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Grazing Principles for Profitable and Regenerative Resource Management Series:

IV. STOCKING RATE: THE ESSENTIAL CONCEPT FOR PROFITABLE AND REGENERATIVE GRAZING MANAGEMENT

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This is the fourth 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

V. Essential Concepts Necessary for Adaptive Multi-paddock Grazing Management to Achieve Desired Livestock and Landscape Goals

VI. Using Essential Grazing Concepts to Properly Implement Successful Adaptive, Multi-paddock Grazing Strategies

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INTRODUCTION

This publication discusses **stocking rate**, how it affects animal productivity and profitability, and environmental and economic cues indicating that it should change and in what way. Stocking rate is one critical management decision to help ensure the goal of profitable grazing management to improve the forage resource. While it is not the only criterion needed to accomplish that goal, without it, nothing else that you do is likely to be successful in the end.

Stocking rate expresses the relationship between the number of animals and the grazing management unit utilized over a specified time period. Many people use the terms “stocking rate” and “carrying capacity” interchangeably. However, **carrying capacity** describes the average number of livestock and/or wildlife that may be sustained on a management unit compatible with management objectives. Common units of measurement for both stocking rate and carrying capacity include acres/**animal unit year-long** (ac/AUY), acres/**animal unit month** (ac/AUM), or **animal unit days**/acre (AUD/ac) so that they can be easily compared. In the case of stocking rate, the units are measuring the demand for forage, while the units for carrying capacity are expressing forage supply on the area for that period.

CONCEPTS ASSOCIATED WITH STOCKING RATE

Stocking rate is simple to understand—forage demand based on some standard animal unit for a period of time per unit area. If it is not set correctly, tinkering with other management actions will prove unsuccessful. Because growing conditions vary considerably across years, carrying capacity varies over time. The optimum stocking rate, therefore, varies with weather and economic circumstances based on management goals and the amount and quality of forage.

[1](Society for Range Management, 2005)

The many factors affecting optimum stocking rate make a thorough understanding both complex and critical for successful and profitable management of rangeland resources. The remainder of this section is based on Frasier and Steffens.[2] Some illustrations help to understand the relationship between livestock productivity and stocking rate, as well as how stocking rate affects the economics of a forage-based livestock enterprise.

Biological relationships associated with stocking rate: The production per animal curve (average gain/animal, Figure 1), based on Jones and Sandland, shows how at very low stocking rates, individual animal performance is maximized.[3] Stocking fewer animals than the number at which competition begins makes no economic sense, since additional animals added below that threshold stocking rate yield the same incremental increase in production.

However, after that stocking rate threshold is reached, individual performance decreases for all the animals proportionally to the reduction in the animals' opportunity for diet selection until productivity drops to 0 (no net gain, no net reproduction), and eventually becomes negative. However, because the incremental decreases in individual performance are small, the additional production from one more animal more than makes up for the decreased performance of all the animals for a while (red total gain curve, Figure 1) until the number of animals is half of what would cause production to be equal to 0 (maximum total production per acre).

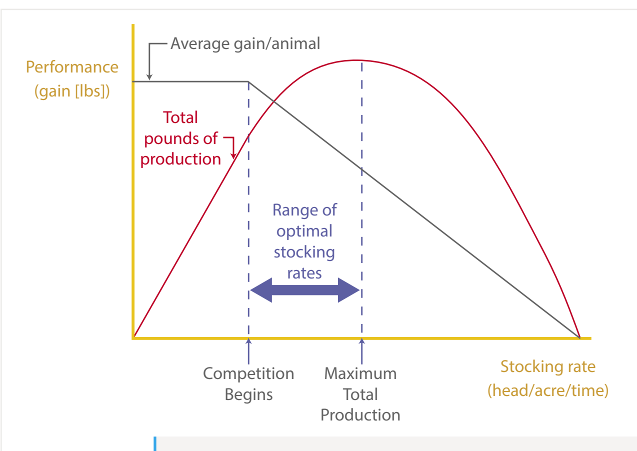

Figure 1. The effect of increasing animal numbers on a fixed forage base on individual animal productivity and productivity per acre.
Derived from Jones and Sandland; Hart.[3, 4]

[2](Frasier and Steffens, 2013)
[3](Jones and Sandland, 1974)
[4](Hart, 1986)

Just because animals are still producing does not mean that the number of animals at which total production of the area is maximized has not been exceeded. Notice that even on the "downhill side" of the red total pounds of production curve, individual performance is still positive. After total production is maximized (dotted vertical line in the center of Figure 1), further increases in stocking rate diminish both performance per animal and total pounds of production for the area, even though animals may still be growing or reproducing. So, the optimum economic stocking rate will *always* be somewhere between that which maximizes individual performance and that which maximizes total production for the management unit.

