Grazing Management (Draft)

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Introduction

Grazing managers can influence or control the season, frequency, duration and intensity of grazing. Season of grazing has to do with when during the year that grazing occurs. It may occur all year or it may occur just during a certain period or season of the year. Frequency and duration of grazing have to do with how often a pasture is grazed, how long a pasture is grazed and how long it is rested between grazings. Intensity of grazing has to do with stock density, stocking rate and carrying capacity. Stock density is the number of animals per acre at any point in time. This term is often used in intensive grazing management systems. Stocking rate is defined as the number of animals grazing an area of land for a specified period of time.

Season of Grazing

Season of grazing refers to the portion of the year or growing season during which a particular area is grazed. On annual rangeland grazing can occur throughout the year but forage quality is poor during the dry season (George et al. 2001a). Historically livestock producers have grazed annual rangelands during fall, winter and spring and then moved livestock to public lands for high elevation grazing from May to October (George et al. 2001b). Irrigated pasture can also be a source of summer forage during this period. Many ranchers, especially those that are distant from high elevation meadows, graze annual rangelands all year.

Seasonal grazing has been studied by several researchers on California's annual rangelands. ***In each case seasonal grazing offered no forage or livestock production advantage over continuous grazing.*** Heady and Pitt (1979) found that ewe and lamb performance at the University of California's Hopland Research and Extension Center (UC HREC) was better in one pasture grazed continuously year-long than in a similar pasture that was divided into three paddocks and grazed in March, April or May and then continuously the rest of the year. June ground cover and botanical composition in those pastures grazed on a repeated seasonal basis showed the same yearly differences as the pasture grazed continuously. Total standing crop in June also responded similarly to both grazing treatments over the 3-year period.

Ratliff (1986) reported on an 8-year (1961-1968) comparison of continuous and seasonal grazing at the San Joaquin Experimental Range (SJER), in the Sierra Nevada foothills in Madera County, California. Cow and calf weight responses showed continuous grazing of annual rangeland to be most productive for cow-calf production. At weaning, calves under continuous grazing treatments averaged 55 lbs (25 kg) heavier than calves under seasonal grazing treatments. No advantage of one grazing treatment over another was found for mature cow weights.

Bartolome and McClaren (1992) concluded that seasonal grazing at moderate utilization levels offers little potential for changing forage production or composition on unimproved annual grasslands and savannas and that differences between years were due to weather and stocking rate, not the seasonal grazing treatments. In this study at UC HREC sheep, generally dry ewes, grazed the 2 study pastures each year during the dormant season (May to October). Stocking rates were adjusted to produce residue levels in October within moderate stocking guidelines for annual grassland and oak woodland (Clawson et al. 1982). In mid-October of each year the sheep were moved into the fall-winter grazing treatment where stocking was adjusted to achieve the 50 percent utilization typical of moderate grazing pressure. On February 15 animals were moved into the adjacent spring treatment pasture which had not been grazed since October. Seasonal use of pastures was constant over the study period.

In annual rangelands season or time of grazing can be used to suppress one species while increasing another. Laude et al. (1957) found that after herbage removal, soft chess (*Bromus hordeaceus*) was found to continue tillering and flowering much longer than foxtail fescue (*Festuca megalura* and now *Vulpia myuros*). He concluded that early grazing could be continued to the growth termination stage of the foxtail fescue resulting in reduced foxtail fescue seed production while allowing soft chess to tiller and produce abundant seed. When comparing early clipping responses of soft chess and red brome (*Bromus madritensis*) they found increased flowering in the regrowth of soft chess relative to red brome that persisted to mid-April after which the flowering in both species decreased. They concluded that if grazing continued until the late season decline in flowering that soft chess would be favored over red brome.

One of the earliest studies where annual plant competition to seeded native perennials was reduced by targeted grazing was reported by Love (1944, 1952) and by Love and Williams (1956). Grazing from April 2 to April 20 has been shown to improve stand establishment of purple needlegrass (*Nassella pulchra)* and nodding needlegrass (N. *cernua)* when compared to deferment of grazing until April 20 and then grazing until May 21. The early grazing treatment plant counts of seeded purple needlegrass were

111 plants but only 23 plants under deferred grazing. Plant counts for foothill needlegrass were 228 with early grazing but only 24 with deferred grazing. Additionally the plants in the deferred grazing treatments had weak root systems that barely held the crowns in contact with the soil.

In another study reported by Love and Williams (1956) continuous grazing was compared to seasonal rest during the 63 day flush of flowering and seed set by bur clover (*Medicago polymorpha*). They found that lamb production per acre was greater with continuous grazing than with the rotational grazing that resulted in rest during bur clover flowering and seed set. However bur harvest from the pasture rested during flowering was more than three-fold greater than with continuous grazing.

Intensity of Grazing

Intensity of grazing or stocking rate is a fundamental variable determining the sustainability and profitability of rangelands (Smith 1899; Sampson 1923). In determining stocking rate, grazing managers attempt to balance the forage demand of grazing animals with forage production over the changing seasons. In this section we will define some terms, discuss the estimation of carrying capacity and stocking rate and describe how stocking rate can be monitored.

Animal Units and Animal Unit Months

Stocking rate and carrying capacity are often expressed as ***animal unit months*** (AUM). The original definition of an AUM was the amount of forage a cow and her calf would consume in 1 month. This definition worked reasonably well for several years until cows started getting bigger and calf weaning weights increased. To accommodate bigger cows and calves the definition of an AUM was put on a weight basis. Today an ***animal***

unit (AU) is commonly defined as 1000 lbs of body weight and an AUM is the amount of forage that an animal unit will consume in 1 month. If the cow and her calf weigh 1000 lbs then they are still 1 animal unit. More likely the cow weighs 1200 lbs and her calf grows to 400 or 500 lbs by weaning. So the cow without a calf is 1.2 animal units. However, by weaning time the cow and her calf are around 1.6 or 1.7 animal units. The 1000 lb animal unit can be applied to most large herbivores to get a rough estimate of stocking rate. However, tables of animal unit equivalents are often used to provide a more precise estimate that recognizes interspecies differences in metabolic and intake rate. For example, a mature sheep has an animal unit equivalent of 0.20. This means a sheep eats about 20 percent of the forage a cow will eat in one month. Table 1 contains animal unit equivalents for several domestic and wild herbivores. Occasionally you will see the term ***animal unit year*** (AUY). An AUY is 12 AUMs or enough forage to feed an AU for 12 months.

Carrying Capacity and Stocking Rate

Carrying capacity is the maximum ***stocking rate*** possible which is consistent with maintaining or improving vegetation or related resources. It is based on average production over several years. Many livestock operations base their stocking rate on carrying capacity estimates handed down from generation to generation, on the advice of their neighbors or local experts and on trial and error. Stocking rate is usually documented in private and public land leases. Carrying capacity for annual grasslands is often in the range of 6 to 12 acres per animal unit year (Figure 1). Sierra foothill and coast range oak-woodland carrying capacity is commonly in the range of 10 to 30 acres per animal unit per year (Figure 2).

