over when making grazing management decisions. A manager can adjust the number of animals grazed, alter pasture size, or manipulate the amount of time an area is exposed to grazing (or more important, the amount of time the area is rested). However, it is important to understand that a change in any one component of the stocking rate can necessitate changes in the other two (Table 4). For example, if a 100-acre pasture had a stocking rate of 0.5 AUM per acre, it could support 100 AUs for 15 days, 50 AUs for 30 days, or 25 AUs for 60 days.

The decision to manipulate one or more of the components of stocking rate should be guided by animal and pasture management objectives and economic considerations. Decisions to change animal numbers are most feasible when the area is either under- or over-stocked. For example, an extended drought could necessitate a temporary reduction in herd size to minimize the impact on the forage base. As herd size is changed, the grazing period must be adjusted accordingly to maintain a desirable stocking rate (Table 4).

Adjusting pasture size is not always economically feasible. However, there may be situations when altering pasture configuration, or subdividing a single large pasture into smaller units, will improve grazing distribution and animal performance (Table 4). Several factors need to be considered when adjusting pasture size. First, decreasing pasture size requires smaller animal numbers or shorter grazing periods. Shorter grazing periods at a high stock density require more intensive management than otherwise, because the margin of error on the time

Example 2
Estimating stocking rate

What is the carrying capacity of a 100-acre pasture with an average available forage production (50 percent of total production) of 4376 lb dry matter per acre (from Example 1)?

Available forage:
4376 lb dry matter per acre × 100 acres =
437,600 lb available forage

Carrying capacity:
437,600 lb dry matter available ÷ 780 lb/AUM =
561 AUMs

If the pasture was part of a four-pasture rotation system and would be grazed for 3 months (the grazing period) out of the year, what would the desirable stocking rate be?

Stocking rate for grazing period:
561 AUMs ÷ 100 acres =
5.61 AUMs/acre

For an annual stocking rate:
5.61 AUMs/acre ÷ 3 months/year =
1.87 AUs/acre/year

If Kimo Smith had 100 head of 1000-lb breeding cows, for how many months could the 100-acre pasture support his herd? What would the stocking rate be?

Monthly forage demand:
100 AUs × 26 lb/AU/day × 30 days/month =
78,000 lb/month

Grazing period:
437,600 lb ÷ 78,000 lb/month = 5.6 months

Stocking rate for grazing period:
(100 AUs ÷ 100 acres) ÷ 5.6 months =
1 AU/acre ÷ 5.6 months = 0.18 AU/acre/month

Annual stocking rate:
0.18 AU/acre/month × 12 months/yr =
2.16 AUs/acre/yr

in pasture is greatly reduced. Second, increasing pasture size without increasing animal numbers will generally lead to poor grazing distribution even if the grazing period is increased. Uneven grazing distribution in large pastures leads to patchy grazing with a mixture of under- and overutilized areas. If continued, the overutilized areas will lose productivity and support fewer and fewer animals. Eventually, the forage grasses may be replaced by undesirable species that do not support grazing at all (Figure 4).

The easiest, most flexible and economically feasible component of stocking rate to manipulate is the grazing period. By managing the amount of time a pasture is grazed, a manager can easily and quickly compensate for situations of over-stocking that can arise from time to time. For example, short-term drought can cause pasture production to be short. Decreasing the grazing period for each grazing unit can temporarily prevent over-grazing with out reducing animal numbers.

Stocking rate and animal performance

Figure 5 (from Ohlenbusch and Watson 1994) shows examples of the relationship between stocking rate and animal performance from research conducted in different regions (for more examples see Heitschmidt and Taylor 1991). Long-term, sustained animal production and profits occur halfway between maximum animal production per acre and the point at which individual animal performance begins to decline (Hart et al. 1988).

At low stocking rates, individual animal performance is maximized because animals are free to select high-quality forage (i.e., grazing pressure is low; see Figure 5). Consequently, with low grazing pressure, palatable plant species in under-stocked pastures are at risk of overutilization, because animals have unrestricted choice and repeatedly consume preferred species first. Furthermore, total animal production per unit area is necessarily low owing to fewer animals in a pasture compared to higher stocking rates (Heitschmidt and Taylor 1991).

