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Grazing Principles for Profitable and Regenerative Resource Management Series:

I. ECOLOGICAL CONCEPTS IN AN ECONOMIC CONTEXT

Tim Steffens* and Morgan Treadwell**

This is the first in a series of Texas A&M AgriLife Extension Service 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

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

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

*Assistant Professor and Extension Rangeland

**Associate Professor and Extension Range Specialist

INTRODUCTION

In the United States, as in several other countries, many people are becoming increasingly concerned with the effects that livestock have on the environment. Sustainability is becoming an increasingly important concept, even in mainstream agriculture. However, Colin Seis, the originator of pasture cropping, has said, "Conservation is not enough. Regenerative management is needed to produce a sustainable future." In Western cultures, regenerative management must not only meet the needs of people (social sustainability), but also be profitable (economic sustainability) and improve natural resources (ecological sustainability). Grazing livestock production can meet all three of these criteria only if it provides the high-quality protein and fiber needed by society, at a fair profit for the producer, while maintaining or improving the natural resources.

Generally, grazing is economically viable when considered as a "value-adding" enterprise. Much of the land area of the world is not capable of sustainably producing cultivated crops, and many crop residues can be consumed by animals for their maintenance or growth while still providing adequate cover to protect soils from erosion. The manure deposited can also speed the process of decomposition to cycle nutrients back into the soil and make them available again for the next crop. Properly managed grazing can provide an *economically* sustainable way to utilize these plants to meet *social* needs by converting them into valuable products.

Since consumption of plant material by **herbivores** has been a natural process in many **ecosystems** since the last Ice Age, properly managed grazing is potentially one of the most *ecologically* sustainable forms of agricultural production available to mankind. Many, if not most, civilizations that have persisted for long periods, particularly in arid and semi-arid climates, have used grazing as their primary form of agricultural production.

[1](Society for Range Management, 2005)

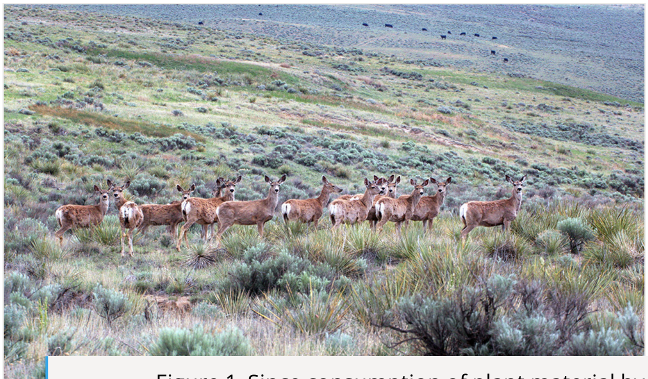

Figure 1. Since consumption of plant material by grazing and browsing wild animals has been a natural process in many ecosystems since the last Ice Age, properly managed grazing is potentially one of the most ecologically sustainable forms of agricultural production available to mankind. The mule deer and cattle in this picture are sharing a productive rangeland landscape in a semi-arid region. *Photo courtesy of Tim Steffens.*

Examples from history include the Mongols and the Cossacks of the Asian steppes and the Lapps and Asian Inuit peoples of the sub-polar arctic. However, when improperly managed, grazing results in the loss of the land's long-term productive potential because of soil erosion and declining plant vigor, which leads to economic deterioration for the society over time. Examples of the latter include the Greeks and many of the societies of the Middle and Near East. The following is a discussion of how grazing can affect plants and natural communities in different ways. The principles discussed allow these effects to be predicted so that livestock can be used as a tool to economically manipulate vegetation in a way that improves the productive capacity of the resource and meets the needs of plants, animals, and people.

ECOLOGICAL PRINCIPLES IN AN ECONOMIC CONTEXT

Natural communities are a result of environmental factors associated with an area (primarily soils and climate), adapted species available to colonize the area, competitive relationships among species, **disturbance** history, and the adaptation of those species to current and past disturbance and use. We can think of an ecological system in terms of an economic system. In both systems, different groups compete for limited resources in order to produce various products. The most limiting of these resources at a given site determines the community of **organisms** that can live there and their potential productivity.

