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Grazing Principles for Profitable and Regenerative Resource Management Series:

# VI. USING ESSENTIAL GRAZING CONCEPTS TO PROPERLY IMPLEMENT SUCCESSFUL ADAPTIVE, MULTI-PADDOCK GRAZING STRATEGIES

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This is the sixth in a series of Texas A&M AgriLife Extension publications to help readers better understand the ecology of grazed lands, the way plants grow, develop, and react to **defoliation** by **herbivores**, how to manage forage quality and quantity, management of stocking rate to improve grazing profitability, essential concepts related to proper grazing management, and how to apply these concepts successfully using adaptive grazing management strategies. We suggest you read these in order, but each can be read separately if you already have a firm background in these topics. A complete glossary of technical terms used throughout all of the publications can be found at the back of each publication. Several of these terms were supplied by the Society for Range Management, and their definitions are placed in quotes.[1] When needed, additional clarification is provided. When a technical term is used for the first time in each publication, it is shown in boldface type.

### Other Titles in the Principles of Regenerative Grazing Management Series

I. Ecological Concepts in an Economic Context
II. Grazing Management and Its Effects on Plant Competition at Different Scales
III. Factors Affecting the Magnitude of Grazing Effects on Plant Responses and Forage Quality
IV. Stocking Rate: The Essential Concept for Profitable and Regenerative Grazing Management
V. Essential Concepts Necessary for Adaptive Multi-paddock Grazing Management to Achieve Desired Livestock and Landscape Goals

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## INTRODUCTION

An understanding of why and how management affects the distribution, timing, frequency, and intensity of grazing can help promote more palatable and productive plants while maintaining profitability. In previous publications in this series, we described ecological processes driving the productivity of rangeland plant communities, relating those concepts to economic principles. We provided information about how plants grow, mature, and lose forage quality under different growing conditions and ways to manage forage quality and quantity with grazing. We also discussed the value of having a variety of different plants and how they respond to being grazed. We then provided some guidelines regarding how to mitigate those effects by changing frequency, timing, intensity, and distribution of grazing and providing adequate recovery periods that vary with growing conditions and the severity of defoliation.

We also discussed how individual animal performance and animal production per acre change with stocking rate and weather conditions, then used that relationship to illustrate why the optimum stocking rate changes when variable costs or the value of production are altered. However, the optimum stocking rate is not related to overhead costs. We then talked about tools used to accomplish those purposes, including **stocking rate**, **recovery** period, number of **paddocks**, and **area allowance (stocking density)**, with some general guidelines about how they can be used to achieve desired outcomes.

When management is altered, changes in animal distribution, grazing behavior, and plant growth must be correct and of sufficient magnitude to have a reasonable chance that resource and livestock performance goals will be met. For instance, moving

[1](Society for Range Management, 2005)

through several paddocks too quickly may allow animals to select higher-quality forage during a grazing period, but may not allow enough recovery for grazed plants to regain enough vigor to maintain their competitive ability or for the animals to have enough to eat when they return. Such management results in "rotational **overgrazing**" that may only delay degradation at best or cause more rapid failure at worst.

Increasing paddock numbers affects multiple factors at the same time but at different rates. Understanding how different management parameters change relative to each other using different strategies as paddock numbers increase can help explain why "rotational grazing" can be successful or disastrous, depending on the strategy and the actions chosen. That knowledge can help managers make better decisions to adapt to changing conditions.

## SEVERAL IMPORTANT GRAZING MANAGEMENT RELATIONSHIPS ARE NON-LINEAR

Increasing the number of paddocks decreases the **area allowance** (increases **stocking density**). More paddocks may or may not decrease the animals' ability to select an adequate diet or change the patchiness of utilization on a landscape, depending on the variety of plants in a **paddock** and among paddocks, the degree to which it changes animal distribution, and how well management adapts **recovery** and grazing periods to changes in growing conditions. More paddocks can allow shorter grazing periods with a given recovery period and help prevent grazing the same plants more than once in a grazing period. It also can facilitate adequate plant recovery between grazing periods, which can improve the frequency and productivity of higher-quality plants. Success or failure is determined not by the number of paddocks, but by the strategies employed and adaptive management responses to changing conditions, though the number of paddocks can have a profound effect on management flexibility and effectiveness.

If done properly, higher paddock numbers produce desirable results faster, but when mistakes are made, undesirable consequences are dramatically and quickly apparent. Therefore, it may be desirable to start with fewer paddocks per herd to "learn the ropes," then further subdivide them according to a long-term plan as management skills develop. By doing so, land managers can implement the strategy as they learn, allowing them to stop development when additional production can no longer finance additional infrastructure.

[2](Gammon and Roberts, 1978)

The decreased area allowance associated with adaptive, multi-paddock (AMP) grazing results in a misconception held by many people that animals should eat everything in the paddock before moving. However, such a strategy will decrease animal performance if followed for long. An animal's nutrient intake depends more on total forage demand per unit of area in a paddock for a grazing period—what Gammon and Roberts referred to as **stocking intensity**—than on the rate of forage depletion.[2] Stocking intensity and area allowance are not necessarily related, just as the speed of travel and distance traveled are not *necessarily* related. Instead, the management of time relative to the rate in each case determines the outcome. With the right strategy, the average intensity of use in paddocks under AMP management can be lighter than in continuously grazed paddocks stocked at the same rate, because the length of the grazing period decreases faster than the area allowance does, though preferred areas will still likely be grazed more intensely than less preferred areas.

Another misconception is that more paddocks *allow* longer recovery periods. While more paddocks may make longer recovery more attractive because of improved livestock performance, they are not necessary to provide longer recovery periods for plants. The recovery period is a management decision that should be adapted to growing conditions (soil moisture and temperature) and the intensity of grazing use on desired species, with longer recovery needed during drier conditions. Grazing

Figure 1. This photo, taken in a 12- to 14-inch precipitation zone, shows how high densities of livestock were used to manage vegetation structure. In this case, cattle broke the top growth of sand sagebrush to get to a desirable cool-season grass (western wheatgrass). When management of plant structure or undesirable plants is the objective, care should be taken to use animals with a low nutrient requirement, like dry cows that can lose some body condition. These objectives should be accomplished over a very short grazing period with an extended period of regrowth afterward. Doing so minimizes detrimental effects on more desirable vegetation that will likely be grazed intensely. *Photo courtesy of Tim Steffens.*

periods for individual paddocks should be based on the desired recovery period, the number of paddocks, and their carrying capacity relative to the average carrying capacity of all the paddocks in the management unit.