Anything that would increase forage quantity or quality available for the animals (e.g., improved distribution on the landscape, favorable rainfall, increased proportions of palatable, nutritious plants from which to choose, etc.) would increase production potential, raising and flattening the individual performance curve. It would also increase the number of animals at which maximum production per acre is achieved and the maximum total production.

Decreasing forage quality or quantity available (by the opposite actions as those given as examples in parentheses in the previous paragraph) would tend to decrease maximum productivity per animal and cause individual performance to decline more rapidly as animal numbers increase. Diminished forage quality or availability would also decrease the number of animals at which maximum production per acre is achieved. The range of optimum stocking rates would also be narrower. Therefore, optimum stocking rate will vary with growing conditions and plant composition, making flexible stocking rates crucial to maintain a profitable, forage-based livestock enterprise.

The optimum stocking rate also varies with risk aversion. In the diagram, marginal production decreases as soon as competition for available forage quality begins (diminishing returns, as shown by the flatter slope of the red curve) and decreases rapidly as maximum production per acre is approached, while risks associated with weather and prices increase as maximum production/acre is approached. Therefore, small increases in production/acre with increasing animal numbers need to be weighed against the likelihood of drought or market downturns that could quickly put you on the wrong side of the curve.

Marginal increases in total production have to cover increased costs associated with carrying another animal. As maximum production per acre is approached, revenue from the marginal increase in production will not cover the increased costs, even in "normal" conditions, so you will never likely want to maximize production per acre. As seen in the next section, the optimum stocking rate also varies with the relationship between **variable costs** and the value of the production.

Relating biological relationships to profitability: Only four things can be done to increase profitability:

1. Decrease **overhead costs**;
2. Increase the value per unit of production;
3. Decrease variable costs per unit of production; or
4. Increase **turnover** (number of units produced per unit of time).

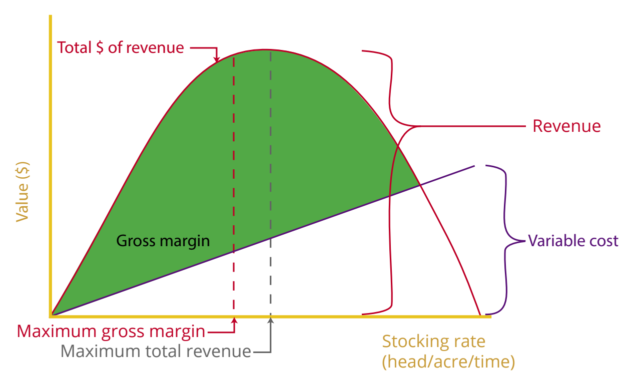

Figure 2. A simplified diagram illustrating the economic concept of gross margin derived from variable costs and revenues and accounting for the biological relationships illustrated in Figure 1.
Derived from Frasier and Steffens; Beierlein et al.[2, 5]

Of these, only the last two can be improved directly by manipulating stocking rate. Figure 2 is a simplified illustration to help understand how variable costs, **revenue**, and **gross margin** vary with stocking rate.

Revenue, in this case, is simply income derived from the land's production through the livestock enterprise. Variable costs increase with the number of units produced. Variable costs include such items as feed, medicine, vaccines, death loss, depreciation on breeding stock, interest on livestock loans, etc. Gross margin is the difference between variable costs and revenues. Beierlein et al. illustrate these concepts showing revenues as a straight line with a positive slope.[5] However, such a representation of revenue would not account for the biological relationships between stocking rate and performance previously shown in Figure 1. Figure 2 more accurately reflects those relationships and shows why maximizing production, or even revenues, is not necessarily wise.

[5](Beierlein et al., 2014)

The number of animals at which gross margin is maximized is less than the number at which revenue is maximized. The reason for the difference is that the value of the additional production does not cover the additional variable costs associated with the extra animals once the gross margin is maximized, even if revenue continues to increase.

The maximum gross margin occurs where the vertical distance between the variable cost curve and the revenue curve is greatest. If the variable cost curve was moved upward, the last point at which it was touching the revenue curve would be directly above the number of animals on the horizontal axis at which gross margin is maximized. If the variable costs per animal were higher, the cost curve would be steeper, and the gross margin would be maximized at a lower stocking rate. If the peak value of production was higher (e.g., because each pound of production was worth more or each animal produced more income at any particular stocking rate), the gross margin would be maximized at a higher stocking rate, but still at a lower stocking rate than that at which production was maximized.

In order to make a profit, overhead costs must be paid out of the gross margin. Therefore, the gross margin must be greater than overhead costs for that level of production. Overhead costs are associated with land or labor and remain relatively constant over wide ranges of stocking rate or productivity. The term "overhead costs" is used rather than the popular term, "fixed costs," since we can choose to some extent whether we spend money for an overhead cost or not, and they are, therefore, not truly "fixed." Overhead costs include things like full-time employees, equipment depreciation, real estate taxes, leases, infrastructure maintenance and depreciation, insurance, etc. Land or equipment purchases are not overhead costs, since they only trade one asset for another, and net worth does not change as a result of the expenditure of the cash. It is the interest on the money, depreciation on the asset, repairs, insurance, taxes, etc., associated with this capital asset that are overhead costs. In Figure 3, the overhead cost line is the same distance above the variable cost line at all stocking rates, because the same amount of overhead is added to variable costs at all stocking rates.