Plant species use different strategies to compete for limited resources. A plant species may outcompete its neighbors by using relatively constant, though possibly scarce, supplies of a resource more efficiently or aggressively than its neighbors. Such a strategy is often seen in relatively moist environments where deeper- and denser-rooted species with longer lives use water and soil nutrients more effectively than their shallow-rooted competitors. An analogy from the business world is the large corporation that can produce a product cheaper than its smaller competitors because of vertical integration and economies of scale. It can, therefore, control the supply of raw materials and obtain them at less expense.

Plants may also compete by being able to use resources at lower levels of availability than their neighbors. One example of this "strategy" is cactus, which requires very little water to survive. Another example is a plant species adapted to the dense shade of heavy forest canopies that can carry on **photosynthesis** at high rates in limited light. An analogy in the business world is the enterprise that specializes in low-input, low-cost production. Though total productivity may be relatively low, they can produce their product cheaper with a higher margin per unit or survive longer during unfavorable conditions until markets improve.

Another adaptive strategy is to use a resource at a different place, the way some shrub species use water from deeper in the soil profile than shallow-rooted **herbaceous** plants. They may be the only species with a significant quantity of roots in that part of the profile, and so can exploit that source without competition. In an economic system, these types of businesses are those that utilize small, localized sources of material to produce a product.

Another way that plants sometimes compete is to opportunistically utilize resources by "hogging" them during times of abundance, then die or go dormant when resources become scarce until they are again available. This strategy is used by annual species and some **perennials** that go dormant during periods of scarcity. In the business world, these people are called speculators—those who only invest their money when they see what appears to be a short-term opportunity to make a big profit and then leave the market.

Diverse competitive strategies are important to provide resilience to the system when disturbances like fire, drought, or other climatic extremes occur. A wide variety of long-lived, productive plant species that grow under different conditions to be used by a diverse range of animal species for food and cover can lead to a profitable, resilient business that also provides other benefits, such as clean water and abundant wildlife.

Just as the performance of an economic system is scale dependent, so is the performance of an ecological system. The national economy may be growing, but if

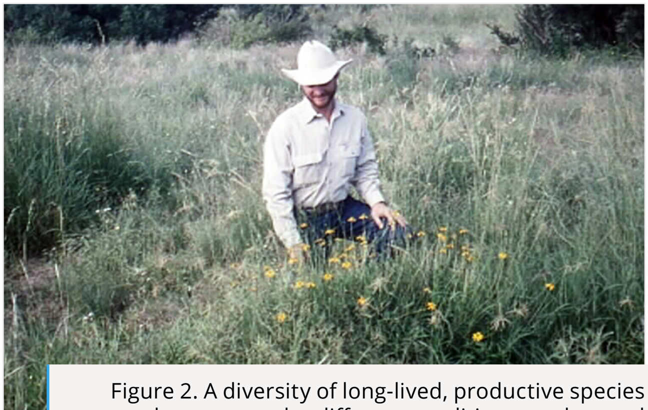

Figure 2. A diversity of long-lived, productive species that grow under different conditions can be used by a wide array of animal species for food and cover while supporting a profitable, productive and resilient business and other benefits, such as clean water, stable soils, and productive wildlife habitats. This grazed South Texas rangeland has a great mix of forbs, grasses, and shrubs that can be used by both wildlife and livestock. *Photo courtesy of Tim Steffens.*

an individual is unemployed, their personal economic status is experiencing a depression. In the same way, some communities on a landscape may be stable or improving, while others may be deteriorating. We can measure how our management actions affect natural communities at different scales, just as we can use various economic indicators to measure the condition and trend of economic activity for a household, community, state, or nation.

The condition of four natural processes can be used as indicators to evaluate the current state of the ecosystem with regard to our goals as managers. They are the:

- Water cycle,
- Nutrient cycle,
- Energy flow, and
- Succession.

The trend in condition of these indicators over time allows us to determine whether the condition of the **plant community** is improving or deteriorating as a result of management, even before changes occur in the species composition, productivity, or carrying capacity of the plant community.

Water and Nutrient Cycles

Water and nutrients are raw materials allocated to different users in ecological as well as economic systems. Just as cash flow is an indicator of the rate of business activity, the rate at which water and nutrients become available and then used indicates the level of biological activity that is occurring in the respective system. If a relatively large proportion of these raw materials are transformed efficiently into complex organisms, the system is operating efficiently, and if we are adding more value than any additional cost we incur, profitably. If a high proportion of these materials are lost from the biological system, it will likely be both unsustainable and unprofitable in the long term. Just as we refer in economic terms to an increase in net worth as an improvement in our economic condition (profit), we also can refer to a long-term increase in the natural capital of a biological system (e.g., soil moisture holding capacity, organic matter, proportion and productivity of palatable plants, etc.) as improving its ecological condition.