Diet selection and animal performance change as paddock numbers per herd increase, but also differ when the number and size of paddocks are the same and different management strategies are employed. Animals' ability to select diets that meet their needs, determined to a large extent by stocking intensity, determines how well they perform. In addition, changes in the frequency, timing, intensity, and distribution of grazing and the ability of plants to recover and regrow between grazing events determine how they will respond to management. Successful grazing managers know how to adaptively change periods of exclusion and grazing as paddock numbers and area allowance change to achieve desired plant recovery and stocking intensity. By adapting these management decisions correctly, palatable plants will reliably perform well in competition with less palatable neighbors, and animal performance is acceptable.

The table and diagram on the following page contain information on how parameters associated with stocking intensity, diet selection, and the opportunity for plant recovery between grazing periods change as the number of paddocks per herd increases or when different management strategies are employed with the same number of paddocks. Highlighted cells indicate the strategy employed in each case—grazing **cycle length** or recovery period held constant.

Figure 2. This photo from a 16- to 18-inch annual precipitation zone illustrates how higher stocking densities—accomplished by using multiple paddocks per herd—do not necessarily result in high grazing intensity. The left side of the photo has just been grazed, and the paddock on the right is the paddock to which they were moved. The water source is about 30 feet behind the photographer. This is a very sandy, fragile soil. The taller grass patches in the photo are big bluestem. These paddocks were stocked at similar to slightly higher rates than neighbors in the area grazing continuously. *Photo courtesy of Tim Steffens.*

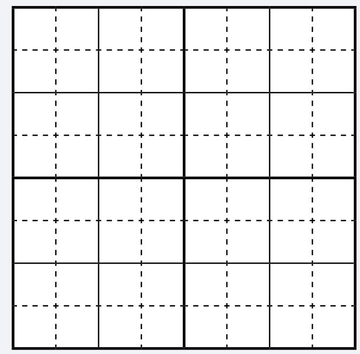
Figure 3. This photo in a 12- to 14-inch precipitation zone shows good growing season grass cover and low stature of sand sage when cattle learned to use winter foliage of sand sage at moderate rates to supplement dormant grass. The small paddocks were used once during the growing season and once in the dormant season with a high stocking density and short grazing periods to achieve moderate utilization of grasses. The rapid rate of dry grass disappearance in the dormant season encouraged them to learn to mix dormant grasses with sage in moderate amounts without toxic effects. The higher protein content of the sage allowed them to maintain condition in winter without other supplementation. The sand sage regrew throughout the summer when it was not selected by cattle, and the moderate growing season use of grasses allowed more rapid regrowth with higher winter digestibility because of a higher proportion of leaf on grasses. Once they learned to use the native forages in this way, and their production cycle was synchronized to forage availability, these cattle received no purchased feeds other than a mineral supplement. *Photo courtesy of Tim Steffens.*

Scenarios A and B in the table represent a drier climate where longer intervals between grazing periods would be needed for plants to fully recover after grazing. Scenarios C and D represent moister areas where the period required for a full recovery would be much shorter and where longer periods of regrowth might diminish forage quality excessively. However, the number of animals remains constant, and the sizes of paddocks change in the same way across all scenarios to maintain more continuity among the different management strategies for comparison of stocking rate and stocking intensity.

It is important to remember that these numbers are used as an example under a specific set of circumstances held constant within a scenario to compare management strategies. Under variable growing conditions, the recovery period should increase as growing conditions become drier. Stocking rates are generally higher in moister environments, since forage productivity would be higher than in the dry environment, but the numerical relationships within a scenario would change in the same way. In scenarios A and C, livestock movement decisions are based on an adequate recovery period for their environment and vary the grazing period to accommodate that. Scenarios B and D hold the cycle length and stocking intensity constant when more than one paddock is used per herd and vary grazing and recovery periods to accommodate that. The remainder of the discussion will refer to the numbers in the table below. When calling attention to it, we will simply say "the table." For the sake of simplicity, it is assumed that there is a diversity of plants across the unit, but the proportion of different species is similar across the entire area.

These examples provide a simplified way to compare and understand important factors associated with stocking intensity and plant recovery as paddock numbers change in two different environments, using two different management strategies under similar conditions between strategies.

**By the Numbers:** The table below quantifies how many parameters associated with plant-animal interactions exhibit non-linear responses when paddock numbers increase. The effects of four-fold increases in paddock subdivision are shown in this table for 1 through 64 paddocks if a: (A) long recovery period is held constant; (B) long grazing cycle is held constant; (C) short recovery period is held constant; and (D) short grazing cycle is held constant. *Assumptions: management unit = 1600 acres grazed by 50 animal units (AU); The time required for adequate regrowth to the previous standing crop is that shown when recovery period is held constant in each environment.* The diagram to the right describes how the grazing unit is divided with each number of paddocks. Dark solid lines indicate one or four paddocks; light, solid lines indicate 16 paddocks; dotted lines indicate 64 paddocks.