While the above carrying capacity ranges are based on long-term average productivity and experience, range forage productivity varies from year to year depending on prevailing weather conditions (Figure 3). Therefore stocking rate must be adjusted annually in response to these conditions. In a dry year that means that fewer AUs are put in the pasture or that the length of the grazing season is reduced. When forage is in short supply ranches purchase additional hay, rent additional pasture or reduced herd size. High variability in rangeland forage production associated with seasonal and annual variation in weather makes estimation of proper stocking rate difficult. Therefore, it is common for stocking rates to be conservatively applied to minimize the consequences of low production years and prolonged drought.

Often carrying capacity is estimated from average annual productivity which is available from ecological site descriptions (formerly range site descriptions) for USDA Natural Resources Conservation Service (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/). To calculate carrying capacity you need to determine the ***total available forage*** in the pasture and you need to determine ***animal demand for forage***. Early range managers followed the "take half, leave half" approach to determining total available forage. The allowable use approach was instituted because taking 50 percent of the forage was too much or too little in some cases. The allowable use approach is a percentage of the total forage produced that can be removed by grazing. That percentage may range from 35 to 60 percent depending on the vegetation type and on the objectives of private or public range managers. In California we often use the RDM approach to estimating total available forage. In this method RDM is subtracted from total annual production and the remainder is then multiplied by a utilization factor. In the following section we will illustrate how to calculate total available forage and animal demand for forage using the allowable use and RDM methods.

Calculating Stocking Rate (sidebar or appendix)

To calculate carrying capacity you need to determine the *total available forage* in the pasture and you need to determine *animal demand for forage*. There are two ways to calculate total available forage. The first is the *residual dry matter method* commonly used on California's annual rangelands. The second is the *allowable use method* used on perennial rangelands throughout the western U.S. Finally you may need to adjust your carrying capacity estimate for steep slopes and distance to water.

Calculating Total Available Forage (Residual Dry Matter Method)

On California's annual grasslands and oak-woodlands stocking rate is calculated by another method that insures that adequate residual dry matter (RDM) remains at the end of the grazing season (UC Leaflet 8092)

Total Available Forage (lbs) = (Production (lbs/a) – RDM (lbs/a)) X harvest efficiency (%) X pasture area

- Production (lbs/a) estimates based on averages for several years are often available for ecological sites from the USDA Ecological Site Information System (ESIS) website or from range production tables in Soil Data Mart. Current year's production can be determined by weighing dry forage clipped from small plots of a known area.
    - The amount of RDM that should be left behind varies with rainfall, slope and canopy cover and can be determined from UC Leaflet 8092.
    - UC Leaflet 8092: http://anrcatalog.ucdavis.edu/FreePublications
    - Harvest efficiency or grazing allocation is a term that has been used for the forage that is available for grazing by cows or other livestock. Too maintain a conservative stocking rate the grazing allocation or harvest efficiency should be about 50 percent.

If production is determined to be 1600 lbs/a, RDM to be 500 lbs/a, harvest efficiency is 50 percent and pasture size is 1000 acres then:

Total Available Forage =(1600-500) X .5 X 1000 = 1100 X .5 X 1000 = 550,000 lbs of forage

Calculating Total Available Forage (Allowable Use Method)

Total Available Forage (lbs/a) = Production (lbs/a) X Allowable Use (%) X Pasture Size

(A)

- Production can be determined in the same way as for the RDM method.
- Allowable Use guidelines are available in Table 2 or from textbooks (Valentine 2001 – pg 388-391, Holechek 2004 – pg 233-247) or from USDA Natural Resources Conservation Service (NRCS) or other agencies.

If production is determined to be 1375 lbs/a, allowable use is 40 percent and pasture size is 1000 acres then:

Total Available Forage = 1375 lbs/a X 0.4 X 1000 = 550,000

Animal Demand for Forage

If we assume that one AUM is 800 lbs of forage on a dry matter basis and that the

pasture will be used for 12 months then:

- Animal demand for forage = 800 lbs/AUM
- 550,000 lbs of forage ÷ 800 lbs/AUM = 687.5 AUMs
- 687.5 AUMs ÷12 AUM/yr = 57.3 AU for 12 months = 57.3 animal unit years (AUY)

Therefore, it takes about 17.5 acres (1000 acres/57.3) to support 1 animal unit for 1 year (12 AUM).

If the pasture is to be used for only 6 months then:

550,000 lbs of forage ÷ 800 lbs/AUM ÷ 6 months on pasture = 114.6 AU for 6 months.

Carrying Capacity Adjustments

Carrying capacity and stocking rate are often adjusted for slope, distance to water and canopy cover. Approximate adjustments for slope and distance to water are presented in Tables 3 and 4. Carrying capacity must also be adjusted when productivity is reduced by weeds, brush, or trees that invade or encroach into pastures and range allotments. Canopy cover can also effect forage production and therefore stocking rate. In the oak-woodlands canopy cover and slope are important factors in productivity and stocking rate.

McDougald et al. (1991) have developed a score card procedure for estimating stocking rate that adjusts for canopy cover and slope within three rainfall zones (Table 5). The scorecard method of estimating carrying capacity is based on: (1) the productivity of a site, expressed as the relationship between forage production and canopy cover; (2) grazing use, expressed as the relationship between slope and grazing pressure; and (3) a level of residual dry matter or litter, which indicates allowable grazing pressure and utilization. These variables are displayed as a field scorecard (Table 5) which the experienced range manager can use to estimate grazing capacity on annual rangeland along with actual livestock grazing use history. Poorly distributed watering facilities and conditions hampering livestock travel may lead to inaccurate grazing capacity estimates. Experienced range managers can make realistic adjustments to the scorecard to account for long distances to water and poor travel conditions in specific pastures or allotments.

Monitoring Stocking Rate

When estimating stocking rate the values used in the calculations for daily or monthly intake or consumption rates, allowable use rates, residual dry matter (RDM), animal unit equivalents, methods of estimating total available forage, and adjustments made for distance to water and slope can result in different stocking rate estimates for the same pasture. These potential differences support that these calculations are just estimates that should be fine tuned based on end of season monitoring and experience. Selection of conservative values for stocking rate calculations leaves room for adjustment upward if a few years of experience show that the pasture is under stocked.

There are several indicators that stocking rate is too high or too low. High body condition scores (greater than 5) may indicate potential to increase stocking rate and low body conditions scores may be an indicator of a stocking rate that is too high. If desired forage species are declining in vigor or decreasing in number stocking rate may be too high. Utilization that exceeds the allowable use (see above) or recommended RDM is a good indicator of overstocking. Monitoring of stubble height (Lile et al. 2003) or residual dry matter (Bartolome et al. 2002) is often used to assess utilization at the end of the grazing season. Increasing amounts of bare ground or prevalence of soil disturbances could also be an indication of over stocking.

Stocking Rate Effects

Forage Production and Composition

In California researchers have shown that annual rangeland productivity is most influenced by prevailing weather but the amount of RDM in the fall also influences productivity (George et al. 2001 and Bartolome et al. 2002). Fall RDM is the result of grazing intensity during the growing season and summer dry season Moderate grazing should result in RDM levels near the guides in UC Leaflet No. 8092 (Bartolome et al. 2002). Moderate grazing results in a patchy appearance with an average residue about

2 inches tall which equals or exceeds the recommended RDM level (Figure 4). Light grazing results in a less patchy appearance than moderately grazed areas and unused forage averages 3 or more inches in height, exceeding the recommended RDM level. Heavy grazing produces a closely grazed appearance with fall residue averaging less than 2 inches which is below the minimum recommended RDM levels. With low RDM small rocks, sticks, and manure are clearly visible.