As stocking rate increases to a moderate level, individual animal performance declines (Figure 5). This is because the average forage quality consumed per animal is reduced as a direct result of the increase in animals per unit area. However, total animal production per unit area increases as more animals are carried per acre. Under normal conditions a moderate stocking rate will not adversely impact the forage resource.

At high stocking rates, total animal production per area declines as a result of poor individual animal performance (Figure 5). Individual animal performance is poor because each animal in the herd must now compete for a limited and rapidly diminishing supply of quality forage. As the forage resource is diminished under high stocking rates, the nutritional demand of each animal goes increasingly unmet. Prolonged, excessively high stocking rates will result in a loss in body condition score, lower calving rates, and poor herd health. Adjustments to stocking rates after animal performance noticeably declines are too late, because the impact on the animal and the forage resource is already severe. Over the long term, over-stocking leads to a reduction in palatable species, an increase in weedy or undesirable species, a subsequent decline in carrying capacity, and a loss in profitability of the ranching operation (Figure 4).

Summary

Every livestock operation has an appropriate stocking rate, whether it runs one grazing animal or a thousand. Successful grazing management depends on the skillful manipulation of the components that make up the stocking rate: number of animals, unit area, and time. A well calculated stocking rate is vital to a sustainable grazing operation, as it will optimize forage and animal performance, maintain land resources, and ensure consistent economic returns. Therefore, stocking rate is the most important tool in the manager's toolbox.

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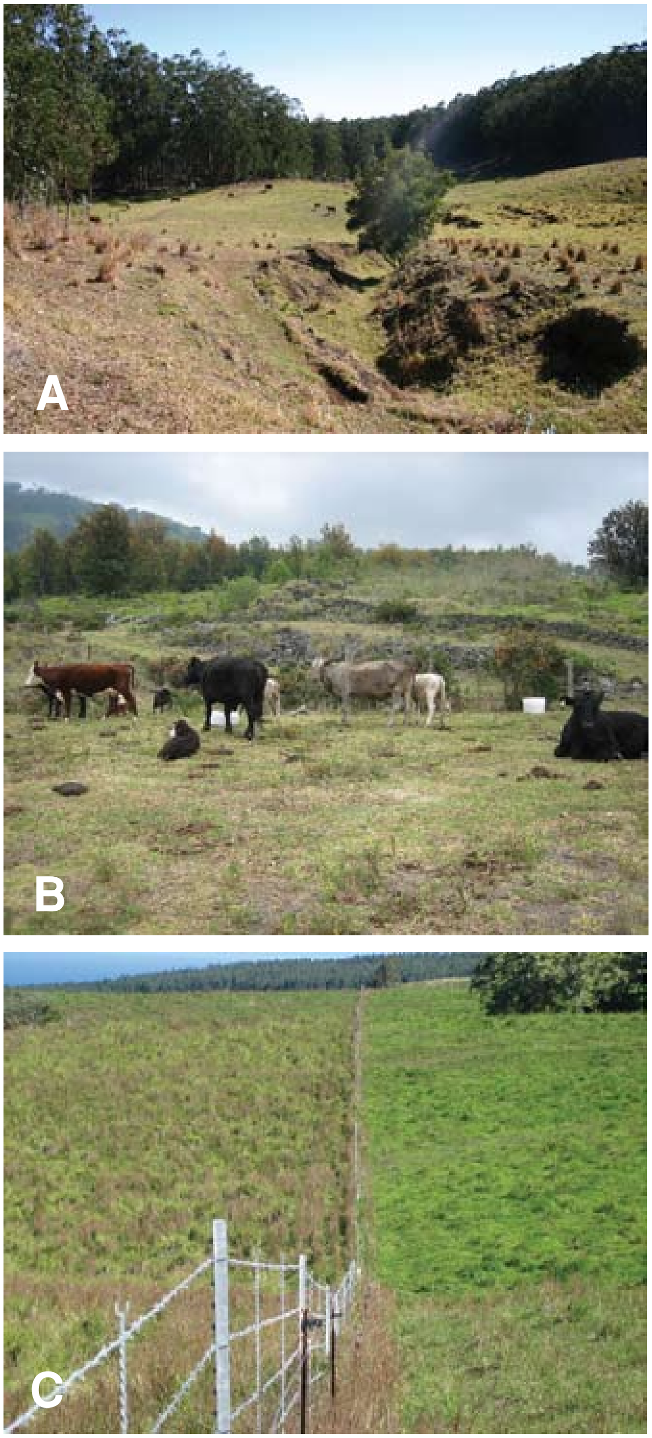

