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## Managing Livestock Stocking Rates on Rangeland



Proceedings of Symposia conducted at:

Victoria, Texas
October 5, 1993

Amarillo, Texas
October 11, 1993

Fredericksburg, Texas
October 13, 1993

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# Managing Livestock Stocking Rates on Rangeland 

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The committee wishes to express sincere appreciation to the respective county Extension agents and program committees for local planning and support at each respective symposia location. Each author is to be commended for their willingness to share expertise through this publication and their presentations. Judy Winn, Agricultural Communications provided guidance and helped expedite publication of the proceedings. Last but not least is the major task of editor that Jerry Cox and J. F. Cadenhead so willingly accepted and completed with excellent results under major time constraints.

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## FOREWORD

Stocking rate decisions have a significant impact on short and long term sustainability of ranch resources. Stocking rate influences both livestock performance and climatically controlled forage production. Thus, livestock stocking rates are the most important management decision affecting the ranching business and the rangeland resource. Managers of rangeland constantly face the problem of balancing animal demands with a fluctuating forage supply. Forage demand must balance with forage available if range forage is to be effectively converted to animal production while the range production capability is maintained or improved. Timely stocking rate adjustments improve economic benefits and minimize dramatic stocking rate adjustments during a drought.

Data from 7,000 ranchers surveyed in 1990 indicate the need to teach stocking rate concepts: thus, the Extension Rangeland Ecology and Management Program Unit of the Texas Agricultural Extension Service initiated Project Range Care to teach concepts related to stocking rate decisions. The primary objectives of Project Range Care are to help Texas ranchers understand the relationships between stocking rate decisions and short- and long-term ranch sustainability; to teach forage sampling techniques to determine existing forage supplies, project future livestock forage demands and determine appropriate seasonal stocking rates; and to teach methods to monitor rangeland condition and trend to determine impacts stocking rate decision impacts. Intensive county level workshops have been combined with traditional Extension programs to accomplish these objectives. The three symposia conducted in 1993 at Amarillo, Fredericksburg and Victoria are part of the Project Range Care program. The symposia topics were selected to demonstrate the importance of livestock stocking rate decisions, how they affect ranch resources, and techniques that may be used to improve stocking rate decisions.

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# WHY STOCKING RATE DECISIONS ARE IMPORTANT AN OVERVIEW 

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## INTRODUCTION

The Society for Range Management has defined stocking rate as:
"The actual number of animals, expressed in either animal units or animal unit months, on a specific area at a specific time" (Range Term Glossary Committee 1964) and more recently as:
"An area of land which the operator has allotted to each animal unit for the entire grazeable period of the year" (Range Term Glossary Committee 1974).

Likewise, the Forage and Grazing Terminology Committee (1991) of a broad-based array of resource organizations and agencies defines it as:
"The relationship between the number of animals and the grazing management unit utilized over a specified time period."

All definitions encompass animals, area, and time. Livestock have basic requirements of diet (quantity and quality), cover, and living space. Unit area (e.g. acre, hectare, section) denotes a space that supports vegetation, portions of which supply forage for the grazing animal. This vegetation-animal relationship occurs over a period of time. So, basically, stocking rate decisions consider this relationship and attempt to balance livestock needs and demands with forage availability so that animals and the range resource can at least maintain or better yet, gain in productivity.

It has been said that the stocking rate decision is one of the most critical that a rancher or livestock operator has to make (Pieper 1981, White and McGinty 1992). Proper stocking rates will influence optimum animal performance and sustain or improve the range resource. These, of course, contribute to ranch profitability and the meeting of the short- and long-term ranch firm goals and objectives. Consequently, improper stocking has broad long-term negative impacts on livestock, the range resource, finances, and associated commodities such as white-tailed deer, turkey, and bobwhite quail. Stocking rates may also have impacts (negative or positive) on endangered species and on water quantity and quality.

## STOCKING RATE - PRACTICES AND ATTITUDES

If stocking rates are so important then why do so many ranchers overgraze? The reasons are many and complex. Some ranches are too small to be economic units and the operator is under pressure to add more animals. Other operators overgraze and then overfeed supplements. This masks the over grazing until the resources are badly damaged (Shoop and McIlvain 1971). Still others are over optimistic that rains will come sooner than later. They won't destock until forced to do so in times of crisis. Many rely on "eyeballing" the pasture and animals as a basis for decision-making and over estimate available forage.