Water that falls as precipitation can run off and be channeled through watercourses that reach the ocean, evaporate from the soil, plant surfaces, or bodies of water, or be absorbed into the soil, where it flows beneath the surface or is absorbed by plants and transpired. Therefore, *anything* that softens the impact of precipitation on the soil surface and slows down the rate of overland flow increases infiltration and promotes rapid absorption by plants when they are available to use this moisture. They can then efficiently grow more leaves that will increase the cycling of water through the biological system. Just as you can have the same net income, but with either a high return on investment or a low return on investment, the amount of rain you get may not be as important as how effectively the water cycle is working.

Nutrients cycle through the ecological system by being absorbed and manufactured into plant tissues, followed by consumption, digestion, growth, and decomposition by animals and microbes. If nutrients are immobilized in dead plant material that fails to decompose quickly, or are transported off the site through accelerated erosion, the nutrient cycle is functioning ineffectively. Likewise, money that is immobilized in non-performing assets loses value quickly, and the business is less profitable than it could be. Anything that encourages uptake by plants as soil nutrients become available will increase the amount of available forage to grazing animals. Vigorous, highly digestible plants can rapidly return nutrients to the soil through the compounds they release from their roots as they grow. Additionally, highly digestible plant material, leaves in particular, that drop to the soil surface (**litter**) will also decompose faster, making more nutrients available for plant use. When this production, consumption, decomposition, and reabsorption is interrupted at any point, the mineral cycle becomes less effective, causing "leakage" of nutrients (leaching or transport off-site through erosion, runoff, etc.) from the system. Therefore, it is important to not only have plant material get back to the soil and decomposed quickly, but to also have living plants available for as much of the year as possible to reuse these nutrients as they are released.

Figure 3. Dense, tall **vegetative** cover increases infiltration of rainfall and may catch drifting snow in colder areas, as in the top photo. The middle photo shows the results of an efficiently functioning water cycle achieved by providing adequate residue following grazing, and then, providing adequate regrowth for plants to properly recover from grazing. Poor vegetative cover at the soil surface causes soil to crust when rain falls, sealing the soil surface, decreasing infiltration, and increasing runoff. Such conditions also increase soil temperatures and evaporation rates, which decrease plant available moisture and productivity. Over time, soil will be eroded where the soil surface is left unprotected between grass clumps, which is referred to as "pedestaling." This case of severe pedestaling, as seen in the bottom photo, is about 4 inches high. *Photos courtesy of Tim Steffens.*

Figure 4. Maintaining higher-quality forage is important to keep nutrients cycling through the system. The top picture shows dung from an animal that was eating high-quality forage that is easily digested by animals and facilitates the breakdown of fecal material by insects like the dung beetles in this picture, earthworms, and soil microbes, as can be seen in the middle picture, where the cow pies have been broken up by these organisms. Forages like those in the bottom photo, with high proportions of green leaves, are broken down easily by grazing animals or directly by the soil microbes. Notice that the soil surface is almost 100 percent covered with living or dead plant material. However, because of rapid microbial decomposition, the litter mat is not so deep or dense that it would intercept too much rainfall before it can get to the soil surface. There is also no significant amount of standing dead material from the previous year. Together, these indicate both highly effective nutrient and water cycles. *Photos courtesy of Tim Steffens.*

Indicators of water and nutrient cycles that are functioning at a high level include abundant green plant material and a variety of species with different rooting depths that improve moisture infiltration and promote growth under a wide range of climatic conditions. Plant litter can protect the soil surface from the impact of falling raindrops and create better habitat for beneficial soil microbes. A high proportion of readily digestible plants in the community allow microbes and enzymes in the digestive tracts of animals to rapidly begin the breakdown of plant material, which in turn, facilitates further decomposition of animal dung by insects, earthworms, and soil microbes to quickly cycle nutrients through the system. However, the continuous disturbance associated with long grazing periods without adequate grazing deferment may compact soils, destroy surface **structure**, and thereby, decrease water infiltration. Therefore, plants need to regrow a full complement of leaves and enough root material between defoliations to protect the soil from erosion, repair soil structure, and decrease raindrop impact so they can maintain their vigor and competitive capability with neighbors.