| Item | A. Long recovery held constant (Semi-arid environment) | | | | B. Long cycle held constant (~1 year in a semi-arid environment) | | | | C. Shorter recovery held constant (Moist environment) | | | | D. Short cycle held constant (Moist environment) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of paddocks | 1 | 4 | 16 | 64 | 1 | 4 | 16 | 64 | 1 | 4 | 16 | 64 | 1 | 4 | 16 | 64 |
| Number of paddocks recovering | 0 | 3 | 15 | 63 | 0 | 3 | 15 | 63 | 0 | 3 | 15 | 63 | 0 | 3 | 15 | 63 |
| Paddock size (acres) | 1600 | 400 | 100 | 25 | 1600 | 400 | 100 | 25 | 1600 | 400 | 100 | 25 | 1600 | 400 | 100 | 25 |
| Herd size (Number of head) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Average stocking rate (AUD/ac) | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 |
| Area Allowance (ac/Animal) | 32 | 8 | 2 | .5 | 32 | 8 | 2 | .5 | 32 | 8 | 2 | .5 | 32 | 8 | 2 | .5 |
| Grazing period (days) | 365 | 105 | 21 | 5 | 365 | 88 | 22 | 5.5 | 365 | 63 | 12.6 | 3 | 365 | 48 | 12 | 3 |
| Recovery period (days) | 0 | 315 | 315 | 315 | 0 | 264 | 330 | 346.5 | 0 | 189 | 189 | 189 | 0 | 144 | 180 | 189 |
| Stocking intensity (AU·D/ac) | 11.4 | 13.1 | 10.5 | 10.0 | 11.4 | 11.0 | 11.0 | 11.0 | 11.4 | 7.88 | 6.3 | 6.0 | 11.4 | 6.0 | 6.0 | 6.0 |
| Cycle length (days) | — | 420 | 336 | 320 | — | 352 | 352 | 352 | — | 252 | 201.6 | 192 | — | 192 | 192 | 192 |
| Cycles/year | — | .87 | 1.09 | 1.14 | — | 1.04 | 1.04 | 1.04 | — | 1.45 | 1.81 | 1.90 | — | 1.90 | 1.90 | 1.90 |
| Average number of days grazed/year | 365 | 91.3 | 22.9 | 5.7 | 365 | 91.3 | 22.8 | 5.7 | 365 | 91.4 | 22.8 | 5.7 | 365 | 91.2 | 22.8 | 5.7 |
| Area allowance reduction/grazing period reduction ratio | — | 1.15 | .80 | .95 | — | .964 | 1.0 | 1.0 | — | .69 | .8 | .95 | — | .52 | 1.0 | 1.0 |

## Recovery Period Held Constant (Scenarios A or C in the table)

Repeated defoliations of desired plants under continuously grazed management, or with few paddocks and long grazing periods, allow animals to mix diets of higher quality because they often graze regrowth that is more nutritious. However, long grazing periods, even when conservatively stocked, cause detrimental effects on plants that are grazed too often, decreasing the long-term carrying capacity.

When using multiple paddocks per herd, animals can compensate for higher rates of forage disappearance and lower area allowance during a grazing period if faster rotations allow them to explore more of the landscape over a period of time. For example, with four paddocks/herd and a recovery period of 315 days, animals are exposed to one paddock of 400 acres for 105 days (Scenario A). With 64 paddocks and the same recovery period (315 days in scenario A), the same 400 acres are used in only 80 days (16 25-acre paddocks) with no particular acre exposed to grazing for more than 5 days. In the latter instance, minimal regrowth during the short grazing period decreases the likelihood of repeated severe defoliations in a grazing period. These plants may be grazed again when animals return to the paddock, but adequate recovery should improve the composition and productivity of palatable plants over time compared to a single 105-day grazing period. Additionally, lighter stocking intensity in each grazing period should keep animal performance high. With four paddocks, animals may regraze higher-quality regrowth to maintain diet quality throughout the 105-day grazing period, but plant community composition may not improve because of multiple defoliations during a grazing period on these preferred plants without adequate recovery.

## Moist Versus Drier Environments

A moister environment (scenario C) allows more immediate improvements in stocking intensity (e.g., going from continuous to four paddocks in scenarios A versus C). Grazing periods are much shorter than in the drier environments, because shorter recovery periods are needed in moister environments. The grazing periods decrease much faster than area allowance, resulting in much lower stocking intensities. Because of the faster stock moves, livestock will see more of the total grazing unit in the same time period when paddock numbers are further increased (i.e., 35 of 64 25-acre paddocks in scenario C versus 16 of 64 25-acre paddocks in scenario A in 105 days). However, the relative change in the area grazed and stocking intensity within a strategy in the two environments with a given change in paddock numbers is the same (e.g., stocking intensity decreases by 24 percent going from four to 64 paddocks in each case because the grazing period decreases by a factor of 21, while area allowance decreases by a factor of 16 in both scenarios).

With an adequate recovery period held constant, more paddocks of smaller size result in lower stocking intensity and improved opportunities for animals to select an adequate diet (stocking intensities for scenarios A and C) while decreasing the likelihood of multiple defoliations during a grazing period (grazing

Figure 4. This water point had 12 paddocks coming into it in very sandy soils with an average annual precipitation of 12 inches. The small water lot around the trough encouraged cattle to get a drink and leave to begin grazing again, rather than loaf around the water point where they would have utilized the grasses more heavily and transported nutrients from where they were consumed to the water point. *Photo courtesy of Tim Steffens.*

Figure 5. The principles outlined in this section work in dry or moist environments. This photo was taken in a 24-inch precipitation zone. The area had been dominated by guajillo and blackbrush previously, with other brush species making up minor components of the community. It was roller chopped on grids, leaving islands of brush as seen to the left of the man. A summer burn was then applied with no supplemental seeding of native grasses. Subsequent management was one short growing season grazing period with another moderate dormant season grazing period each year. The manager's objective was to improve bobwhite quail habitat, but he carried almost 150 percent of the livestock that neighbors did with no supplemental hay feeding. Some of the grasses in the photo include Arizona cottontop, hooded windmill grass, and pink pappusgrass. *Photo courtesy of Tim Steffens.*

periods in scenarios A and C). Except when cycle length is greater than the original continuous grazing season (e.g., the four-paddock example in scenario A), stocking intensity decreases with increasing paddock numbers when recovery is held constant (scenarios A and C) because the grazing period decreases faster than area allowance (a value of less than one on the bottom row). However, each additional subdivision of paddocks after the cycle length is less than 1 year provides a smaller decrease in stocking intensity (diminishing returns) because the area allowance reduction to grazing period reduction ratio approaches 1 as paddock numbers increase (bottom line of Table 1).