Close grazing, resulting in low RDM, can delay fall growth and reduce winter growth of annual rangeland forage plants (Heady 1961). Moderately grazed pastures produce new plant growth two to three weeks earlier than those grazed closely. The residual vegetation left on the ground under moderate grazing protects young plants from drying winds and cold temperatures (Hormay 1944). Biswell (1956) reported that botanical composition of vegetation is influenced by intensity of grazing and by season of use. Moderate grazing usually produces the densest cover and more desirable species. Light grazing results in an increase in tall annual grasses. Heavy grazing has been used to control weeds such as medusahead (*Taeniatherum asperum)* and yellow starthistle (*Centaurea solstitialis*) (Launchbaugh 2006, DiTomaso et al. 2008) but may increase summer weeds (Biswell 1956).

Grasses can shade out other species, so grass often dominates when residue builds up due to favorable weather or light grazing pressure. Light to moderate grazing, resulting in higher RDM in the fall, encourages dominance by slender wild oats (*Avena barbata*), soft chess (*Bromus hordeaceus*), wild oats (*Avena fatua*), medusahead, ripgut brome (*Bromus diandrus*) and other tall species.

Grazing opens the canopy, increasing the occurrence of shorter species such as legumes and other forbs. Heavy grazing, resulting in low RDM in the fall, encourages higher proportions of short or decumbent species such as Silver European hairgrass (*Aira caryophyllea*), turkey mullein (*Eremocarpus setigerus*), quakinggrass (*Briza minor*), nitgrass (*Gastridium ventricosum*), broadleaf filaree (*Erodium botrys*), burclover (*Medicago polymorpha*), redstem filaree (*Erodium cicutarium),* and clovers (*Trifolium* spp.). On a moderately utilized range, livestock do not graze heavily enough to make complete use of the available forage; thus, a patchwork of grasses and forbs is apparent (Hormay 1944).

Using sheep, Rosseire (1987) evaluated the influence of grazing intensity on species composition and herbage production of oak-woodland and improved grassland at UC HREC over a 5-year period using 3 grazing treatments (100, 150, and 200 % of moderate stocking). Plant species and production responses differed significantly between the oak woodland and improved grassland. On the woodland, ripgut brome (*Bromus diandrus*) and wild oats (*Avena barbata* and A. *fatua*) were most sensitive to increasing grazing intensity while wild barley (*Hordeum leporinum* and H. *hystrix*) and annual fescue (*F. megalura*) were least sensitive. On improved grassland, subterranean clover (*Trifolium subterraneum*) increased and soft chess (*Bromus hordeaceus*) decreased with increasing grazing intensity. Soft chess remained most plentiful on woodland range under heaviest grazing and it continued to be a major species under heavy grazing of the grassland, demonstrating tolerance to grazing intensity. Filaree (*Erodium cicutarium* and E. *botrys*) declined on woodland but increased on grassland as grazing intensified. Peak standing crop was not significantly affected by grazing intensity on woodland range but was greatest at 150 percent of moderate stocking and lowest at 200 percent of moderate stocking on the improved grassland. Decline in grassland herbage yield under the heaviest grazing treatment was due to reduction of soft chess which was displaced by subterranean clover. Effects of grazing intensity on composition and productivity were impacted more by annual growing conditions than by grazing regimens.

Herbage Allowance and Intake

Stocking rate has a major effect on animal performance, but comparable stocking rates may result in a wide range in performance across environments because of differences in forage mass or sward characteristics. Herbage or forage allowance is a function of both forage mass and stocking rate and can be a powerful tool for explaining differences in animal performance (Matches et al. 1981). A definition of herbage allowance is the weight of herbage per unit of animal live weight but more refined definitions have been developed (Sollenberger et al. 2005). The amount of herbage available for grazing, its digestibility and the amount of herbage remaining after grazing have been shown to influence animal performance. Higher animal gains can be expected with lower stocking rates than with higher stocking rates, and animals gains decrease as stocking rate is increased. For example Reardon (1977) reported that dry mater intake for steers was related to yield of pasture and to daily herbage allowance. Increasing stock density decreases the amount of herbage available per animal. With decreasing available forage, intake decreases. Animal performance usually increases with increasing forage intake. For example dry matter intake of ryegrass increases with increasing herbage allowance up to about 1500 to 3000 kg DM/ha where intake reaches a plateau (Hodgson 1977, Ellis et al. 1984, and Telford 1980). Similar results have been found for winter wheat (Redmon et al. 1995). Researchers have found that intake rate initially increases with increasing herbage availability (Figure 5), becoming insensitive to herbage availability beyond a certain level (Willoughby 1959, Arnold & Dudzinski 1967, Arnold 1975, Mulholland et al. 1976). In a fertilizer study at UC SFREC researchers estimated forage level and average daily gain for steers during the growing season (February – May). Regression of gain on forage level reveals that rate of gain increases to about 1250 kg of forage per ha and then tends to level off (Raguse et al. 1988) with further increases in forage level (Figure 6)

Livestock Production

There is a fundamental trade-off between gain per animal and gain per unit of area (Figure 7). At very low stocking rates animals can selectively forage with little competition from each other. This promotes high gain or high body condition of individual animals but does not result in maximum productivity per acre. As stocking rate increases competition between animals for forage increases resulting in a decrease in individual animal performance. At heavy stocking rates individual animal performance also decreases because lower quality plants make up a larger portion of the diet and total intake can be reduced. Between the extremes of light and heavy grazing there is an optimum stocking rate (Figure 7) that maximizes productivity per acre (Mott 1060). Bement et al. 1969 developed a stocking-rate guide for short grass plains (Figure 8) showing animal gain per acre and animal daily gain in relation to ungrazed herbage remaining at the end of the grazing season and approximate stocking rate. In Figures 3 and 4 this optimum stocking rate is where the production per head and production per acre curves intersect.

Using production data reported in 1959 by Wagnon et al. (Table 3 – pg 27) we plotted calf crop, calf gain and cow gain against animal units per ton of forage to estimate the optimum stocking rate for annual rangelands at the SJER. The results of this analysis show that the optimum stocking rate for calf crop and calf gains was at moderate to heavy stocking rates of about 8 acres per AU which is equivalent to a forage allowance of 0.15 to .2 AU/ton of forage (Figure 9). The optimum stocking rate for cow gain was at lighter stocking rates of about 12 to 16 acres per AU which is equivalent to a forage allowance of 0.1 and 0.15 AU/ton of forage.

In 1944 Gus Hormay published “Moderate Grazing Pays on the California Annual Type” where he reported studies at the San Joaquin Experimental Range showing that moderate grazing of annual rangelands results in better gains than heavier stocking rates. He also reports that moderate grazing maintains the annual range type in a productive condition.

Water Quality

Livestock grazing has been shown to influence surface water quality and riparian area health. While reducing heavy stocking rates may help protect water quality and riparian areas, reducing residence time in streams and associated riparian areas using traditional livestock distribution practices (George et al. 2007) is often more effective. Studies have shown that riparian health is related to time invested in management by the land owner/manager (Ehrhart and Hansen 1996, Ward 2002).