Figure 4. Improper stocking rates result in overutilization of key forage species (A and B), increase in weedy species (A, B, and C), soil erosion (A), and poor animal condition (B). Compare the increase in broom sedge on the left side of the fence and the absence of this weedy grass on the right side of the fence in C. The difference is due to the stocking rate, which is properly maintained on the right.

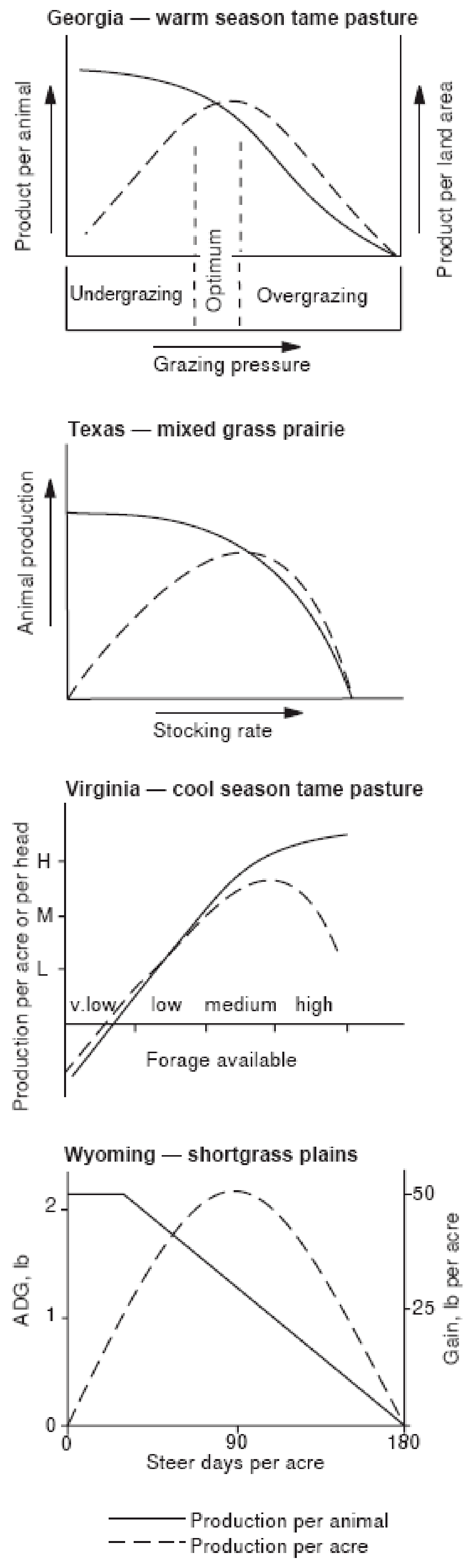

Figure 5. Relationship between stocking rate and animal production based on research from different regions. (From Ohlenbusch and Watson 1994, Georgia; Hoveland 1986, Virginia; Blaser et al. 1986, Texas; Kothmann 1975, Wyoming; and Hart et al. 1988).

Table 4. For a given total pasture acreage and herd size, the management decision to divide the area into different numbers of pastures affects various measures of grazing pressure. Variables of particular importance are the responses of stock density, stocking rate, grazing days, and days rested per year. Formulas used to calculate the variables are in brackets.