Assuming that the recovery period is correct in each case, lower stocking intensity would provide for both good animal and **plant community** performance. There are fewer opportunities for plants to be grazed over the course of a year because the grazing period decreases. A greater percentage of the plants on a management unit are also excluded from grazing on any particular day, and the length of deferment between grazing periods allows grazed plants to fully recover. Each of these benefits are particularly noticeable in moister environments where the recovery period required is much shorter, as in scenario C. Though preferred plants may be defoliated heavily during a grazing period with any number of paddocks, the average degree of use will be the same or lighter with more small paddocks than with fewer large paddocks when the recovery period and stocking rate are held constant because the grazing period decreases more proportionally than the area allowance.

## Constant Recovery Versus Constant Cycle Length

When growing conditions are generally moist and temperatures are mild (scenarios C and D in the table), the recovery period needed is relatively short. When the recovery period is held constant (C), stocking intensity improves considerably with the first subdivision and continues to improve with increasing paddock subdivision, but at a slower rate. If the cycle length is held constant (D), there is no advantage for the animals of having more paddocks per herd (stocking intensity remains the same, rather than decreasing, as in scenario C). To make matters worse, the recovery period varies widely, as paddock numbers increase with a constant cycle length. Assuming similar growing conditions, the recovery is either too short or too long in most circumstances, which would lead to either too little regrowth or lower quality, respectively. When regrowth is insufficient, plants will suffer, and there will not be enough grass available when the animals return. If the recovery is too long, ample forage may be available, but the animals will be “starving in belly-deep grass.”

When longer recovery periods are required because of drier conditions (scenarios A and B), the decrease in stocking intensity will be much lower with the initial subdivision of paddocks, and stocking intensity may even increase at first, if the cycle length is longer than the continuous grazing season (e.g., scenario A, four paddocks). As with the moister environment described in the previous paragraph, the recovery period varies widely when the cycle length is held constant, causing either insufficient regrowth or lower forage quality compared to when recovery period determines the grazing period. See the fifth publication in this series and Steffens et al. in the “Bibliography” section for a more detailed discussion of what constitutes adequate recovery.[3]

## Cycle Held Constant

The recovery period varies with the number of paddocks when the cycle length is held constant (scenarios B and D in the table) with no decrease in stocking intensity. In addition, faster rates of forage disappearance make diet quality decline more rapidly over the course of a grazing period as paddock numbers increase. Combined, these two results make lower individual animal performance much more likely. In each environment, the assumption is that the recovery period that is held constant is optimum for the growing conditions (the heading of the table). Therefore, the recovery period will be too short for other alternatives in scenarios B and D, which will decrease forage availability over time. Shorter recovery periods will also decrease the ability of grazed plants to compete with ungrazed neighbors, since they will not be fully recovered from the previous defoliation when animals return, while the regrowth will be more attractive to the livestock than more mature plants that were not grazed previously. Over time, this type of management will decrease carrying capacity as well as animal performance.

When the cycle length is held constant (scenarios B and D), area allowance is the same for a given number of paddocks as when the recovery period is held constant (scenarios A and C) since it does not depend on the length of the grazing period. Someone without a firm grasp of the concepts discussed earlier could drive by two neighbors, one using the strategy in scenario A and the other the strategy in scenario B, see the same number of animals using the same number of acres in a paddock and expect similar results for the two management strategies. However, the different approaches to choosing a recovery period—one based on a recovery period adequate for the growing conditions and the other based on cycle length or stocking intensity—would yield entirely different outcomes for both animals and plants.

[3](Steffens et al., 2013)

# MANAGEMENT MATTERS: SOME GUIDELINES

## What is the value of more paddocks?

1. ***More paddocks on a fixed land base provide more management flexibility and may—but do not necessarily—improve animal distribution on the landscape. However, they are not a magical cure for all problems.***

   As shown in the table and previous discussion, the rate of forage disappearance increases as the paddock size decreases. However, increasing paddock numbers on a specific land base with a constant herd size reduces stocking intensity if the grazing period decreases more than area allowance does (as happens when using the same recovery period with more paddocks), but stocking intensity increases when area allowance decreases to a greater extent than the grazing period. The degree of increase or decrease in nutrient intake will depend on the availability of forage quality, length of the grazing period, and rate of forage depletion.

   As forage disappears over the course of a grazing period, diet quality decreases because livestock select the higher-quality plants preferentially. In environments with relatively scarce high-quality plants, animals may regraze these preferred species when grazing periods are long enough for regrowth to occur (e.g., four paddocks).

   When regrowth is slow and the length of recovery needed is long (e.g., during the dormant season or in dry environments), higher-quality components are exhausted quickly. In the latter part of the long grazing periods, animals will not have enough high-quality plants to mix with the remaining low-quality herbage to meet their requirements throughout the grazing period. Therefore, animal performance may suffer more, or they may require more supplemental feed with longer grazing periods and fewer paddocks. However, when they can consume the high- and low-quality plants over a short period of time, as would happen with many paddocks per herd and short grazing periods, the mix may meet their dietary needs over a greater proportion of each grazing period.

   A fast rate of forage disappearance may also encourage animals to sample a wider range of plants in an effort to meet nutrient requirements. If these new foods can be mixed together over a short enough period of time, as would happen with many paddocks per herd, animal performance may not be adversely affected. The array of plants the animals consider to be acceptable would increase, thereby increasing carrying capacity.

   More paddocks may also allow intense use for a short period of time in one paddock while allowing lighter use in the next to increase the patchiness of use on the landscape. The resulting increase in habitat "edge" may be accomplished while still maintaining adequate animal performance, if it occurs over a period of only a few days, because of compensatory intake when they go to the lightly used paddock.

   "Bonus" plants are palatable and nutritious plants that are available for short periods of time but are only infrequently present. Moving rapidly through paddocks when these bonus plants are available allows livestock to consume the bonus plants in preference to more reliable, and usually more productive, perennial plants. Levels of utilization on the bonus plants, and possibly recovery periods for perennials, can then increase. In that way, animal intake can be maintained while improving the opportunity for perennial plants to set seed and/or germinate new plants with less competition from the bonus plants.

   More paddocks can also allow more groups of animals to be managed separately (e.g., different sire groups, classes, species, sexes, etc.) while still facilitating adequate recovery between grazing periods. More paddocks can also facilitate shorter grazing periods and longer recovery in times of drought by combining herds.