Summary of Stocking Rate Effects

High Stocking Rates

- Animal performance reduced
- Intake and forage quality reduced

- Desirable forage plants replaced by less desirable species
- Overall forage productivity reduced
- Increase in bare soil and preferred grazing areas become degraded
- Increased replacement feed costs
- Potential for water quality impacts due to increased bacteria, sediment, and nutrient loading

Low Stocking Rates

- Economic potential not fully realized, enterprise sustainability at risk
- Mature animals maintain over-fat body condition which can reduce reproductive capacity
- On perennial dominated rangelands patchy grazing results in development of "wolfy" plants that are used little or not at all. This reduces overall productivity. This occurs less in annual dominated rangeland types but under used patches of less desirable vegetation may occur.
- Some desirable forage species can be crowded out by taller growing species
- Reduced biodiversity of species that thrive under moderate grazing

Increasing Carrying Capacity

Changes in grazing management (season, frequency, duration and intensity of use) generally will not change carrying capacity. Grazing capacity of some range allotments can be increased by improving livestock distribution with such practices as water development, supplement placement, herding and fencing (UC Leaflet 8217). Brush and weed control, seeding and fertilization may also be options for increasing carrying capacity. On irrigated pasture carrying capacity can also be improved with better fertility management and improved irrigation management.

Frequency and Duration of Grazing

Introduction

Frequency and duration of grazing have to do with how often a pasture is grazed, how long a pasture is grazed and how long it is rested between grazing periods. This is where grazing methods ranging from continuous grazing in a single pasture to very intensive rotational grazing are considered. Grazing methods vary from season or yearlong ***continuous grazing*** to intensive ***rotational grazing***. Rotation frequencies can vary from seasonal to daily resulting in a continuum of grazing methods (Holechek 2004). Basically grazing systems differ in their frequency and duration of grazing.

Grazing Systems

Continuous and Seasonal Suitability Grazing

The duration of grazing under continuous grazing is all year or all season in a single pasture. Historically in California and the U.S., most pastures are continuously grazed throughout the grazing season. While continuous grazing can be practiced if proper stocking rates are followed, preferred species may be more heavily used while less preferred species are lightly used. If a native species is preferred (not always the case) it could be grazed too heavily and frequently leading to reduced vigor and competitive ability. With most rotational grazing, only one pasture is grazed at a time, while the other pastures rest. Resting grazed pastures allow native and non-native herbaceous vegetation to restore energy reserves, replace leaf area, rebuild vigor, and deepen their root systems. Rotational grazing can be practiced in a range of intensities from two pastures to more than 30.

Continuous grazing and seasonal suitability grazing (Holechek 2004) are commonly used on annual rangelands. These grazing systems are the result of research and adaptive management (trial and error) over several generations. Some have speculated that desirable plants, particularly grasses, will be grazed excessively under continuous grazing. However, research does not support this view when proper stocking rate is implemented. With continuous grazing, stocking rate must be very light during the growing season because adequate forage must be left to carry animals through the dormant season. Under light stocking, animals are allowed maximum dietary selectivity throughout the year. For example, cattle and sheep preferentially select forbs (i.e., broad-leaved plants) during certain times of the year, which can greatly reduce grazing pressure on grasses. Rotation systems that restrict livestock from part of the range during the growing season can waste much of the forb crop because some forb species complete their life cycle quickly and become unpalatable after maturation. So the forbs have dried up and even shattered by the time some of the pastures are grazed in the rotational grazing system.

Seasonal suitability grazing (Holechek 2004) is a system that describes how many ranchers manage grazing and forage. It has a flexible rotation schedule that fits the needs of the ranch operation. Often the ranch is subdivided into several pastures that are used in a flexible rotation that takes advantage of available forage, available water, shade or other characteristics of a pasture. Sometimes the ranch is subdivided into different vegetation types such as fencing meadows from uplands. It may include installation of riparian pastures so that riparian areas can be managed separately. A few ranchers accomplish rotation without internal fences. Instead they have several water troughs and they rotate by alternately opening and closing (filling and emptying) the troughs forcing the animals to move for water.

Rotational Grazing

Grazing systems are specialized grazing management practices that facilitate rest periods between grazing periods or deferment for two or more pastures (Heitschmidt and Taylor 1991). The principles of rotational grazing were first described near the end of the 18th century in Scotland (Voisin 1959), but implementation of rotational grazing systems on rangelands is a relatively recent phenomenon. Rangeland grazing have progressed from simple deferred systems (Sampson 1913), to more sophisticated rotational systems (Merrill 1954; Hormay and Evanko 1958; Vallentine 1967; Tainton et al. 1999), and most recently to intensive short duration systems (Savory 1978, 1983, Savory and Parsons 1980). The goal of these grazing systems was to increase production by ensuring that key plant species captured sufficient resources (e.g., light, water, nutrients) to enhance growth and by enabling livestock to more efficiently harvest available forage. Production objectives for grazing systems include 1) improved species composition or productivity by ensuring key plant species a rest period during the growing season, 2) reduced animal selectivity by increasing stock density (i.e., animals/land area) to overcome small scale heterogeneity (i.e., patch grazing), and 3) ensure more uniform animal distribution within large heterogeneous management units by improving water distribution and/or cross-fencing.

A recent review (Briske et al. 2008) of studies that compared rotational and continuous grazing systems on rangeland determined that rotational grazing rarely results in increased plant or animal productivity when compared to continuous grazing. During this review it was learned that plant production was equal or greater in continuous compared to rotational grazing in 87 percent (20 of 23) of the experiments that were reviewed. Animal production per head was equal or greater in continuous compared to rotational grazing in 92 percent (35 of 38) of studies. Animal production per acre was equal or greater in continuous compared to rotational grazing in 84 percent (27 of 32) of the studies.

From 1955 to 1960 continuous and deferred rotational grazing were compared on two 40 acre pastures grazed by sheep at UC HREC (Heady 1961). The rotationally grazed pasture was divided into three paddocks. Each year one paddock was grazed early in the growing season, one in the middle of the growing season and one late in the growing season. There were no differences in herbage production or animal productivity between continuous and rotational grazing. Differences in production between years were greater than differences due to grazing system.

Grazing management systems have frequently been controversial because production improvements attributed to grazing systems are often difficult to verify in research studies. While the preponderance of experimental evidence indicates that rotational grazing does not result in greater plant or animal productivity than continuous grazing there remain scientists and managers who are convinced that rotational grazing is better than continuous grazing. How can there be such a divergence of opinion? One source of these differing opinions is that experimental comparisons of rotational and continuous grazing follow rigid experimental guidelines that allow for valid comparisons of grazing system treatments but fail to document improvements and improved flexibility in management facilitated by pasture subdivision and rotation (Teague et al. 2013).

In a management situation a rotational grazing system may allow for other benefits that do not change productivity but may reduce costs. Animals are easier to find and round up when they are isolated to one segment of a pasture. Subdivision decreases distance to water and travel distances. Subdivision inherent in rotational gazing systems facilitates improved control over season, intensity, frequency and duration of grazing. The infrastructure (fences, subdivision, water development, etc.) of rotational grazing and the rigorous planning and attention to detail inherent in intensive grazing systems may provide added value that makes rotational grazing more profitable or easier to manage. Initiation of the grazing system may be facilitating better management than was present before.

