RANGE AND PASTURE PRODUCTIVITY

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Summary

The fundamental challenge faced by range and pasture managers is how to balance forage removal and the plant communities' ability to maintain vigor, growth and production. Plant production is strongly influenced by genetics and the growing environment. The growing environment of the plant includes climate, topography, local soils, and disturbances such as defoliation and fire. These have the ability to alter the condition of vegetation and change total forage availability. Range and pasture managers must operate within these constraints and strive to balance periodic forage removal with the ability of vegetation to renew leaf area and achieve periodic

reproduction. Vegetation responses to grazing animals are closely linked to plant adaptations to herbivory, such as defoliation avoidance and tolerance, and specific characteristics of the defoliation regime such as the severity, timing and frequency of biomass removal. At the community level, plant species mixtures are more likely to utilize soil resources efficiently, thereby increasing production. Large herbivores influence plant communities through the preferential selection of some plants over others, with non-defoliated plants benefiting from a competitive advantage over those remaining non-defoliated. Over time, selection pressure through repeated grazing reduces desirable productive forage plants and replaces them with those that either have superior grazing tolerance or those that are avoided due to low forage value. The single most important tool that range and pasture managers have to modify the impact of defoliation on vegetation is stocking rate. Stocking rates should be consistent with local carrying capacities that take into account appropriate severities of defoliation as well as spatial unevenness in forage use among plants and communities. Finally, various grazing systems can be used to help balance the removal of forage with inherent tolerances to defoliation and ensure that range and pasture systems are able to recover and remain productive in the long-term.

1. Introduction

Range and pasture environments are those terrestrial land areas that provide fodder for animals, either domesticated or wild, where animals are allowed to forage directly within plant communities. Foraging may occur under a variety of conditions, ranging from unconfined (i.e. free range) situations where animals have maximum selectivity within vegetationally diverse environments, to tightly controlled situations where animals forage small areas that heavily restrict animal movement and associated selectivity.

Although range and pasture environments are often differentiated from one another, the basis on which this is done has seldom been standardized. While the traditional definition of rangelands has often referred to those plant communities consisting of endemic uncultivated vegetation, and pastures are referred to as lands containing domesticated agronomic (i.e. seeded) forages, this differentiation becomes problematic when categorizing land areas with characteristics of both. For example, heavy grazing often results in the localized loss of grazing-sensitive native plants, only to be replaced by grazing tolerant introduced plants, often of agronomic origin. Over time, this intermingling of species results in an infinite number of plant species mix possibilities, thereby making it difficult to describe such areas as rangeland or pasture.

A potentially more useful way to differentiate between range and pasture environments is through the intensity of management. While rangelands are often characterized by the use of conservative grazing and low input management strategies, pasture environments are more likely to depend on the use of high input strategies to maintain greater productivity. For example, pastures may require more frequent fertilization, regular weed control and periodic plant community renovation (i.e. re-seeding) to maintain forage growth at relatively high and stable levels, which in turn, supports intensive levels of grazing. In contrast, rangelands typically rely less on these inputs, largely due to conservative long-term grazing practices that minimize the risk of detrimental impacts to the plant community.

Productivity of vegetation and animal biomass have long been considered two of the key socio-economic outputs associated with range and pasture environments, both in developing and developed countries around the globe. Biomass produced by range and pasture environments have a variety of uses, depending on the regional economy. Moreover, priorities for those uses may vary considerably depending on whether the land is public (i.e. government owned and controlled) or under private ownership. Additionally, the use of biomass production varies widely from exclusively economic, i.e., harvesting and/or sale of range or pasture or their products (e.g. fuelwood, timber, water, wildlife, etc.), to environmental, which includes the provision of benefits not directly containing a market value but considered important to society. For example, the retention of plant biodiversity on public rangeland, and the provision of diverse habitats for a multitude of associated fauna are considered important environmental benefits. More recently, there has been considerable interest in retaining and even restoring range and pasture environments for their potential to maintain or sequester carbon, particularly in comparison to agronomic lands where carbon has often been released following cultivation. In these situations, the potential environmental benefits of carbon sequestration are clearly a public good, yet as with many other environmental services (i.e. maintenance of downstream water quality, phyto-remediation of pollutants), the economic value of this activity is poorly understood.