## Stocking intensity or recovery—which takes precedence?

2. ***The required recovery period to sustain plants and plant communities and the number of paddocks should determine the length of the grazing period. Recovery periods should be determined based on current and likely growing conditions and the level of use during the grazing period from which the paddock is recovering—poorer conditions or heavier use mean that a longer recovery is needed.***

   When the cycle length is held constant (scenarios B and D of the table), stocking intensity also remains constant as paddock numbers increase. Additionally, the recovery period changes with increasing paddock numbers. At some number of paddocks, the recovery would be right, but will be either too long or too short in every other instance with a given set of growing conditions. With such a management plan, improvement for either plants or animals would be pure luck and will likely fail at some point. Therefore, a proper recovery period based on growing conditions is always paramount to achieve adequate forage quantity and quality. If you are unfamiliar with when rain and growth are likely, rainfall records can be found for your area online. Expected plant production curves are available through the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS).

A consistent, adequate recovery with increasing paddock subdivision decreases stocking intensity, provided the cycle length is not greater than the continuous grazing season (scenario A dividing from one to four paddocks). Most stocking intensity improvement with increasing paddock subdivision occurs by the time 8 to 16 paddocks per herd are developed, when the recovery period is adequate and held constant (scenarios A and C). In addition, the lower stocking intensity with smaller paddock size results in more consistent diet quality over the course of a grazing period and from one grazing period to another. The advantage of paddock subdivision with regard to diet quality and stocking intensity during a grazing period is more pronounced and immediate when required recovery periods are shorter (stocking intensity in scenario C) than when required recovery periods are long (stocking intensity in scenario A).

A common mistake under drought conditions is to decrease forage demand by decreasing grazing periods, causing inadequate recovery between defoliations—essentially, forced, rotational ***over*grazing**. Grazing periods for individual paddocks should be based on the desired recovery period, the number of paddocks, and their **carrying capacity** relative to the average carrying capacity of all paddocks in the management unit (e.g., scenarios A and C for dry and moist conditions, respectively). In the examples, each paddock has an equal carrying capacity. Under drier conditions, the proper response is to increase recovery periods. With more paddocks per herd, animal performance may be maintained at a higher level, as stated previously, compared to increasing the recovery period with a lower number of paddocks, since stocking intensity would be lower with the same number of animals and more paddocks per herd than with fewer paddocks.

With a set number of paddocks, increasing the recovery period will also mean longer grazing periods. However, taking these actions while maintaining the same number of livestock will increase the intensity of use in paddocks. Intense use of plants requires a longer recovery and decreases livestock performance. When stocking intensity is increasing, and recovery is inadequate in the next paddock, moving faster will compound the overgrazing problem. The proper response would be to increase the recovery period and decrease the number of animals, since you are overstocked. To facilitate changing the stocking rate to accommodate drought, there should ideally be some class of livestock that can be easily moved and sold without excessive financial loss. Early weaning of calves, trader cattle, stockers, or age classes of animals that are overvalued are all possible ways of decreasing livestock numbers without undue financial loss.

Increasing the number of paddocks per herd increases the total number of days of recovery during the year compared to the total number of days grazed in a year (second line from the bottom in the table). In the table, the average number of days grazed in a year decreases as the number of paddocks per herd increases, with the other days of the year all receiving no livestock grazing. Again, this effect is dramatic until 8 to 16 paddocks per herd are developed, at which point the rate of improvement becomes less significant. As the number of days a paddock is deferred from grazing during the year increases, the likelihood that it will receive rain and grow without being defoliated at a sensitive time increases.

## What factors affect the frequency and intensity of defoliation?

3. ***The frequency of plant defoliation during the year is determined by the diversity of plants available, the changes in relative palatability among them over the course of the grazing season, the length and timing of grazing periods, and the length of time livestock are gone. The actual intensity of defoliation is related to stocking intensity and the relative palatability of plants in the paddock, with palatable plants receiving heavier use, even at light stocking intensities.***

Days grazed per year and length of the grazing period tell us something about the frequency of defoliation expected on preferred species. Since animals will probably graze preferred plants intensely when they find them, higher frequencies and intensities of defoliation are expected on these plants at the same stocking intensity when grazing periods are long than if they are short. Likewise, if plants in a paddock are exposed to grazing for a high total number of days per year, the intensity and frequency of use are likely to be particularly high on those preferred plants.

The palatability and quality of plants change as they mature. Cool-season plants generally begin growth and mature earlier than warm-season plants. Even among warm- or cool-season plants, some species start growth sooner or mature faster, so animals will change the species they prefer over the course of a season or year.

Changing palatability relationships among species can sometimes be used advantageously to provide opportunities for animals to consume better diets while providing regular, adequate recovery for grazed plants. For instance, in areas having both cool- and warm-season grasses, the stock may be grazing primarily cool-season plants in March or April and then switch to warm-season species as the season progresses. With short grazing periods and many paddocks per herd, it may be possible to graze the cool-season plants only one time during a grazing period in early spring. Then, in mid-summer, they can return when they will not eat cool-season plants that are more mature or summer dormant, preferring immature warm-season grasses instead. In some environments, another dormant season grazing period may also be possible, if enough regrowth has occurred, while still providing most of a growing season of recovery for all of the species.

When evaluating the effect of paddock numbers on the frequency of defoliation, the effects on both defoliations per year and defoliations per grazing period must be considered. When sufficient recovery between grazing periods is provided, defoliations per grazing period are particularly important, since grazing periods per year will not be a major issue. The length of the grazing period should be as short as possible without spending more money on water development and fencing than can be recovered.

Fencing and water development costs affect the optimum number of paddocks per herd. In areas with very low annual rainfall, few existing livestock distribution problems, and short periods during the year when growth actually occurs, few paddocks may be needed. Exceeding the number needed may become uneconomical. Where growth rates are faster and occur over longer periods of time, more paddocks may be desirable, because more grazeable forage can be gotten under control with a given length of fence in a moister environment. Inexpensive fencing makes more paddocks economically feasible. The table shows the biological relationships, not necessarily economic relationships.