Grazing Native Perennial Grasses

Grazing effects on native perennial grasses in California's annual-dominated rangelands have received little attention because they were not the dominant or key species for management. Some native perennial grasses increase (Pacific hairgrass, *Deschampsia holciformis*) with protection from grazing and others decrease (California oatgrass, *Danthonia californica*) and some, like California needlegrass (*Nassella pulchra*) increase when protected from grazing in some studies and not in others. Although intense continuous grazing is one of the disturbances that contribute to the loss of native perennial grasses and their replacement by nonnative annual grasses and forbs, little is known about the growth response of these native grasses to intensity, season, frequency, and duration of defoliation. In a review of grazing effects on California needlegrass (George et al. 2013) concluded that early spring and summer grazing and rest during flowering and seed set are important components of seasonal grazing. Providing for rest following grazing and avoiding prolonged close grazing are also important. Following are some guidelines for managing for purple needlegrass:

1) First, do no harm! Avoid grazing closely and continuously over many months and years.

2) Apply early spring grazing to reduce competition from invasive annuals.

a) On productive soils, use heavy spring grazing to reduce invasive species and follow with rest during flowering and hard summer–fall grazing to reduce litter and produce a harsh microclimate for germination and seedling establishment the following growing season.

b) On less-productive soils, limit heavy spring grazing to high-production years and follow with rest during flowering and hard summer–fall grazing to reduce litter and produce a harsh microclimate for germination and seedling establishment the following growing season.

3) Graze during the dry season to create a harsh soil surface microclimate during germination and seedling establishment the following year.

4) Rest for at least 4 weeks following spring grazing to allow regrowth and tillering. Rotational grazing can facilitate application of this rest treatment.

5) Rest during flowering to allow for seed set before soil moisture is depleted. Depending on the timing of spring grazing, Guideline 4 could accomplish this objective.

6) Avoid close grazing during the growing season. Minimum stubble height of 5–10 cm (2–4 inches) will ensure regrowth and tillering. Growing season-long, with close grazing (less than 2.5 cm) for two growing seasons in a row can result in plant mortality.

7) It might be logistically difficult to apply all of these guidelines in a timely manner to all pastures. If rest cannot be applied to all pastures during flowering and seed set annually, then this rest treatment should be rotated annually so that purple needlegrass has a chance to flower and set seed in each pasture every few years.

8) Rotational grazing can facilitate application of most of these practices. Rotational grazing that provides for at least 4 weeks of rest following grazing during the growing season, avoids grazing the same pasture during flowering each year, avoids grazing below a stubble height of 5 cm during the growing season, and removes standing litter during the dry season should maintain the vigor and competitive ability of purple needlegrass.

Although these guidelines should be generally applicable to most sites, intra- and inter-annual weather differences and site differences will influence tillering and regrowth. Consequently, grazing management must be an adaptive process that responds to prevailing conditions by adjusting the season, intensity and frequency of grazing to prevailing regrowth conditions. If it is a dry year or the site has a low production potential, then intensity and frequency of grazing should be reduced. Likewise, if the potential for regrowth is higher, then purple needlegrass might tolerate more frequent and intense grazing.

Targeted Grazing

While rotational grazing on rangelands may not result in improved plant or animal productivity when compared to continuous grazing, rotational grazing may facilitate achievement of other ranch objectives. Recently the term “targeted grazing” (Launchbaugh 2006) has received increased use. Targeted grazing is the application of a specific kind of livestock at a determined season, duration, frequency and intensity to accomplish defined vegetation or landscape goals. While many of the practices and objectives of targeted grazing have been around for many years the focus on grazing as a vegetation management tool is timely and holds great promise for ecosystem management. For example, rest and deferment may improve the condition or health of degraded rangeland vegetation. Plant species composition may be improved, biodiversity may increase, and ground cover may increase.

Strategic application of increased stock density may be used to manage weed populations (Launchbaugh 2006, DiTomaso et al. 2008) or reduce standing crop that competes with threatened or endangered species such as vernal pools (Marty 2005). Pastures containing critical habitat such as riparian areas or nesting habitat can be rested during critical periods and used at times that will not harm habitat. Resting pastures during restoration projects may facilitate plant establishment and reproduction.

Management Summary

- Seasonal grazing has been studied by several researchers on California's annual rangelands. In each case seasonal grazing offered no forage or livestock production advantage over continuous grazing.

- In annual rangelands season or time of grazing may be used to suppress one species while increasing another.

- Plant production and animal production per head increases with decreasing stocking rate (grazing intensity).

- Herbage allowance is a more precise predictor of animal performance than stocking rate but can be difficult to apply on pastures that are heterogeneous.

- Animal production per land area first increases with increasing stocking rate and then decreases. Peak production per acre is at or near the optimum stocking rate.

- Over the long run moderate stocking rates balances production per animal and production per acre at or near the economic optimum.

- Residual dry matter in the fall provides an indicator of grazing intensity that should influence the decision to change stocking rate.

- On annual rangelands and rangelands in general plant and animal productivity are not improved by rotational grazing systems when compared to continuous grazing.

- While rotation grazing does not improve productivity it may facilitate control of season, frequency, duration or intensity of grazing that meets other ecosystem management goals.

- Targeted grazing prescriptions can be applied to manage rangeland weeds and to reduce competition to desirable vegetation.

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Terminology (sidebar or appendix)

Allowable use. (1) The degree of utilization considered desirable and attainable on various parts of a ranch or allotment considering the present nature and condition of the resource, management objectives, and levels of management. (2) The amount of forage planned to be used to accelerate range improvement.

Animal-Unit (AU). Considered to be one mature cow of approximately 1,000 pounds, either dry or with calf up to 6 months of age, or their equivalent, based on a standardized amount of forage consumed.

Animal-Unit-Month (AUM). The amount of dry forage required by one animal unit for one month based on a forage allowance of 26 pounds per day. The term AUM is commonly used in three ways: (a) stocking rate, as in “X acres per AUM”; (b) forage allocations, as in “X AUMs in Allotment A”; (c) utilization, as in “X AUMs taken from Unit B.”

Available forage. That portion of the forage production that is accessible for use by a specified kind or class of grazing animal.

Carrying capacity. The maximum *stocking rate* possible which is consistent with maintaining or improving vegetation or related resources. It may vary from year to year on the same area due to fluctuating forage production.

Continuous grazing. The grazing of a specific unit by livestock throughout a year or for that part of the year during which grazing is feasible. The term is not necessarily synonymous with *yearlong grazing*, since seasonal grazing may be involved.

Deferment. Delay of livestock grazing on an area for an adequate period of time to provide for plant reproduction, establishment of new plants, or restoration of vigor of existing plants.

Deferred grazing. The use of deferment in grazing management of a management unit, but not in a systematic rotation including other units.

Deferred-rotation. Any grazing system which provides for a systematic rotation of the deferment among pastures.

Forage allocation. The planning process or act of apportioning available forage among various kinds of animals, e.g., elk and cattle.

Grazing distribution. Dispersion of livestock grazing within a management unit or area.

Grazing, heavy. A comparative term which indicates that the stocking rate of a pasture is relatively greater than that of other pastures. Often erroneously used to mean overuse.