Figure 5. This pair of photos demonstrate indicators of an inefficient nutrient cycle. Note the high proportion of old, weathering forage that makes for poor digestibility by grazing animals and slow degradation and incorporation into the soil by insects and microbes. The old, weathered cow dung will also require a long time to break down. In both cases, many of these nutrients may be lost from the system to weathering. *Photos courtesy of Tim Steffens.*

Energy Flow

Energy only flows through the ecological system (one way) and is not recycled. It is captured first in green plants (primary producers), since they are the only organisms that capture energy from the sun and convert it directly into a useful form through photosynthesis. Consumers and decomposers, which include animals, bacteria, and fungi, use the stored energy from the plants either directly or indirectly. Each consumer or decomposer in the food web uses products produced by one group and converts some of that energy into other useful forms, with some loss as heat. They can, therefore, be referred to as secondary producers. For example, herbivores are plant consumers, but convert some of the plant energy into products useful to humans and other **carnivores or omnivores**. In that way, energy flow through a biological system is like money in an economic system. It is not used up, but only changes hands (system-wide), and it only comes in or goes out (individual business or organism).

Like money, energy can also be stored. However, bear in mind that both money and energy are only useful when used. The only reason for storing energy or money is to use it at a different time or place. Also, like money in an inflationary period, each time energy is stored, some is lost. Generally, the faster and steadier that energy flows through the biological system (cash flows through a business), the higher the rate of biological (economic) activity.

High rates of energy or cash flow may or may not indicate a high degree of system efficiency. A business can have a rapid cash flow without being profitable if it does not add enough value to the raw materials used to cover production costs, or if cash inflows are a result of liquidation of **capital assets**. Capital assets in a business can be defined as those things such as machinery, real estate, etc., that are used to produce wealth, but are not themselves consumed as a normal business activity. Capital assets of the ecological system consist of breeding animals, soil organic matter and associated decomposers, seed banks in the soil, **perennial** plant crowns, stems, and roots. Just as we lose the potential to produce wealth from the business when we maintain cash flow at the expense of capital assets, long-term potential ecological productivity is lost when ecological capital assets deteriorate.