To better understand today's ranching community, the Texas Agricultural Extension Service surveyed Texas ranchers in 1990 to provide baseline information concerning ranch characteristics, criteria for making grazing and brush management decisions, and the types of decisions and technologies applied. Two of the major areas of consideration when setting stocking rates included leased vs owned land and the factors influencing the establishment of stocking rates (Hanselka et al 1990).

Maintenance of proper livestock stocking rates has always been a significant problem on leased rangeland. When surveyed, only 54 percent of the ranchers indicated they owned and operated all of their ranch acreage. Eighteen percent leased all of their grazing and 18 percent operated a combination of leased and deeded grazing land. Ten percent of those surveyed owned their ranch but leased all the grazing to others.

The tenure of the lease is known to impact livestock stocking rates. For example, short-term leases tend to promote over grazing as lessees often attempt to maximize per acre production with little regard to the long-term impact on forage production and range condition. Thirty-six percent of the respondents who leased rangeland reported a lease tenure of one year or less, while 38 percent responded with lease contracts of two to five years. Six- to 10 -year lease contracts were reported for 8 percent of the respondents, while 17 percent had tenures of greater than 10 years.

When asked if the lease agreement included clauses that dictated stocking rate, 78 percent responded NO. Of those that indicated such a clause was included, the majority ( $15 \%$ ) indicated only a maximum stocking rate was dictated. Lease agreements were also found to be lacking in clauses that dictated the type of livestock that could be grazed. Eighty-seven percent reported this to be the case.

The method in which lease payments are determined also impacts livestock stocking rates, especially when no cap on livestock numbers is included in the contract. When lease payments are based on a per acre charge, lessees are encouraged to reduce per animal grazing costs by maximizing livestock numbers. Eighty percent of those that leased reported this to be the case. Lease payments were determined by the number of animals grazed only 11 percent of the time. Eight
percent indicated lease payments were based on a combination of annual or monthly payments, exchange of services or percentage of income.

All respondents, whether they leased, owned or managed rangeland were asked to rate the importance of several factors when they establish their annual livestock stocking rate for rangeland. Forage and livestock considerations as well as past experience and weather all rated high. Wildlife considerations and other people's advice rated much lower.

Each respondent was also asked if his annual stocking rate had decreased, increased or stayed the same over the past 10 years. Thirty-eight percent reported no change, 37 percent reported a decrease while 25 percent increased stocking rate. When those who reported a decrease in stocking rate were asked what factors influenced that change, 88 percent indicated drought as a major factor. Brush and weed invasion ( $28 \%$ ), less forage available ( $39 \%$ ) and the need to increase forage reserves ( $22 \%$ ) or individual animal performance ( $32 \%$ ) also received high ratings.

Essentially the same question was posed to those who reported a stocking rate increase for the past 10 years. Factors the respondents felt most responsible included weed and brush control ( $68 \%$ ), more forage available ( $58 \%$ ), changed grazing programs (44 percent) and fence development (47\%).

It is known that in order to properly balance livestock numbers with fluctuating forage supplies some type of "seasonal" adjustment of livestock numbers is necessary so it should be noted that 45 percent of the respondents indicated they did not make this type of adjustment. Of equal importance to the actual setting and fluctuation of livestock numbers is a "feed-back" mechanism to monitor the effect of stocking rate on range conditions and trend. Visual inspection of pastures ( $89 \%$ ) and animal performance ( $62 \%$ ) were the two most used techniques by respondents to monitor long-term changes in range vegetation. These techniques represent the two poorest choices for measuring long-term stocking rate impact. Only 8 percent reported the use of vegetation transects, 10 percent use grazing exclosures and 2 percent use photopoints or repeat photographs.

When these quantitative data are analyzed, several trends become apparent (Rowan, White, and Conner 1993). The first of these is that decisions made by Texas ranchers over a 10 year period concerning stocking rate levels were dominated by perceptions about weather. Over half of stocking rate changes were related to rainfall or drought. As rancher perception of a positive rainfall effect increased, so did stocking rates, and vice versa. Although the presence or absence of rainfall cannot be managed, proactive stocking decisions should include a strategy for adjusting stocking level in response to changing environmental conditions.