Grazing management plan. A program of action designed to secure the best practicable use of the forage resources with grazing or browsing animals.

Grazing period. The length of time that animals are allowed to graze on a specific area.

Grazing pressure. An animal to forage relationship measured in terms of animal units per unit weight of forage at any instant.

Grazing season. (1) On public lands, an established period for which grazing permits are issued. May be established on private land in a *grazing management plan*. (2) The time interval when animals are allowed to utilize a certain area.

Grazing system. A specialization of *grazing management* which defines the periods of grazing and non-grazing. Descriptive common names may be used; however, the first usage of a grazing system name in a publication should be followed by a description using a standard format. This format should consist of at least the following: the number of pastures (or units), number of herds, length of grazing periods, length of non-grazing periods for any given unit in the system followed by an abbreviation of the unit of time used. *See deferred grazing, deferred-rotation, rotation, restoration, and short duration grazing*.

Herbage allowance. Weight of forage available per unit animal on the land at any instant.

Holistic Resource Management. Holistic Resource Management (HRM) is a goal oriented approach to the management of the ecosystem including the human, financial, and biological resources on farms, ranches, public and tribal lands, as well as national parks, vital water catchments, and other areas. HRM entails the use of a management model which incorporates a holistic view of land, people, and dollars.

Light grazing. A comparative term which indicates that the stocking rate of one pasture is relatively less than that of other pastures. Often erroneously used to mean underuse.

Moderate grazing. A comparative term which indicates that the stocking rate of a pasture is between the rates of other pastures. Often erroneously used to mean *proper use*.

Overgrazing. Continued heavy grazing which exceeds the recovery capacity of the community and creates a deteriorated range.

Overstocking. Placing a number of animals on a given area that will result in overuse if continued to the end of the planned grazing period.

Overuse. Utilizing an excessive amount of the current year's growth which, if continued, will result in range deterioration.

Proper use. A degree of utilization of current year's growth which, if continued, will achieve management objectives and maintain or improve the long-term productivity of the site. Proper use varies with time and systems of grazing.

Range readiness. The defined stage of plant growth at which grazing may begin under a specific management plan without permanent damage to vegetation or soil. Usually applied to seasonal range.

Rest. Leaving an area ungrazed, thereby foregoing grazing of one forage crop. Normally rest implies absence of grazing for a full growing season or during a critical portion of plant development, i.e., seed production.

Rest period. A time period of no grazing included as port of a *grazing system*.

Rest-rotation. A grazing management scheme in which rest periods for individual pastures, paddocks, or grazing units, generally for the full growing season, are incorporated in to a grazing rotation.

Rotational grazing. A grazing scheme where animals are moved from one grazing unit (paddock) in the same group of grazing units to another without regard to specific graze: rest periods or levels of plant defoliation.

Sacrifice area. A portion of the range, irrespective of site, that is unavoidably overgrazed to obtain efficient overall use of the management area.

Seasonal grazing. Grazing restricted to a specific season.

Short-duration grazing. Grazing management whereby relatively short periods (days) of grazing and associated non-grazing are applied to range or pasture units. Periods of grazing and nongrazing are based upon plant growth characteristics. Short duration grazing has nothing to do with intensity of grazing use.

Stocking density. The relationship between number of animals and area of land at any instant of time. It may be expressed as animal-units per acre, animal-units per section, or AU/ha.

Stocking rate. The number of specific kinds and classes of animals grazing or utilizing a unit of land for a specified time period. May be expressed as animal unit months or animal unit days per acre, hectare, or section, or the reciprocal (area of land/animal unit month or day). When dual use is practiced (e.g., cattle and sheep), stocking rate is often expressed as animal unit months/unit of land or the reciprocal.

Use/utilization. (1) The proportion of current year's forage production that is consumed or destroyed by grazing animals. May refer either to a single species or to the vegetation as a whole. Syn., degree of use. 2) Utilization of range for a purpose such as grazing, bedding shelter, trailing, watering, watershed, recreation, forestry, etc.

Yearlong grazing. Continuous grazing for a calendar year.

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Table 1. Animal Unit Equivalents for domestic and wild herbivores.

Cattle	**Animal Unit**
Mature cows without a calf	1.0
Cow with a calf	1.2
Weaned calf to yearling	0.6
Steers and heifers (1-2 years)	1.0
Mature bulls	1.3
Sheep	
5 weaned lambs to yearlings	0.6
5 mature ewes with or without lambs	1.0
5 mature rams	1.3
Goats	
6 weaned kids to yearlings	0.6
6 does with or without kids	1.0
6 mature bucks	1.3
Horses and Mules	
Mature horse (1200 lbs)	1 to 1.25
Mature mule	1 to 1.25
Wildlife	
6 deer	1.0
Antelope, mature	0.20
Bison, mature	1.00

Table 2. Proper use factors for California rangelands

Suggested proper use factor (%)	Rangeland Ecosystem or Type
35	Semi desert grassland
35	Sagebrush - grasslands
40	Short grass prairie
50	Oak-woodland
50	California annual grassland

Table 3. 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

Table 4. Approximate reductions in carrying 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

Table 5. Estimated carrying capacity scorecards for three rainfall zones.

Southern California Zone (less than 10" precipitation)

	Slope Class			
Canopy Cover(%)	**<10%**	**10 - 25%**	**25 - 40%**	**>40%**
	AUM/acre			
0 - 25	0.7	0.4	0.3	0.1
25 - 50	0.4	0.3	0.2	0.1
50 - 75	0.2	0.1	0	0
75 - 100	0.1	0	0	0
	RDM lb/acre			
	200	250	300	350

Central Coast and Central Valley Foothills Zone (10" to 40 " precipitation)

	Slope Class			
Canopy Cover(%)	**<10%**	**10 - 25%**	**25 - 40%**	**>40%**
	AUM/acre			
0 - 25	2	0.8	0.5	0.3
25 - 50	1.5	0.6	0.4	0.2
50 - 75	1	0.4	0.3	0.1
75 - 100	0.5	0.2	0.2	0.1
	RDM lb/acre			
	400	600	800	800

Northern California Zone (greater than 40" precipitation)

	Slope Class			
Canopy Cover(%)	**<10%**	**10 - 25%**	**25 - 40%**	**>40%**
	AUM/acre			
0 - 25	3.5	1.3	0.8	0.5
25 - 50	2.8	1	0.6	0.3
50 - 75	1.8	0.7	0.5	0.2
75 - 100	0.9	0.3	0.2	0.1
	RDM lb/acre			
	750	1000	1250	1250