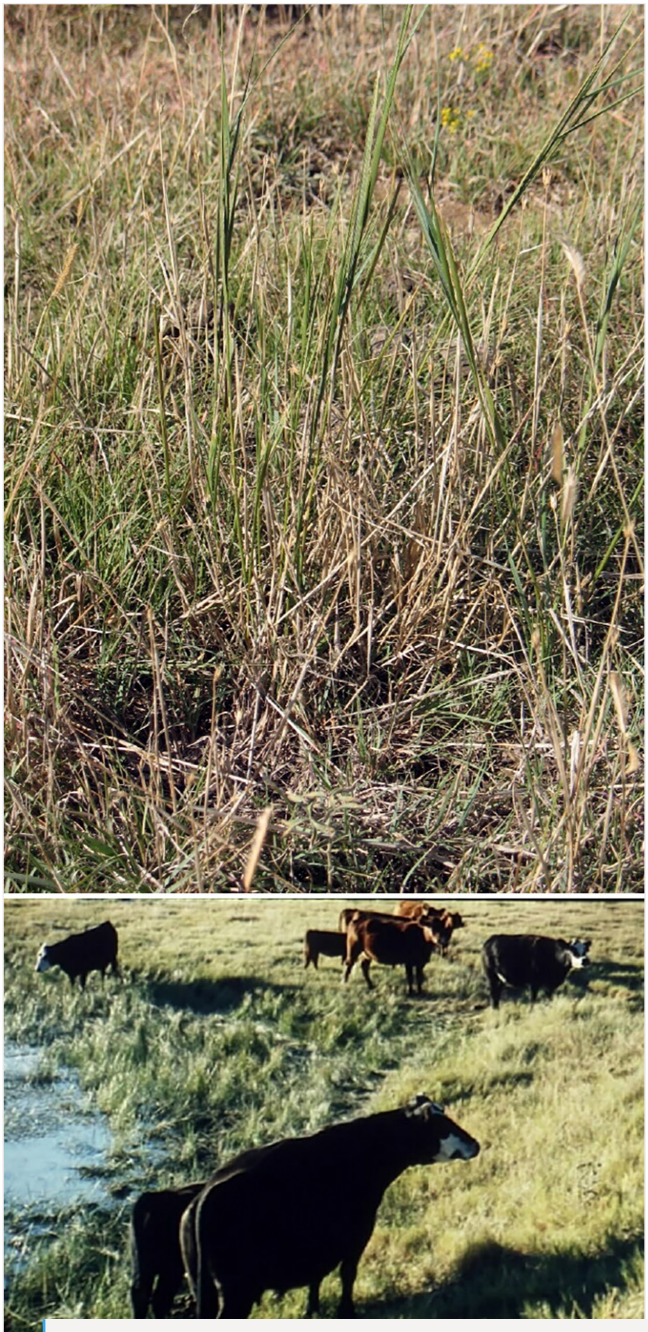

Figure 6. An abundance of palatable plants with high leaf densities, different growing seasons, rooting depths, and growth habits, like the green, cool-season western wheatgrass in the center of the top photo amid an abundance of warm-season blue grama, sand dropseed, and sideoats grama, with scattered forbs like the mustard in the background, can capture sunlight effectively under a wide variety of growing conditions. Harvesting it at its optimum quality and quantity, leaving enough leaf material for fast recovery, and providing enough time for another full complement of leaves to regrow after grazing helps to convert that captured energy into livestock profitably. As can be seen from the dense grass growing right to the water's edge in the pond, it will also improve water and nutrient cycles to increase the plant and animal productivity (that is, **carrying capacity**) over time. *Photos courtesy of Tim Steffens.*

The biological system may also have a high rate of energy flow, but with much of the energy lost for use by humans and other higher organisms. Examples include when the energy is respired through organisms that are no longer growing or reproducing, or when plant material decomposes, washes, or blows away without enough replacement. This non-productive use of energy may happen when "artificial" or stored sources of energy are used to enhance the production of certain parts of the biological community. These subsidies of energy may take the form of fossil fuels, fertilizer, pesticides, etc., and may also harm water and nutrient cycles.

A relatively continuous cover of vigorous plants that capture and store energy from the sun during the majority of the year, without the need for energy inputs in the form of fossil fuels or fertilizer is one of the best indicators of efficient energy flow. Significant deterioration of capital assets like soil organic matter, topsoil, reproductively active parts of vegetation, etc., would indicate poor energy flows.

Successional Status

Just as economic indexes measure the level of development, complexity and diversity of economic systems, successional status measures the development of ecological complexity and diversity of a system. When evaluating **successional status**, species composition of the community is compared to a potential desired community. Those producing relatively close to potential are referred to as late **seral** communities. Those producing at a lower level are mid- or early seral communities.

In advanced economic systems, a more diverse group of producers provide more goods and services to a more diverse group of consumers with a given amount of raw materials and capital assets than a similarly sized group of producers in a less developed economic system. Because of this increased diversity of enterprises and the relationships among them, "One man's trash is another man's treasure," and resources are, therefore, used more efficiently.

Likewise, in later successional communities, raw materials like soil moisture and nutrients are converted to biologically useful forms more efficiently because products produced by one group of **organisms** become the raw materials that others use to live. Increasing diversity enhances nutrient cycling in the system and plant community productivity, thus resulting in more **vegetative** cover on the soil surface. This vegetative cover protects the soil from erosion, increases infiltration, and therefore, enhances water cycles. Energy conversion and productivity are also likely to occur over a wider range of conditions, providing more system resilience in unstable conditions. Greater resilience is a result of many different species performing similar functions, but with each having different optimum biological requirements, so that some plants are available at all times to respond to moisture and temperatures.

The need for diversity is, however, scale-dependent. That is, species diversity may be required on a landscape scale, but may or may not be required, or even desired, on a given **ecological site**, much as a variety of businesses are good for a region, but zoning confines certain types of businesses to areas where conditions for that type of enterprise are most desirable. The types of plants that dominate a community are determined by ecological site potential, frequency and severity of disturbance, annual precipitation, and depth to which moisture infiltrates the soil. Depth of infiltration may be affected by the effectiveness of the water cycle, soil depth, seasonality, and size of rainfall events, etc. Table 1 shows the relationship among these factors and the dominant type of plants expected in many cases in North America.

Formerly, **succession** was considered to be a linear process in which species replaced each other predictably in a plant community over time until a stable **climax** community was achieved in the absence of disturbance. Disturbance, as a result of excessive grazing, drought, fire, or other factors, would cause the community to revert to an earlier successional state. When the disturbance was removed, it was thought that the community would progress through the same predictable stages back to the stable climax community. That view of successional processes, however, did not successfully explain plant community changes in some circumstances. It was particularly a problem where "naturalized" exotic species have become an important part of the plant community, on areas where extreme soil degradation has occurred, or where other environmental influences like pollution or species extinction have changed the productive potential.