Note that much of the original gross margin has been consumed by the overhead costs. Maximum profit occurs where the greatest vertical distance between the total cost curve and the revenue curve occurs. The number of animals corresponding to that point would be the stocking rate at which profit is maximized. Since the lines are parallel, maximum profit occurs at the same stocking rate as that at which gross margin is maximized. You would, therefore, have to decrease overheads to increase profitability if gross margin has already been maximized.

Figure 3 shows that overhead costs affect the maximum potential profit, but do not affect the stocking rate at which profit is maximized. Therefore, the optimum stocking rate is an economic decision based on biological relationships between stocking rate and animal performance, as well as value of production and variable costs associated with carrying another animal unit, but NOT on overhead costs. As the value of production increases, the logical motivation would be to increase stocking rate, whereas when variable costs increase, the logical motivation would be to decrease stocking rate, assuming there has been no change in the productivity of the animals or the resource due to things like drought.

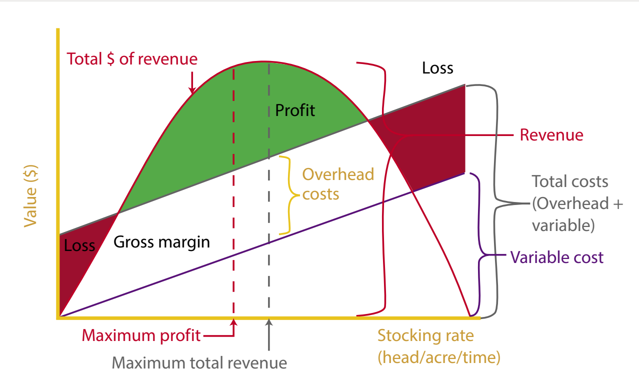

Figure 3. An illustration of profit relationships across a range of stocking rates. Overhead costs must be subtracted from the gross margin to determine profit. *Derived from Frasier and Steffens; Beierlein et al.*[2, 5]

MANAGEMENT SIGNIFICANCE

As stated previously, you cannot address excessive capitalization (high overhead costs) by putting more animals on a fixed land base if you have already maximized gross margin. Therefore, if overhead costs are too high to be paid for with production levels within these biological limits, overhead costs must usually be decreased, rather than increasing stocking rate. The reason overhead costs are too high is likely underutilized equipment or high labor costs.

If the business has maximized its gross margin, but there is too much equipment for the scale of the operation, finding more property to make better use of underutilized assets may work (though there will be some additional overheads, such as a lease of the new property, that must be taken into account). The other alternative is to get rid of underused equipment and rent it as needed or hire the work done.

Improved grazing management sometimes requires more infrastructure in the form of fencing and water development. If overhead costs are already too high, increased infrastructure expenditure may make the problem worse, at least in the short term. However, grazing management may address overhead issues if improved livestock distribution can increase the amount of forage effectively available to the animals, thereby increasing carrying capacity of the operation. Another exception may be if fewer people are needed (lower labor costs) to care for the same number of animals, as has often been seen when multiple **paddocks** per herd make animals easier to gather and move from one paddock to another. However, if paddocks are large and hard to gather, the additional labor needed for more frequent livestock movements would again increase costs.

Markets are generally assumed to be beyond the manager's control, but there are things that can offset adverse market conditions, at least to some extent. Producers can improve the value of their livestock by improving health programs, livestock disposition, breeding programs, genetics, improved handling and husbandry, all of which can improve performance for the next owner. By choosing when and where you sell, and then letting potential buyers know about these attributes, the value of animals may improve and be more stable because of a good reputation. The improved handling and husbandry made possible with frequent, low-stress moves to fresh pasture may help with these efforts.

Conservative stocking may decrease variable costs (feed, vaccines, medicines, wormer, etc.) because animals can select a higher-quality diet and may be under less environmental stress, which would improve performance and decrease the likelihood of disease. However, enough animals need to be carried to maximize gross margin.

If you have done all of the things previously discussed but profitability is still low, the problem is likely turnover. Turnover can only improve profit if gross margin is positive. Viable strategies to increase turnover include maintaining more but smaller animals, changing over animal inventory more often, or improving reproductive performance on breeding stock. Another possible way to increase turnover would be to increase carrying capacity by using multiple, smaller paddocks per herd to get animals to places they underutilize, off of places that they over utilize, provide for adequate recovery for grazed plants, and get them away from their own pathogens and parasites. By doing so, the stocking rate at which gross margin is maximized would increase.

The next publication in this series discusses other important concepts that must be understood for successful grazing management to achieve lifestyle, livelihood, and landscape goals.

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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