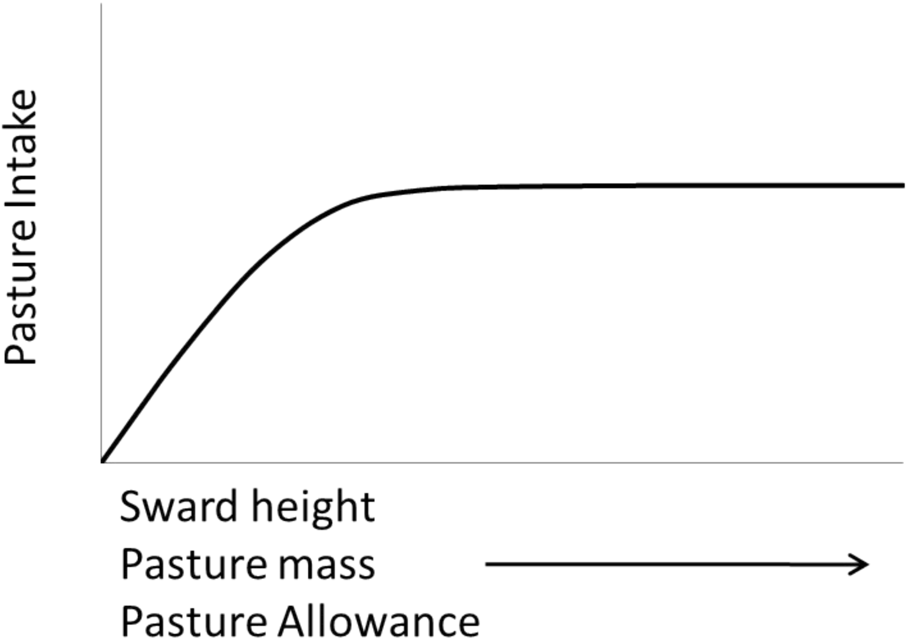
Pasture Intake
Sward height
Pasture mass
Pasture Allowance

Figure 1

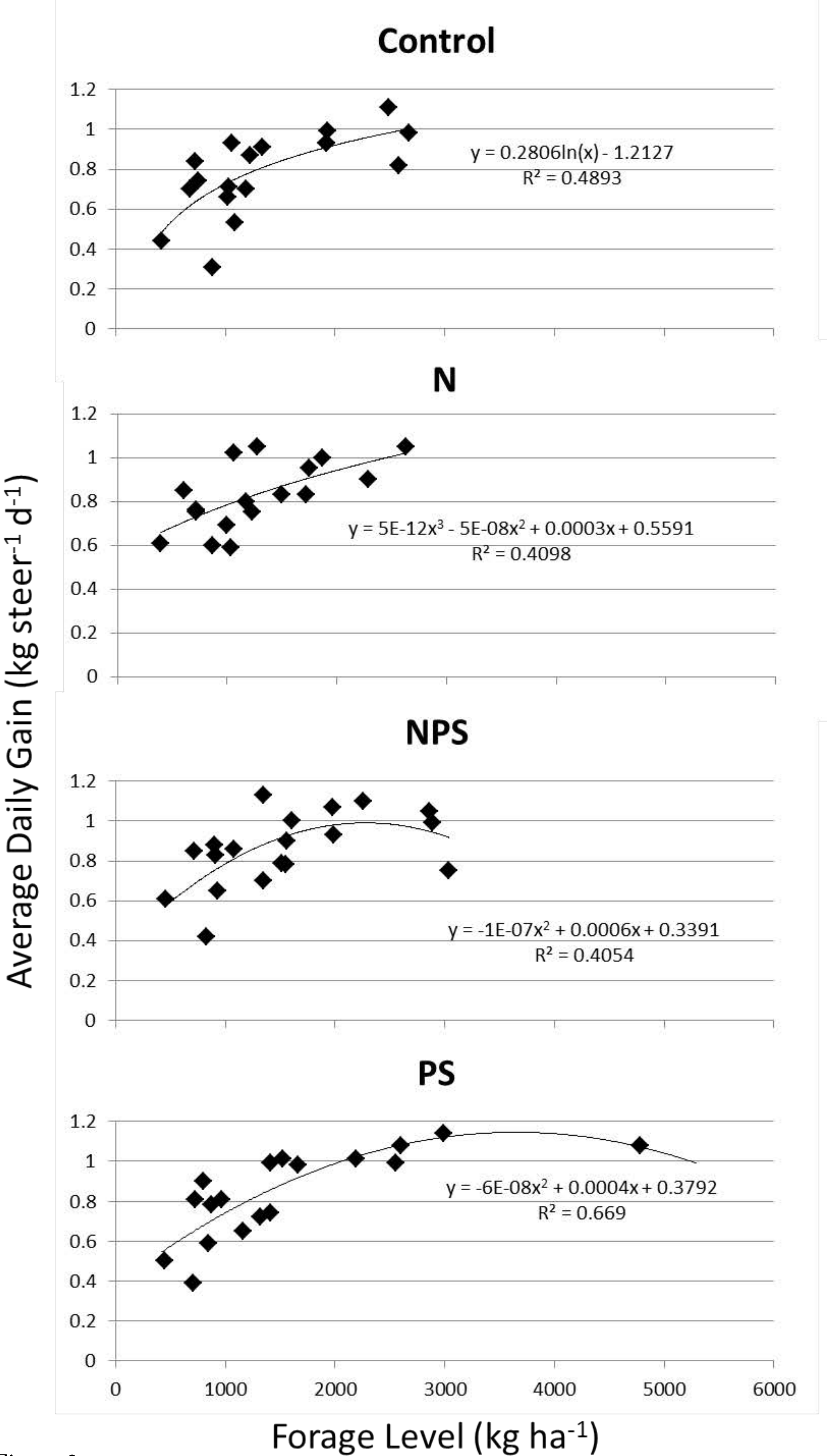
Control
y = 0.2806ln(x) - 1.2127
R² = 0.4893
N
y = 5E-12x³ - 5E-08x² + 0.0003x + 0.5591
R² = 0.4098
NPS
y = -1E-07x² + 0.0006x + 0.3391
R² = 0.4054
PS
y = -6E-08x² + 0.0004x + 0.3792
R² = 0.669
Average Daily Gain (kg steer-1 d-1)
Forage Level (kg ha-1)
0
0.2
0.4
0.6
0.8
1
1.2
0
1000
2000
3000
4000
5000
6000

Figure 2

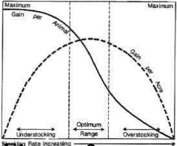
Maximum
Gain per Animal
Maximum
Gain per Acre
Understocking
Optimum Range
Overstocking
Stocking Rate Increasing