On public land, governments or their public land agencies/administrations typically determine the use of range and pasture vegetation. The most obvious benefit of public land stewardship is the ability of government-led administrations to manage for ‘optimal’ uses based on the collective good. This process is often facilitated through consultation with members of the public or public stakeholder agencies (i.e. non-governmental organizations - NGOs), a process often referred to as coordinated resource management planning (CRMP) in North America. CRMP is a mechanism to ensure that the interests of many user groups are taken into account during subsequent rangeland management planning. Although CRMP is highly effective in ensuring public consultation into land management, this process is burdened by the subsequent challenge and difficulty of trying to accommodate many varying opinions and attitudes on land use, most of which cannot be simultaneously maximized. In addition, changes in public land stewardship are often difficult to implement due to the need to placate many interest groups. However, this model is in sharp contrast to the ‘tragedy of the commons,’ where uncontrolled access to resources, including public rangeland, may result in rapid depletion, resource degradation, and long-term economic hardship as well as a permanent or semi-permanent loss of ecological sustainability.

Contrary, on private land, a single user or user group has the authority to establish management priorities. Although these priorities are often economic in nature due to the need to support a family unit (or similar ownership group), environmental considerations often remain significant in this process, particularly in developed countries where family economies enable considerations to extend beyond survival and sustenance. In this case, environmental interests flow largely from the desire to balance economically profitable land use and long-term ecological sustainability. This step is considered important for maintaining farmers’ quality of life and the potential for future generations to make a successful living in the long-term from these areas. The primary benefits of private range and pasture stewardship lies in the fact that these operators are able to be innovative in managing their land-base, with obvious rewards (both economic and environmental) for a job well done. However, private land ownership alone does not guarantee long-term conservation of rangeland resources, and may in fact, exacerbate range and pasture degradation due to the absence of a third party to monitor land use activities. On private range and pasture lands, the primary mechanism to ensure proper land use is through specific laws and associated regulations, which may be unsuccessful due to the inability of regulators to monitor and enforce landowner behavior.

This chapter focuses on the following themes: a review of the key factors regulating vegetation productivity in range and pasture environments, the ways in which animal production may be quantified from these lands, the role of feedbacks between herbivory and plant production, and finally, a review of the practical management strategies available to mitigate the impacts of herbivory on plant community productivity and sustainability.

2. Concepts, Terms and Measures

2.1. Vegetation Productivity

Many terms exist to describe plant biomass in rangeland environments. All these terms largely reflect the ability of a plant or associated community (i.e. mix of plants in a given area) to convert solar energy into plant biomass. The effectiveness of vegetation in converting sunlight into photosynthetic material is known as capture efficiency. Although total standing biomass is a parameter useful for quantifying total energy flow (i.e. carbon capture) in the community, seldom is total biomass an effective indicator of the potential to support large animals. For instance, while forests accumulate large amounts of standing biomass, much of this biomass is in the form of lignified wood, which is neither palatable nor digestible to herbivores.

A number of more useful terms exist to describe levels of plant production for use by foraging animals. Above-ground net primary production (ANPP) refers to the total biomass of new shoot growth produced in a given growing season. Because it excludes older material, ANPP better describes the amount of standing biomass that could be consumed by animals, particularly in woodlands. ANPP is often referred to as current annual growth (CAG) in the case of woody species, and in agronomic environments, is often described as plant yields. ANPP for grasses and forbs is difficult to assess because of the ongoing loss of plant material (i.e. leaves) with senescence and decay throughout the growing season. In temperate environments where growing seasons are relatively short, ANPP can be estimated reasonably well at peak standing biomass towards the end of the active growth period when most plants are nearing peak production but prior to advanced decay. However, in warmer areas, including tropical environments, where growth is continuous throughout the year, ANPP may be easily under-estimated with single samplings due to the non-synchronous growth of different plant species.

ANPP can be further proportioned into the growth produced by woody and non-woody plants. The latter is referred to as total herbage and consists of the aggregate growth of grasses, broadleaf dicots (i.e. forbs), and sedges (Figure 1). Because herbage excludes woody material, herbage production values are often of greatest use in the assessment of maximum grazing potential for bulk or roughage feeding animals such as cattle, bison and horses. ANPP values can be further proportioned based on their likelihood of consumption by herbivores.

As all herbivores exhibit preferential selection to some degree when feeding, plant biomass can be further defined based on whether it is likely to be selected or avoided by animals. Forage refers to that fraction of total ANPP that is both available and suitable for consumption by herbivores. The component of forage consisting only of woody material (i.e. CAG stems and leaves) is known as browse. Browse values are particularly important in identifying the feed available to concentrate selectors, herbivores known to exhibit highly selective feeding on woody species, such as goats, deer, and moose.

	Palatable Fraction				Non-Palatable Fraction			
	ANPP	Herbage	Forage	Browse	ANPP	Herbage	Forage	Browse
Grass and Grass-likes	√	√	√		√	√		
Forbs	√	√	√		√	√		
Woody (Shrubs and Trees)	√		√	√	√			

Figure 1. Constituent components of total ANPP, herbage, forage and browse, as divided into palatable and unpalatable defined fractions of various growth forms.