When grazing periods are long enough that significant regrowth can be anticipated while animals are in the paddock, multiple defoliations in a grazing period can be expected on preferred plants. Once multiple defoliations during a grazing period are minimized, the number of days grazed per year and the number of cycles per year indicate the maximum number of times that a plant might be defoliated in a year. The additional benefit of shorter grazing periods begins to diminish significantly at about 8 to 16 paddocks per herd.

## How does the timing of grazing from year to year affect plant community responses?

4. ***Varying the timing of grazing period(s) from year to year will help maintain a diversity of species within paddocks.***

   Different plants will often be evident on different soils or topographic positions on a landscape. However, the time during the year when plants are grazed can favor some plants over others, even on the same soil type. If the time a paddock is used does not vary from year to year, plants that are not consumed because they are dormant, unpalatable, or for other reasons will be favored over those species that are most actively growing and palatable when paddocks are grazed. Consistently favoring one group of plants over another can, for example, turn a very good warm-season paddock into a paddock dominated by cool-season species or vice versa.

   Always remember that if your goal is to increase species diversity in a paddock so that high-quality forage is likely for a longer period of time during the year, avoid grazing it at the same time each year. By planning for cycle length(s) that do not divide evenly into a year and varying the recovery period in response to growing conditions, the timing of grazing periods will normally vary from year to year.

## How do increased paddock numbers affect the spatial distribution of animals and the time considerations for how long they should be there?

5. ***Smaller paddocks may help distribute animals more equitably in a paddock and across the landscape. However, lower area allowances make plant utilization and nutrient intake much more sensitive to the length of the grazing period.***

   Area allowance decreases at a constant rate as paddock size decreases, which can have both good and potentially bad effects. On the one hand, livestock distribution may be more uniform in the paddock. Better distribution with regard to time and space should improve the equitability of use across the paddock, resulting in fewer heavily grazed and lightly grazed areas in the same paddock, though some variation in utilization is still likely in diverse paddocks. Careful attention to paddock size as well as fence and water placement can also improve distribution across the landscape.

On the other hand, higher paddock numbers also make the proper selection of recovery and grazing periods much more critical. If grazing periods are too long during slow growth, animals will be forced to eat low-quality, unpalatable, or poisonous plants and decrease nutrient intake (low forage availability). Excessively long grazing periods during rapid growth will also be associated with recovery periods that allow plants to become too mature, thereby lowering forage quality (phase III growth described in the third publication of this series). It will also increase the probability that animals will defoliate preferred plants more than once while they occupy a paddock, which will weaken preferred plants and increase the incidence of spot grazing when animals return.

Very high paddock numbers with multiple moves per day using temporary fencing may be particularly sensitive to minor grazing period mistakes. These miscalculations can result in large decreases in nutrient intake when multiplied over many paddocks. Likewise, with this type of management, when recovery periods are too short because of minor shortfalls in the grazing period compared to the optimum, animals again enter a paddock and graze plants before they have fully recovered from the previous grazing period (phase I growth described in the third publication in this series). Inadequate recovery periods also decrease nutrient intake over the long term, because the productivity of high-quality plants is reduced.

The good news is that mistakes will normally become apparent more quickly with this type of management, facilitating timely adjustments to livestock moves. Higher paddock numbers also allow quicker assessment of how closely the stocking rate matches carrying capacity. That is, if feed in the paddock the animals are using runs short before the next paddock is ready to be grazed again, the difference between anticipated and actual recovery time indicates not only that you are overstocked, but also by how much. When done properly, more paddocks per herd can result in rapid increases in carrying capacity with adequate animal performance.

### Why does stocking intensity not change consistently with area allowance?

6. ***Area allowance decreases, and the rate of forage disappearance increases proportionally to the size of the paddock, but stocking intensity is also determined by the length of time that forage is disappearing (grazing period).***

A common misconception held by many people is that one purpose of rotational grazing management is to make livestock eat plants that they normally would not. Using this strategy would decrease livestock performance and nutrient intake. It would also cause extremely high utilization on desirable forage species in preferred areas of the paddock before the animals choose less-preferred plants. However, as can be seen from the table regarding forage demand per grazing period and stocking rate, it does not have to be that way.

Stocking intensity decreases at a decreasing rate as paddock numbers increase when recovery period and herd size are held constant, but the average stocking rate is the same for the entire grazing unit (AU-days per acre for the year) with any number of paddocks. Area allowance changes as a result of the decreased area that animals are allowed to use on a given day. Stocking intensity takes into account the decreased area allowance and the decreased grazing period. The decreasing demand per grazing period indicates that the daily forage available under comparable moisture and temperature conditions can potentially increase with more paddocks because of more frequent moves to fresh forage.

Animals will still selectively graze and should be allowed to select those plants that allow them to meet their nutrient requirements under normal circumstances. With a constant recovery period, the cycle length decreases, and the average degree of use should be less severe with more, smaller paddocks than with larger, fewer paddocks, provided that stocking rates are the same in each case. With similar stocking rates, animals remove less per acre during each grazing period in the rotationally grazed paddocks, and more opportunities for adequate regrowth should improve productivity over time compared to continuously stocked paddocks. Plants are often more uniformly used within a paddock, however, and in many cases, only the choicest parts and species are eaten. The quality of available preferred species should be more uniform, however, since there should be a higher percentage represented by less mature regrowth in successive grazing periods and less that is either excessively utilized or overly mature. If a higher degree of utilization is warranted, more animals can be stocked.

## CONCLUSION

When deciding which part of a management unit on which to begin an adaptively managed, multi-paddock grazing program, those most likely to respond rapidly should be the first selected. Be sure more water development and fencing will pay for themselves through improved livestock husbandry, increased carrying capacity, lower risk associated with weather, or improved livestock distribution before making large capital expenditures. Remember, however, that benefits of improved management do not diminish with time as some other range improvements do, but rather maintain or increase in value because of improved husbandry of animals and resources. In drier regions, controlling access to water points can be a cost-effective way to move animals from one grazing area to another to provide plants recovery from grazing, especially with short-term leases, where facility costs need to be minimized.