Figure 3

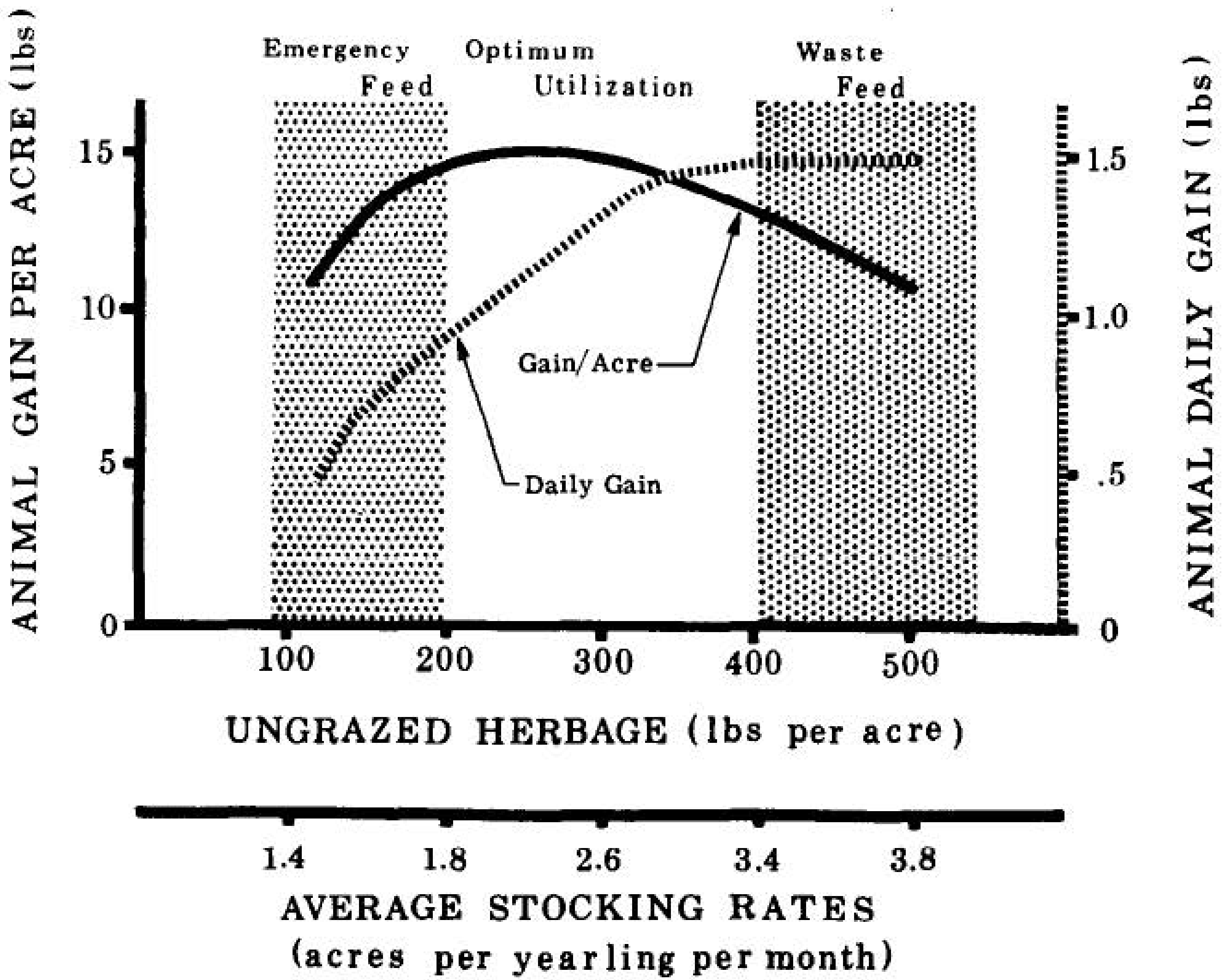

Figure 4

FIG. 1. Stocking-rate guide for beef production on upland blue-

Spring cattle p
cattle at the a
Fall cattle pric
Crow Valley L
at the Experim
The amount
the end of the
within 50 lb/a
reason, average
250, 300, 350,
grazed herbage
guide to study
number of anim
age animal gai
the stocking-ra
stocking rates.
were applied t
estimate cattle
lected stocking

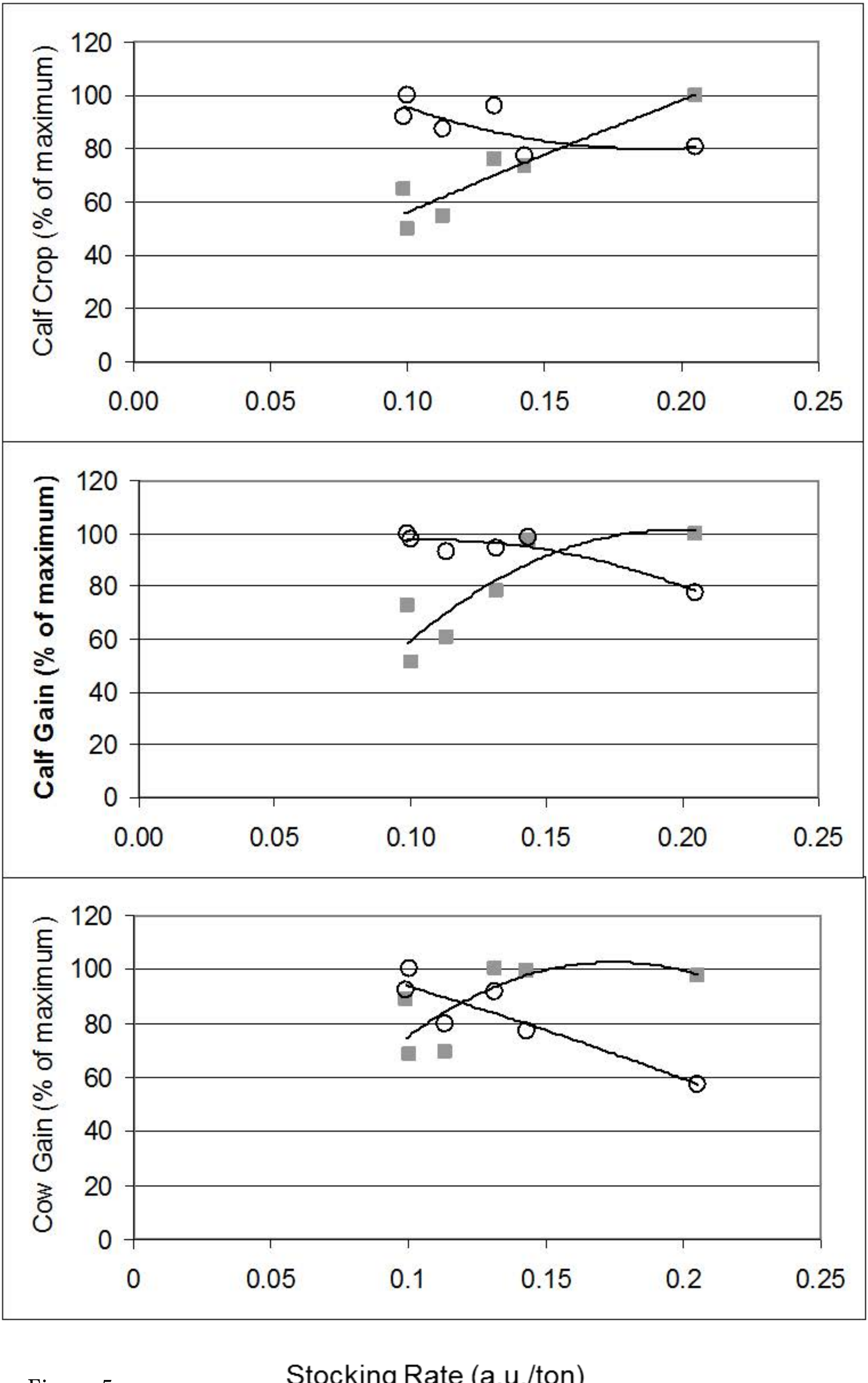
Calf Crop (% of maximum)
120
100
80
60
40
20
0
0.00
0.05
0.10
0.15
0.20
0.25
Calf Gain (% of maximum)
120
100
80
60
40
20
0
0.00
0.05
0.10
0.15
0.20
0.25
Cow Gain (% of maximum)
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25
Stocking Rate (a.u./ton)

Figure 5

Figure 6