Estimating Carrying Capacity on Rangelands

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Photo 1. **Forage production collection. (Courtesy Casey Spackman.)**

INTRODUCTION

Carrying capacity is defined as the average number of wild and domestic animals that a landscape or area can support. Monitoring is the method by which landscape assessments can be made and determines whether the trajectory of rangeland conditions is improving, sustaining, or degrading. Calculating carrying capacity from monitoring data is critical to avoid the overuse of natural resources. Understanding basic concepts of the calculation process can help provide a more accurate estimate of carrying capacity and promote sustainable rangeland conditions.

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Table 1. Range hoop and square conversion factors				
Plot Size	**Conversion Factor**	**Hoop Radius**	**Hoop Circumference**	**Square Dimensions**
0.96 ft^2	grams × 100	0.55 ft	3.5 ft	0.98 × 0.98 ft
1.92 ft^2	grams × 50	0.78 ft	4.9 ft	1.39 × 1.39 ft
2.40 ft^2	grams × 40	0.87 ft	5.5 ft	1.55 × 1.55 ft
4.80 ft^2	grams × 20	1.24 ft	7.8 ft	2.19 × 2.19 ft
Source: Pratt and Rasmussen (2001)				

SITE SELECTION

Selecting monitoring areas representative of the landscape is key for site selection. Understandably, rangeland pastures vary greatly across the landscape, and certain factors may contribute to the under or over-representation of vegetation present. Thus, some general factors should be considered when selecting an assessment site. Because animals tend to congregate around infrastructure and look for easy travel pathways, it is suggested to select areas a quarter to one mile from water sources, fences, roadways, and other manmade structures. Additionally, selecting sites with slopes less than 15% and areas of greater than 5 acres is recommended.

FORAGE QUANTITIES

The amount of forage available for animals is determined by collecting sub-samples of vegetation from a given area with the sub-sample size known. Samples are then dried, weighed, and converted to pounds of forage per acre (Table 1). The following equation can calculate the total available forage:

Available forage in pounds (lbs) per acre × pasture size in acres

Available forage data can be assessed by residual or annual forage production. Residual forage is plant material collected with possible defoliation from animals (Photo 1). This type of assessment should only be used to estimate current forage availability, not a yearly cumulative total. Annual forage production is plant material collected from exclusion cages and used to assess cumulative forage production for the year (Photo 2). When annual forage assessments are taken over 5-10 years, trends can be established to make long-term management decisions, whereas 3-5 years of data can be used to make short-term management decisions. Residual forage assessments can be taken at any time during the year, while annual forage estimates are to be taken at the end of the growing season.

UTILIZATION

The percentage of forage removed by animals or the amount of residual vegetation remaining after consumption is referred to as utilization. Utilization is only an approximation of forage use or an estimate of defoliation intensity (Table 2). When residual and annual forage production data is available, the two can be used to deduce an estimate of percent utilization. The following is an equation to estimate percent utilization:

(annual forage production – residual forage) ÷ annual forage production

Light to conservative defoliation in New Mexico optimizes vegetation production and animal productivity, whereas moderate to heavy defoliation can lead to rangeland deterioration if intensity persists over the long term.

FORAGE DEMAND

Animals consume, on average, 2% of their body weight daily on a dry matter basis. Intake of ruminants may be higher or lower depending on forage quality and stage

Table 2. Defoliation intensity categories		
Defoliation Intensity Category	**Percent Forage Use**	**Defoliation Intensity Description**
Light to nonuse	0-30	Only choice plants and areas show use. No use of poor-quality forage plants.
Conservative	31-40	Choice plants have abundant seed stalks. Areas >1 mile from water show little use. One-third to half of primary forage show defoliation in key areas.
Moderate	41-50	Majority of area shows use. Key areas appear patchy with half to two thirds show defoliation. Area between 1-1.5 miles from water show some use.
Heavy	51-60	All choice plants show defoliation. Shrubs show hedging. Key areas lack seed stalks. Defoliation noticeable at >1.5 miles from water.
Severe	Over 61	Key areas show a mowed or severely hedged appearance. Animal trails to and from available forage. Areas >1.5 miles from water appear mowed or severely hedged.
Adapted from: Holechek and Galt (2000)		

Photo 2. **Comparison of annual (within exclusion cage) and residual forage production. (Courtesy Casey Spackman.)**

of production (NASEM, 2016). Horses and donkeys can consume up to 50% more forage per day due to variations in their digestive system. Forage demand standardizes the number of animals a pasture can support through animal unit equivalents (AUE). One mature cow of 1000 pounds, either dry or with calf up to six months of age, is considered one AUE. There is considerable variation between agencies in calculating AUE across different animals. For instance, North Dakota State University bases AUE on metabolic weight rather than dry matter intake (Manske, 1998). However, basing AUE off dry matter intake can give a general estimate and suffice in calculating carrying capacity. Rangeland animals and their unit equivalents on a dry matter basis can be found in Table 3.