Also, other factors contributing to stocking rate change were age, grazing rights (owned vs. leased), traditional stocking rate factors, traditional grazing program factors, and weed-brush information factors. Older ranchers ( $>65$ years) and
ranchers who leased all of their rangeland tended to decrease stocking rates over time. Nontraditional stocking rate and grazing management decisions do follow other people's advice and consider wildlife factors but these inputs do not significantly influence stocking rate decisions over the long term. Rangeland operators indicated they considered "improved livestock performance" as the most important benefit from initiating a grazing program.

## CONSIDERATIONS IN MAKING STOCKING RATE DECISIONS

Forage quantities and qualities will fluctuate widely over time due to plant phenology and physiology, weather conditions, and season of the year. Concurrently, animal demands will change with changing herd age, size, and sex composition. It behooves the operator to know the quantity of forage required on a daily basis, the length of time the animals will be in a pasture, and the amount of grazeable forage available to the animals in order to make correct decisions.

An animal unit (A.U.) requires $2-3 \%$ of its body weight of air-dried forage daily. When this is combined with the needs of the plant ( $50 \%$ of current growth) and relative inefficiency of grazing programs (25\%), the total amount of forage required/A.U. may be $75-100 \mathrm{lbs}$ of dry forage daily!! Preferred grasses as well as other species contributing to the diet must be considered when evaluating whether enough forage is available over a period of time for the number of animals grazing the pasture. Since forage cycles are dynamic this is often like "shooting at a moving target".

Consequently it is usually recommended that frequent, timely forage evaluations be made and animal number adjustments made if necessary. For example, March adjustments consider forage available after the winter and before spring growth; July adjustments are made after spring growth but before the summer; and November adjustments consider forage supplies after the fall growing season and before winter dormancy.

Experience is often the only method used to evaluate forage availability since less than $20 \%$ of Texas ranchers use quantifiable techniques to adjust stocking rates and to monitor the impact of their decisions on the range resource. Managers should adopt, at the minimum, the use of permanent photo points and/or exclosures that are evaluated on an annual basis to monitor range use, condition, and trend. Also, the seasonal use of vegetation transects and photo guides should result in the adoption of needed grazing management adjustments. Forage sampling techniques allow the rapid determination of existing forage supplies, project future livestock demands, and determine appropriate seasonal stocking rate.

## IMPORTANCE OF TIMELY DECISIONS

Stocking rate decisions should be made before the ranch's resources are jeopardized and adjusted seasonally to balance forage demand with forage supply.

The stocking rate chosen initially may not be the best one for the rest of the year. A rancher should regularly observe forage supply, animal performance, rainfall patterns, etc. in relation to financial needs of the ranch enterprise. If a range is too lightly stocked, the forage supply may be increasing along with range health; yet financial returns may be inadequate to keep the enterprise viable. If too heavily stocked, animal productivity may show temporary increases, but damage to the forage resource may put the ranch enterprise in jeopardy due to range deterioration.

## ECONOMIC IMPORTANCE OF TIMELY DECISIONS

Heavily Stocked Scenario - Let us suppose we are grazing native rangeland at a stocking rate of one cow per 20 acres yearlong with protein supplement for three months and proper minerals free choice. Expected September and October rains do not occur and moderate amounts of early summer forage are used up. A forage survey in October indicates that present forage will run out by February 1. Rather than reduce herd numbers, the rancher decides to feed extra supplements and hay, if necessary, until new forage has grown from winter moisture. By February 1, old forage is gone and Texas wintergrass and forbs are inadequate to provide a diet which maintains body weight of the cows nursing baby calves. Finally in mid-May forage supply begins to stay ahead of forage demand, but the nursing calves are pulling down the body condition of the cows soon thereafter because of short rainfall in June. Some light showers keep him from selling off some early calves in July, and abundant August and September rain makes him feel confident that he has outguessed the weather and kept his cow numbers intact for another year.

However, when he got a bit worried, and pregnancy-tested his cows in September, he finds that he has obtained only a $35 \%$ breedback. Although he expects to have adequate grass going into the winter, he has to decide whether to sell his dry cows and buy back bred cows or to get his dry cows bred for summer calves next year. Either way, a timely decision on stocking rate last fall would have possibly prevented the economic wreck he is in.