There is no "silver bullet" grazing system that, once implemented, solves all problems on all operations. Any successful planned grazing strategy must: 1) be properly stocked—this includes flexibility in stocking rate to adjust to changing growing conditions within and among years; 2) distribute livestock equitably; 3) regulate how long plants are exposed to grazing to decrease the chance of multiple defoliations during a grazing period; 4) provide sufficient opportunity for regrowth between grazing periods; and 5) allow the animals enough forage of adequate quality within and among the grazing periods to meet their dietary requirements. Managing these five factors adaptively, keeping in mind that when you change one thing, many more also change, and remembering the quantitative relationships outlined here can help to make better decisions, identify problems when they occur, and correct them in a timely manner.

The four most important things that determine the success of any grazing management program are the timing and frequency of defoliation, the intensity of defoliation, the opportunity to regrow following defoliation, and the distribution of livestock defoliation across the landscape. Grazing periods should be as short as possible to minimize the number of times a plant is grazed during a grazing period. The stocking rate should not be greater than the carrying capacity for the most profitable level of animal performance while maintaining enough plant cover for soil stability and optimum capture and storage of precipitation, no matter what grazing management strategy is used. That means the stocking rate must be flexible and be reduced during drought. The grazing management program selected should also allow adequate growing season recovery for desired plants and change the time when paddocks are grazed from year to year.

If livestock return to an area too soon, plant vigor may be damaged. Therefore, recovery periods should be shortened or lengthened to reflect growing conditions, which are determined by temperature and moisture. As conditions become drier, recovery periods should increase. If the number of herds and paddocks in a grazing unit is fixed, slow growth means that grazing periods must also be lengthened.

A good rule of thumb to determine if a plant has received enough recovery is that when it has received 30 to 45 days of rapid growth (that is, soils are at or near field capacity and temperatures are optimum for growth), the recovery period would generally be considered sufficient for most cool- or warm-season grasses. However, the actual length of grazing exclusion needed is longer than 30 to 45 days in most instances because of dry periods between rainfall events. Grazed plant tillers in paddocks to which animals will move should have produced at least four fully formed leaves per stem before livestock enter. If you are out of forage in the paddock the animals are currently grazing, and plants in the paddock to which you are about to move have not sufficiently recovered, you are probably overstocked.

Carrying capacity should *eventually* increase as livestock are more equitably distributed on the landscape, enhanced plant cover improves water and nutrient cycles, green leaves more effectively capture sunlight, and therefore, increase the proportion and vigor of palatable species. The stocking rate should *not* be increased until enough forage is available to support more animals. Therefore, grazing management should be viewed as a long-term range improvement that requires periodic management revision, rather than as a short-term fix to increase stocking rate, particularly in areas of low rainfall, since plant community responses will be slower than in moister climates. The major short-term benefit will be closer monitoring and supervision of both livestock and forage resources, more reliable forage availability, and more equitable distribution across the landscape, leading to better livestock husbandry.

## GLOSSARY

**Aggregate** A cluster of soil particles held together in a single group such as a clod or crumb. The more stable and rounder in appearance, the more desirable the aggregate **structure**.

**Animal Unit Day (AUD)** "The forage demand (amount of forage) on an oven-dry basis required by one animal unit for a period of one day."[1]

**Animal Unit Month (AUM)** "The amount of oven-dry forage (forage demand) required by one animal unit for a standardized period of 30 animal-unit-days."[1]

**Animal Unit Year-long (AUY)** "Equal to 12 AUMs."[1]

**Area Allowance** A measure of area/animal at a given point in time. It is measured in units of area/animal with no measure of time. It is the inverse of stocking density and changes linearly with increasing paddock numbers on the same land area with animal numbers remaining constant.

**Biomass** The amount of living material.

**Browse** The part of shrubs, woody vines, and trees available for animal consumption composed of leaves and small, soft twigs of palatable shrubs.[1]

**Bulk Density** The mass per unit of volume (e.g., pounds/cubic foot) of undisturbed soil, including air space. Within a particular soil type, lower bulk density will allow more rapid moisture infiltration and movement through the profile.

**Capital Assets** In the context of a business, capital assets are things with a useful life longer than a year that are used to make the products of the business. They are not intended for sale in the regular course of business operations such as machinery, buildings, or the real property where the business is located. In the case of the range resource, they would be things like seedbanks, soil organic matter, perennial plants, and water resources.

**Carnivore** An animal that eats other animals.

**Carrying Capacity** "The average number of livestock and/or wildlife that may be sustained on a management unit compatible with management objectives for the unit. In addition to site characteristics, it is a function of management goals and management intensity."[1]

**Climax** "The final or stable biotic community in a successional series; it is self-perpetuating and in equilibrium with the physical habitat."[1] Stress or disturbance as a result of excessive levels of grazing or other factors would cause the community to revert to a lower **successional state**. With removal of the stressor, the community would then progress through the same stages back to the stable climax community. This view of **successional** processes, however, has been unsuccessful in explaining **plant community** changes in some circumstances, particularly those where "naturalized" alien species have become an important part of the plant community, on areas where extreme degradation of the soil has occurred, or where other environmental influences like pollution or species extinction have changed the productive potential of the site.

**Cycle Length** The length of time required to graze all paddocks in a unit, i.e., the recovery period plus the grazing period.

**Deferment** "The delay of grazing to achieve a specific management objective. A strategy aimed at providing time for plant reproduction, establishment of new plants, restoration of plant vigor, a return to environmental conditions appropriate for grazing, or the accumulation of forage for later use."[1]

**Defoliation** "The removal of plant leaves, i.e., by grazing or browsing, cutting, chemical defoliant, or natural phenomena such as hail, fire, or frost."[1]

**Disturbance** A change in conditions, processes, or a stress that causes some plants to die in an area. Examples include fire, drought, excessive grazing, floods, etc.

**Dormancy** The period when the plant is no longer growing, usually after frost, but may also be due to drought.

**Ecological Site** "A kind of land with specific physical characteristics which differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its response to management."[1]

**Ecological Threshold** A threshold of soil or other degradation that, once crossed, changes the potential plant community for a site irreversibly on management-level time scales without high levels of management input or extended periods of time.