LANDSCAPE ADJUSTMENTS

For livestock, several parameters limit the utilization of forages across the landscape. It is important to consider these elements when estimating carrying capacity. For instance, as distance from water or slope increases, vegetation use decreases. The exception is domestic goats and sheep, which do not require water daily and can forage more readily on rugged terrain. Cattle on the other hand, tend to graze flatter terrain and stay closer to water. Thus, tables 4 and 5 give recommended grazing adjustment for cattle only. For domestic sheep and goats, distances less than 2 miles from water and slopes less than 45 percent are used at 100 percent. There can be a significant overlap of slope and distance from water in adjustment calculations, thus, these should be calculated separately with the greatest reduction percent used. They should not be combined for a cumulative reduction. The following are equations used after preliminary carrying capacity has been estimated:

WATER: (% area <1 mile × 1)+(% area 1-2 miles × 0.5)+ (% area 2+ miles × 0) × AUE

SLOPE: (% area 0-10% × 1)+(% area 11-30% × 0.6)+ (% area 31-60% × 0.3)+(% area >60% × 0)] × AUE

CARRYING CAPACITY CALCULATION

Once total available forage quantities, desired utilization, and animal forage demand is known, carrying capacity can be calculated. Animal unit equivalents of domestic animals can be adjusted for duration and are standardized as animal unit day (AUD; one day only), animal unit month (AUM; 30 days), and animal unit year (AUY; 365 days),

Table 3. Forage demand of various rangeland animals			
Animal	Animal Weight (lbs)	Daily Dry-Matter Intake (lbs)	Animal Unit Equivalents (AUE)
Cattle (Mature)	1000	20.0	1.00
Cattle (Yearling)	750	15.0	0.75
Sheep	150	3.0	0.15
Goats	100	2.0	0.10
Horse	1200	36.0	1.80
Donkey	700	21.0	1.05
Bison	1800	36.0	1.80
Elk	700	14.0	0.70
Moose	1200	24.0	1.20
Bighorn Sheep	180	3.6	0.18
Mule Deer	150	3.0	0.15
White-tailed Deer	100	2.0	0.10
Pronghorn Antelope	120	2.4	0.12
Caribou	400	8.0	0.40
Source: Holechek (1988)			

Table 4. Grazing reduction with slope for cattle

Percent Slope	Percent Reduction in Grazing Capacity
0-10	None
11-30	30
31-60	60
Over 61	100 (considered ungrazable)

Source: Holechek (1988)

Table 5. Cattle grazing reduction with distance from water

Miles	Percent Reduction in Grazing Capacity
0-1	None
1-2	50
Over 2	100 (considered ungrazable)

Source: Holechek (1988)

$$total\ available\ forage = 20,000\ acres \times 550\ lbs = 11,000,000\ lbs$$
$$animal\ forage\ demand = 20\ lbs\ per\ day \times 356\ days = 7300\ lbs$$
$$AUY = (11,000,000\ lbs \times 0.35) \div 7300\ lbs = \mathbf{527\ AUY}$$

EXAMPLE 2: Using the same ranch from example 1, 60% of the acreage has water available to cattle within 1 mile, 30% between 1 and 2 miles, and 10% over 2 miles.

$$(0.60 \times 1)+(0.30 \times 0.5)+(0.10 \times 0) \times 527\ AUY = \mathbf{395\ AUY}$$

EXAMPLE 3: Using the same ranch from example 1, 40% of the acreage has slopes less than 10%, 20% with slopes between 11 to 30%, 30% with slopes between 31 to 60%, and 10% with slopes greater than 60%.

$$(0.40 \times 1)+(0.20 \times 0.60)+(0.30 \times 0.30)+$$
$$(0.10 \times 0)] \times 527\ AUY = \mathbf{321\ AUY}$$

LITERATURE CITED

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while wildlife is calculated as AUY only. For livestock, if a pasture has a specified grazing duration (e.g., leases or allotments), AUE can be adjusted by multiplying animal forage demand by the specified time period, expressed as animal units per designated days. The following is a generalized equation for a single animal type used to estimate carrying capacity, followed by examples:

$$(total\ available\ forage \times percent\ utilization) \div$$
$$(animal\ forage\ demand) = AUE$$

EXAMPLE 1: A 20,000-acre cattle ranch produces a yearly average of 550 lbs of forage per acre. Utilization of 35% is desired. The ranch uses a year-long continuous grazing system (365 days).

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