When you are forced to sell or buy because of a forage supply miscalculation, you may hit the market at the wrong time. When you are forced to sell because of forage supply reduction due to weather, you may find the market low from the large numbers of drought-stressed animals that other ranchers have brought in.

Too Lightly Stocked Scenario - If half the number of cows were stocked (one cow per 40 acres), the range and animal conditions would be benefitted, however, the ranch enterprise may not survive on half the number of calves going to market.

## ENVIRONMENTAL IMPACT OF TIMELY STOCKING DECISIONS

Forage plants preferred by livestock are easily damaged or destroyed. The results of too-heavy, too-soon stocking may not be seen for several years. Eventually,
loss of desirable forage plants, loss of soil where too much plant cover is removed, and encroachment of undesirable invaders will reduce the value of the rangeland for future production. Expensive weed and brush control measures may be required to resiore forage productivity.

Stocking of rangeland following prescribed burning usually carries a rule-ofthumb procedure to wait for 60 to 90 days to keep from hurting forage recovery. Preferred grasses, forbs and browse may be unusually vulnerable to early grazing. It is not the fire itself but grazing following the fire that has done the most damage to rangeland. Cattle may be turned in following a prescribed burn for a few days to utilize scorched prickly pear, but too soon it sours and they start consuming green sprouts of recovering grasses. Waiting longer than 90 days may be necessary if dry weather prevails. One rancher in 1983 waited an entire year before restocking with cattle so that recovery could occur. Stocking too soon could result in damage that would require several years for recovery.

## SOCIAL IMPACT OF TIMELY STOCKING DECISIONS

People other than ranchers are becomeing more aware of stocking decisions. Concern over the habitat of an endangered bird, the black-capped vireo, has caused some people to pay more attention to the intensity of browsing on shinoak and cedar. Of more general concern, but certainly not as visible, is the impact of stocking on recharge of the Edwards Aquifer. With the loss of soil and plant cover from improper stocking decisions, more water goes overland and less goes into the soil profile where it can be used by plants or seep into deeper layers of ground water. Soil loss not only reduces the productivity of the site it is taken away from, but also it affects the quality of water and habitat where it may be deposited.

To ensure adequate grass cover, or residue, on the ground to reduce erosion and sustain some forage production, minimum levels have been established. Where shortgrasses, such as buffalograss and curlymesquite dominate, 300 to 500 pounds per acre (oven dry weight) of residue should be left. With midgrasses, such as sideoats grama, Texas wintergrass and Wright threeawn, 750 to 1000 pounds per acre should be left. And with tall grasses, such as little bluestem and Indiangrass, (and probably some of the planted grasses, such as Kleingrass, Old World bluestem and Johnsongrass) 1200 to 1500 pounds per acre should be left. Stocking rate decisions which retain these values should result in healthy rangeland.

## POLITICAL IMPACT OF TIMELY STOCKING DECISIONS

The tax base of many largely rural counties rests on the productivity of its rangeland. When stocking decisions lead to range deterioration, the long-term health of the local economy is in jeopardy. Reduced productivity of rangeland not only affects the landowners, but also local businesses, schools, and service capabilities of local government. Taxes on rangeland in the past decade have greatly increased for many counties often forcing unrealistic stocking rates in an attempt to cover the
financial needs of the ranch. Rates may be comparatively low because of agricultural land classification, nevertheless, the pressure to add more livestock is often apparent. Several instances where ranchland undergoing a change in ownership was not grazed by livestock because of inadequate fencing, the new owners were told to get livestock or face reclassification of the land to a higher tax obligation.

With political strength more apparent in urban than rural populations these days, it will continue to be difficult to protect rangeland from unreasonable demands. The image of a rich rancher probably should be transformed to an image of a harassed rancher through public education as to the real pressures faced in making stocking decisions at the right time for future protection and production of resources important to the whole community.

## SUMMARY AND CONCLUSIONS

Stocking rate decisions are indeed a basic priority for the ranch manager. These decisions impact range resources, livestock and wildlife enterprises, and financial strategies of the ranch firm. Positive or negative environmental impacts can also result from these decisions. Thus, short and long-term stability of the business is involved. The long-term effects can be economic, environmental, social, and political in nature.