Total acreage:	1500	1500	1500	1500	1500	1500	1500
Herd size or AUs (no. head):	320	320	320	320	320	320	320
Number of pastures (management decision):	1	2	4	8	16	31	61
Acres per pasture (with that no. of pastures):	1500	750	375	187.5	93.6	48.4	24.6
Variables affected:							
Stock density, head per acre [no. head ÷ acres/pasture]	0.21	0.43	0.85	1.7	3.4	6.6	13
Average ***rest period***, days	0	45	45	45	45	45	45
Graze period, days (timing and intensity) [rest period × no. pastures resting]	365	45	15	6.4	3	1.5	0.75
Cycle length, days [graze period × no. pastures]	365	90	60	51.2	48	46.5	45.7
Grazing frequency, cycles per year [days in year ÷ cycle length]	1	4.1	6.1	7.1	7.6	7.8	8
Days grazed per year [graze period × grazing frequency]	365	184.5	91.5	45.4	22.8	11.7	6
Days rested per year (regrowth opportunity) [rest period × grazing frequency]	0	184.5	274.5	319.5	342	351	360
Head per acre per day of grazing [stock density × grazing period]	0.0005	0.01	0.06	0.27	1.13	4.4	17.3
AUDs per acre per grazing period (forage demand per grazing period) [(no. head × grazing period) ÷ acres/pasture]	78	19.2	12.8	10.9	10.3	9.9	9.8
Stocking rate, AUs per acre per year [AUDs/acre/grazing period × (grazing frequency ÷ days/yr)]	0.21	0.21	0.21	0.21	0.21	0.21	0.21

AU = animal unit; AUD = animal unit day; days grazed plus days rested may not equal 365 due to rounding.

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Appendix: Worksheets

Adapted from Brence and Sheley 2003

Worksheet 1. Forage production

Pasture or unit: ________________________________

Date: ___________________________________

Site 1

	1	2	3	4	Total
A.	________	________	________	________	________
B.	________	________	________	________	________
C. Total weight of all samples (A – B = C)					________
D. Average weight per sample (C ÷ 4)					________
E. Average dry weight (D × percent in Table 3)					________
F. Pounds per acre (E × conversion in Table 2)					________

Site 2

	1	2	3	4	Total
A.	________	________	________	________	________
B.	________	________	________	________	________
C. Total weight of all samples (A – B = C)					________
D. Average weight per sample (C ÷ 4)					________
E. Average dry weight (D × percent in Table 3)					________
F. Pounds per acre (E × conversion in Table 2)					________

Site 3

	1	2	3	4	Total
A.	________	________	________	________	________
B.	________	________	________	________	________
C. Total weight of all samples (A – B = C)					________
D. Average weight per sample (C ÷ 4)					________
E. Average dry weight (D × percent in Table 3)					________
F. Pounds per acre (E × conversion in Table 2)					________

Site 4

	1	2	3	4	Total
A.	________	________	________	________	________
B.	________	________	________	________	________
C. Total weight of all samples (A – B = C)					________
D. Average weight per sample (C ÷ 4)					________
E. Average dry weight (D × percent in Table 3)					________
F. Pounds per acre (E × conversion in Table 2)					________

Worksheet 2. Stocking rate

Pasture or unit: ____ ***Date:*** ________________________

Method 1: To be used to determine the number of animals that can be supported by the pasture.

1.	Sum total forage production of all sites sampled (from Worksheet 1)	___________	pounds/acre
2.	Divide line 1 by number of sites sampled (from Worksheet 1)	___________	pounds/acre
3.	Multiply line 3 by 0.5 (i.e., the "take half, leave half" rule to obtain the amount of useable dry forage per acre	___________	pounds/acre
4.	Number of acres in pasture	___________	acres
5.	Multiply line 3 by line 4	___________	pounds available
6.	Multiply average herd weight by appropriate Table 1 value (or use 26 pounds DM/day, 780 pounds DM/month) to obtain the forage demand per animal per day or month	___________	pounds/head/day or month
7.	Divide line 5 by line 6	___________	head/day or month
8.	Number of months or days pasture is grazed each year (see Table 4)	___________	days or months
9.	Divide line 7 by line 8	___________	head supported by pasture for the grazing period

Method 2: To be used to determine how many days or months a pasture will support a given number of animals.

Complete lines 1 through 5 above.

6.	Number of head to use pasture	___________	head
7.	Multiply average herd weight by appropriate Table 1 value (or use 26 pounds DM/day, 780 pounds DM/month) to obtain the forage demand per animal per day or month	___________	pounds/head/day or month
8.	Multiply line 6 by line 7	___________	pounds/day or month
9.	Divide line 5 from method 1 by line 8	___________	total days or months that pasture can support animals