Finally, it should be noted that, other than biomass itself, all of the terms documenting plant material available to the herbivore generally refer to shoot biomass only, and therefore exclude root biomass. While necessary for practical reasons, the emphasis on shoot production fails to recognize the key role of root biomass in supporting plant growth, particularly in arid and semi-arid grasslands where root biomass is the majority of total phytomass, often as large as 80 or 90% of the total plant. Thus, while grazing managers may focus heavily on shoot biomass, they need to be aware that the majority of biomass they are effectively 'managing' is below ground, particularly when considering that a healthy root system is a precursor to supporting the shoot through the provision of adequate water and nutrients.

2.2. Animal Productivity

Socio-economic factors strongly influence the optimal use of range and pasture environments for animal production. In general, animal productivity typically refers to either levels of commodity (i.e. meat or fiber) production, or growth in animal numbers. Large and expanding herd sizes have relevance from the perspective of practical and cultural aspects to society, as these animals may be important as sources of draft power or transportation, and as a form of wealth or symbol of social standing. However, population growth may be equally important in the conservation of rare and threatened animal populations. In either case, animal productivity may be defined through measures of population fecundity and growth, which in turn, will reflect the integrated effects of maternal conception, birth, yearling survival, and ultimately, recruitment into the adult population where they can contribute to future population growth.

2.2.1. Quantifying Animal Impacts: The Stocking Rate Concept

Stocking rates are the single most important factor influencing animal productivity. Stocking rates are an integrated measure representing aggregate levels of forage demand associated with the type, size and number of animals within a given land area, as well as the length of time they are exposed to a given pasture environment. Changes in any of these parameters will alter stocking rates by changing the preferred type and amount of forage required to support a given group of herbivores. For example, while cattle are largely bulk feeders in their foraging strategy, relying heavily on herbage, particularly grasses, they may under-utilize the browse available within heterogeneous rangeland environments containing a mix of grassland, shrubland and forest communities. In contrast, goats may spend greater time in wooded plant communities of these same environments. Goats are concentrate selectors, preferring to feed on high quality current annual growth of browse, and in the process, may exhibit a strong preference for shrub and forest communities.

2.2.2. Measures of Individual Animal Productivity

Individual animal productivity can be assessed through animal-based measures, where productivity is in the form of milk yield per head, wool yield per head, or reproductive success indicators such as calving rates and yearling survival. The quantitative relationship between individual animal productivity and stocking rate consistently results in a pattern that reaches a maximum at low stocking rates, and progressively declines as stocking rate increases (Figure 2). Production declines are gradual at first, only to accelerate as stocking rates increase to high levels, eventually pushing production values per animal to levels below zero.

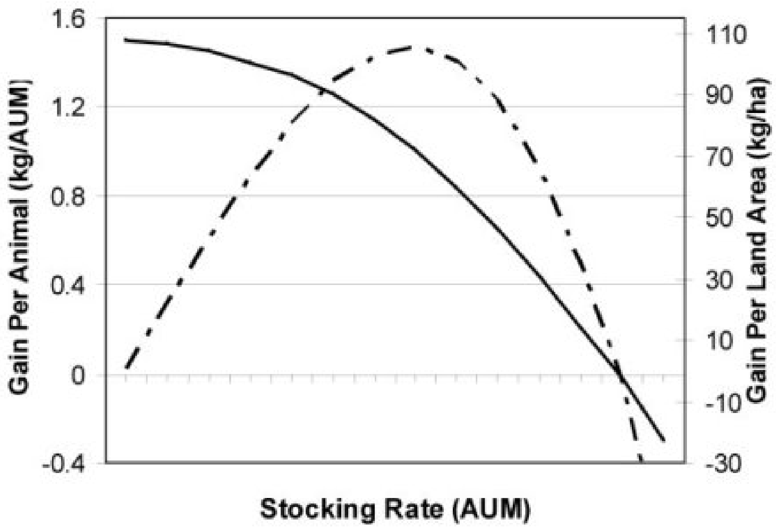

Figure 2. Relationship of individual animal weight gain and weight gain per unit land area with varying stocking rates.