Current thinking is that a site has one to several possible alternate stable states. Each stable state can regress from its potential and still recover its original productivity and species composition as long as the frequency, intensity, size, etc., of disturbance stays within a range of variability to which the community has adapted. However, when disturbance exceeds this **ecological threshold** of intensity, frequency, or size, feedbacks that govern interactions among plants tend to change. The community then becomes dominated by different species, and the former stable state can no longer be attained in management-level timeframes without major alterations to the system, if at all. These ecological thresholds usually are associated with soil degradation, the introduction or extinction of species, or a change in the reproductive success among plants that changes the competitive relationships among important species. Therefore, management should first strive to preserve the productive potential of an ecological site.

The seral state tells us something about the species composition of a community in relation to our management goals and the productive capacity of the site. The trend in species composition tells us whether or not we are progressing toward management goals. So, no particular plant community is good or bad, except in the context of what we want, what we have, and what a site is capable of producing. Although later seral communities are often considered desirable, an early seral community may be desirable because it provides a preferred condition or product, such as habitat for a particular wildlife species. A high seral site may be undesirable because of a declining trend, or because it is inappropriate for a desired use. Furthermore, if the site has crossed an ecological threshold to an alternate stable state, efforts to change the plant community to some desired former state will likely be unsuccessful in the short term. Given environmental constraints and the seral state, plant communities should be evaluated in terms of what can realistically be expected from the area with regard to forage productivity, protection or enhancement, site stability, and habitat use for animals.

Table 1. Common relationship of different environmental factors to dominant species in different environments

Frequency/Severity of Disturbance	High	Med-low	Med-low	Med-low	High*	Low
Annual precipitation	Low	Low	Low to medium	Moderate but erratic	Moderate to high	Moderate to high
Moisture infiltration (depth)	Shallow	Deep	Shallow to moderate	Moderate to deep	Moderate to deep	Deep
Dominant plant type	Annuals	Shrubs	Perennial short to mid-grasses	Perennial mid- to tall grasses, with some woody plants	Tall grasses and woody plants adapted to the disturbance	Trees

*These are disturbances to which the grasses and shrubs are adapted, like grazing or fire.

Indicators that a plant community may have crossed an ecological threshold into an alternate stable state could be a change in basic soil function (water holding capacity, texture, depth of topsoil, etc.), a loss of reproductive capacity for key species in the community, introduction of exotic species that are extremely competitive with native species, or a change in age or spatial distribution of species in the community. Table 2 summarizes and compares characteristics of advanced economies or high seral plant communities with those of developing economies or low seral plant communities.

Table 2. A comparison of developing economies/ low seral plant communities with advanced economies/ high seral plant communities

Developing/low seral state	Highly developed/ high seral state
Relatively high year-to-year variation in composition and, often, productivity	Relatively low year-to-year variation in composition. Productivity varies with precipitation and bounces back quickly.
Average life of organism/ business relatively short	Average life of organism/ business relatively long
Small, volatile, short-term pools of resources that may be available in short-term "booms" followed by "busts"	Larger, stable, longer-term resource pools, though little may be available at any particular time
Wealth or raw materials often "leak" from the system	Most wealth or raw materials stay in system
Large scale fluxes in the "capital assets" of the system	"Capital assets" remain fairly stable
Wide environmental variability because of relatively few "buffers" to the system (regulation, infrastructure, social institutions or organic matter, seedbanks, mulches, etc.)	Environmental conditions relatively stable as a result of numerous "buffers" to the system

Our job as managers is to derive economic value from products that the system is capable of producing sustainably. In other words, we should make a profit by manipulating plants, animals, and natural processes in ways that maintain or enhance the long-term system integrity and productive capacity by using only the production that exceeds what is needed to maintain the integrity and resilience of the community. Desirable plants need to maintain or regain their vigor after grazing or other disturbance and maintain their competitiveness with neighbors. By providing this recovery from grazing, biological diversity and system resilience to natural disturbances are maintained, water and nutrient cycling as well as energy flow are improved, and energy subsidies are minimized.

The next publication in this series discusses grazing management actions and their effects on plants, animals, and profitability.

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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