**Ecosystem** "Organisms together with their abiotic environment, forming an interacting system, inhabiting an identifiable space."[1] I.e., the plants, animals, soils, climate, and other living and non-living things that affect each other through a series of chemical and physical feedbacks.

**Forb** A broadleaf herbaceous plant (not a grass, sedge, or rush); often referred to as a weed.

**Herbaceous Plant** Plants that are not woody.

**Herbage Allowance** The amount of forage on offer compared to the amount that the animals can consume.

**Herbivore** "An animal that subsists principally or entirely on plants or plant materials."[1]

**Litter** "The uppermost layer of organic debris on the soil surface; essentially the freshly fallen or slightly decomposed vegetal material."[1]

**Meristem** A region of plant tissue—found chiefly at the growing tips of roots and shoots, at the nodes, and in grasses, at the collar of leaves and at the base of the plant—consisting of actively dividing cells forming new tissue. The growth points of the plant.

**Omnivore** An animal that eats both plants and animals.

**Organism** Any living thing.

**Overgrazing** "Continued heavy grazing which exceeds the recovery capacity of the plant and creates a deteriorated range."[1] It happens to individual plants and is caused by inadequate opportunity for regrowth following defoliation that weakens, and if continued, can kill that plant. Overgrazing can occur even with low stocking rates.

**Overhead cost** The costs, usually associated with land, facilities, or labor, that do not increase directly with the number of animals.

**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."[1] That is, forage demand in excess of that which will meet animal production and resource goals. Overstocking will always cause one or more of the following: 1) overgrazing; 2) increased variable costs; 3) decreased animal performance; 4) lower profitability.

**Paddock** "A grazing area that is a subdivision of a grazing management unit and is enclosed and separated from other areas by a fence or barrier."[1] The term "pasture" is also used in the United States. However, "paddock" is used in this case because it is most often used in conjunction with controlled grazing management, whereas pasture is a term more commonly used in areas where season-long or year-long grazing is common.

**Perennial** A plant that has a life span of 3 or more years that regrows each year from existing crowns, stems, or roots.[1]

**Photosynthesis** The chemical reaction carried on by green plants in which they change carbon dioxide from the air and water absorbed from its roots to form simple compounds used for energy using the light from the sun.

**Plant Community** "An assemblage of plants occurring together at any point in time, thus denoting no particular successional status."[1]

**Recovery** Regrowth following **defoliation** sufficient for a plant to fully regain its vigor so that it can retain its competitive ability in relation to neighboring plants. With regard to a plant community, recovery may also require additional time for plants to produce reproductive parts and then germinate and establish new plants, if more desirable plants are wanted. In order to ensure recovery, a period of grazing **deferment** is usually required.

**Revenue** The total amount of money received as a result of doing business.

**Rhizome** A horizontal underground stem, usually sending out roots and aboveground shoots from the nodes that is responsible for vegetative reproduction in some plants like Johnsongrass and Tobosa.[1]

**Ruminant** "Even-toed, hoofed mammals that chew the cud and have a 4-chamber stomach."[1] These animals also have a dental pad in the upper jaw instead of incisor teeth, such as a cow, sheep, goat, or deer, but not a horse.

**Seral** "Refers to species or communities that are eventually replaced by other species or communities within a sere."[1] It is sometimes used to refer to the **successional state** of a community growing on an **ecological site.** A high seral community would have a high proportion of species that are long-lived, use resources efficiently (e.g., conserve them with little waste), and are adapted to lower levels of disturbance. Low or mid-seral communities would have a higher proportion of plants that were shorter-lived, more opportunistic, and possibly less efficient in their resource use. High, mid-, and low seral may also refer to plants characteristically found in these respective communities.

**Seral Community** "The relatively transitory communities that develop under plant succession. Syn. seral stage"[1]

**Stocking Density** "The relationship between number of animals and the specific unit of land being grazed at any one point in time. May be expressed in animal units per unit of land area (animal units at a specific time/area of land)."[1] It is the inverse of area allowance and changes asymptotically with increasing paddock numbers on the same land area when animal numbers remain constant.

**Stocking Intensity** The total forage demand per unit area in a paddock for a grazing period.

**Stocking Rate** "The relationship between the number of animals and the grazing management unit utilized over a specified time period."[1] This will be expressed in terms of animal units of forage demand over a described time period per unit of land area such as acres/cow/year, acres/animal unit × month, animal unit × days/acre, etc.[1] Therefore, it is an indirect measure of forage demand on a management unit for a grazing season or year. With continuous grazing, stocking rate and stocking intensity will be the same.

**Stolon** "A horizontal stem which grows along the surface of the soil and roots at the nodes."[1] These are the "runners" commonly seen in species like Buffalograss, Curly mesquite, and Bermudagrass.

**Structure** The characteristic size and shape of the soil aggregates.

**Succession** "The progressive replacement of plant communities on a site which leads to the potential natural plant community."[1]

**Successional State** "The present state of vegetation and soil protection of an ecological site in relation to the potential natural community for the site. Successional status is the expression of the relative degree to which kinds, proportions, and amounts of plants in a community resemble that of the potential natural community."[1] Generally, in higher seral communities, species are usually longer-lived, reproduce less often, and are generally better adapted to conditions where competition is high for limited resources and the plants are generally assumed to be better adapted to moister conditions and are more productive, though there is often much of the energy lost to respiration, such that net productivity approaches respiration.

**Transpiration** The loss of moisture through the leaves of plants.

**Turnover** The number of units produced from a given area over a period of time.

**Variable costs** Those costs that increase with each additional unit of production. In livestock production, usually associated with feed, veterinary costs, shearing, interest, depreciation on the livestock, etc.

**Vegetative** "Non-reproductive plant parts (i.e., leaf and stem) in contrast to reproductive plant parts (i.e., flower and seed) in developmental stages of plant growth. Also, the non-reproductive stage in plant development."[1] This term also may be used for classes of plants that are not woody—that is, not shrubs or trees.

**Vegetative Reproduction** "Production of new plants by any asexual method,"[1] e.g., from **stolons** or **rhizomes**.

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