Changes in individual animal productivity directly reflect the foraging opportunities available to animals within their environment. Maximum levels of animal production at very low stocking rates (i.e. those near zero) reflect the fact that under these conditions animals can exhibit maximum selectivity during foraging. High selectivity allows animals to choose plants with the greatest palatability, which in turn, are typically those offering the greatest nutritive value (i.e. forage quality), leading to maximum individual animal performance (e.g. weight gain). Subsequent declines in production per animal with progressive increases in stocking rate reflect greater competition among animals for a declining forage base, forcing animals to either consume less, or at a minimum, consume forage that is lower in quality (i.e. plants they would normally avoid consuming at low stocking rates), thereby limiting weight gain. Under very high stocking rates, individual animal performance declines sharply to the point that animals are unable to consume enough feed or feed is so inadequate in quality, that they are unable to maintain positive production. Negative animal production is representative of weight loss, and is not sustainable as prolonged weight loss ultimately leads to animal death. The stocking rate at which this occurs within a given year is typically linked to growing conditions, particularly moisture, which strongly influences the total amount of biomass produced and available for consumption.

2.2.3. Land-Based Measures of Animal Production

An alternative method to assess animal productivity is through production measures per unit land area. Using this strategy, production of the herd is essentially assessed relative to the size of the land base, which is particularly important when managing large herds over extensive land areas. Production per unit area is low at stocking rates near zero due to the near absence of animals. As animals are added to the 'area' under consideration and stocking rates initially increase, overall production per area increases, albeit at a diminishing rate. Eventually production per area peaks at moderate stocking rates (though variable depending on the plant community and growing conditions), and then decreases with the addition of more animals. The decline in overall herd productivity is an important threshold, and signifies the specific stocking rate at which point the additional gain achieved by adding another animal to the 'herd' fails to make up for the reduced individual animal performance of all members of the entire herd. As a result, successive increases in stocking rate above this point rapidly reduce overall herd productivity, which eventually falls below zero where the entire herd is unable to maintain its productivity (i.e. begins to exhibit weight loss). Similar to production measures per animal, the point at which production of the herd declines to zero depends directly on the total forage biomass available.

2.3. Carrying Capacity

Carrying capacity is the concept of assessing animal production potential (i.e. through population size for ungulates present year-long, or defined stocking rates over a set time period) in relation to forage availability. Estimates of carrying capacity are important for establishing guidelines for the economically and ecologically sustainable removal of biomass from plant communities, and thereby provide livestock producers and/or wildlife managers with information on appropriate population sizes. Moreover, in areas where a number of land uses are important, including the partitioning of forage resources between wildlife and livestock populations, carrying capacities can be used to allocate forage accordingly.

Carrying capacities can be further defined as absolute and sustainable (or safe) grazing capacities. Absolute carrying capacity is the maximum number of animals (or maximum stocking rate) that can be accommodated from a given area in the short-term. In essence, absolute carrying capacity assumes total consumption of all annual net primary production. However, absolute carrying capacity is not sustainable, as the use of all biomass virtually assures a reduction in vigor of resident plants, which in turn, results in a future decline in community productivity, often exacerbated by microclimatic induced changes (i.e. xerification) with the loss of litter. In addition, animal performance is generally poor, as total gains per animal and per unit area are near zero, with animals barely able to meet their maintenance requirements for survival. Animal populations at absolute carrying capacity are particularly subject to peril, as unexpected declines in forage production (i.e. such as those during drought) are certain to reduce future animal production potential of fixed populations, which would then be marked by greater weight loss and mortality. More importantly, an accelerating cycle of forage loss and population decline can result through grazing induced decreases in range and pasture condition, culminating in widespread desertification of the plant community and potential elimination of the animal population.

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Biographical Sketch

Edward W. Bork is from western Canada and obtained a BSc in Agriculture, specializing in rangeland management from the University of Alberta in 1989, an MSc in Wildlife and Rangeland Resources from the University of Alberta in 1993, and a PhD in Range Science from Utah State University in 1997.

He has been at the University of Alberta in Edmonton, AB, Canada, since 1997 as an instructor and researcher in the area of Rangeland Ecology and Management. His past research has included the assessment of rangeland resistance and resilience to wildlife and cattle herbivory, wildfire and manure disposal in semi-arid region, studies into the use of LiDAR and other technology for monitoring rangeland vegetation, feasibility assessments of agro-forestry production systems in temperate regions, the assessment of tree and shrub encroachment into grasslands, documenting the role of wetlands in livestock production in arid and semi-arid regions, and understanding the impacts of multi-species grazing systems on native rangeland. His current research interests include the integrated management of weeds, primarily Canada thistle, in pasture systems, including defining the optimal role of legumes in forage mixes and their aggregate response to weed control, investigations into the impacts of climate change on the function of northern temperate grasslands, and understanding the mechanisms regulating plant invasion into native grasslands.

Dr. Bork is a member of the Society for Range Management, and served as Associate Chair (Graduate Programs) in the Agricultural, Food and Nutritional Science Department from 2005 – 2008.