Operating within available resources and careful planning provides a stable business environment and reduces risk. As Allison (1988) stated, there is no one poorer than a rancher always out of grass. More consideration of stocking rate decisions allows the ranchman to better meet crisis situations.

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# MANAGING STOCKING RATES TO ACHIEVE RANGE RESOURCE GOALS 

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## INTRODUCTION

The selection of the correct stocking rate is the most important grazing management decision from the standpoint of vegetation, livestock, wildlife, water components and financial return. This has been the basic problem confronting ranchers and range managers since the initiation of scientific range management in the early twentieth century. Specific approaches for setting stocking rates have only recently been developed (Holechek 1988, Troxell and White 1989, Holechek and Pieper 1992). However, it is still generally agreed there is no substitute for experience in stocking rate decisions on individual ranges.

Stocking rate is defined by the Society of Range Management (1989) as the amount of land allocated to each animal unit for the entire grazeable period of the year (Holechek et al. 1989). In Texas, stocking rate is typically expressed as acres per animal unit. The Society for Range Management (1989) defines an animal unit as one mature $(1000 \mathrm{lb})$ cow. Based on the most recent research, this animal would be expected to consume 20 lb of forage per day, 600 lb per month, and 7300 lb per year. An animal unit month is the amount of feed or forage ( 600 lb ) required by one animal unit for one month.

Grazing capacity is often used when discussing stocking rate. This term refers to the maximum stocking rate possible through time without degrading the range. In most cases, ranches are bought and sold on the basis of their grazing capacity.

In this paper I will provide an overview of concepts and knowledge regarding stocking rate selection on southwestern rangelands along with identifying major sources of information. Other authors in the symposium provide more detailed coverage of specific aspects of this subject.

## IMPORTANCE OF RESIDUE

The most important element of stocking rate is grazing intensity or the degree of use of primary forage plants. Grazing intensity determines how much vegetation remains for the maintenance of plant, soil, wildlife, and water components of range ecosystems. I will briefly review the importance of residue in range management and refer the reader to textbooks by Holechek et al. (1989), Vallentine 1990, and Heitschmidt and Stuth (1991) for a more detailed analysis of this subject.

Beyond a certain residue threshold, livestock performance declines as palatable and nutritious plants and plant parts are removed. Forage scarcity forces animals to expend extra energy in travel that could otherwise go into weight gain, milk production and hair growth (wool). Several studies document the adverse impacts of heavy stocking rates on livestock production and financial returns. An example of these studies using data from a southern prairie cattle operation is provided in Table 1.

Table 1. Influence of grazing intensity on cattle production at the Southern Great Plains Experimental Range, Woodward, Oklahoma (Source: Shoop and McIlvin 1971).

|  | Cow/Calf-Southern Great Plains Experimental Range |  |
| :--- | :---: | :---: |
| Average annual precipitation (inches) | Heavy Stocking | Moderate Stocking |
| Years (total) | 23 | 23 |
| Drought years | 9 | 9 |
| Acres/cow | 4 | 4 |
| Estimatcd harvest efficiency of forage (\%) | 12 | 17 |
| Calf crop weaned (\%) | 62 | 44 |
| Calf weaning weight/cow (lb) | 81 | 92 |
| Calf weaning weight | 314 | 424 |
| Net returns per cow (\$) (Average all years) | 388 | 461 |
| Net returns per acre (\$) (Average all years) | 9.00 | 29.44 |
| Net returns acre (\$) (Non-drought years) | 0.70 | 1.88 |
| Net returns acre (\$) (Drought years) | 2.70 | 2.90 |
|  | -4.45 | 1.48 |


|  | Yearling Cattle-Southern Great Plains Experimental Range |  |
| :--- | :---: | :---: |
| Years (total) | Heavy Stocking | Moderate Stocking |
| Drought years | 17 | 17 |
| Acres/yearling | 5 | 5 |
| Average forage production (lbs./ac.) | 6 | 9 |
| Average forage production in drought years (lbs./ac.) | 1045 | 1162 |
| Average wt. gain/yearling (lbs.) (Average all years) | 530 | 810 |
| Net returns per yearling (\$) (Average all years) | 322 | 363 |
| Net returns per acre (\$) (Average all years) | 8.29 | 8.94 |
| Net returns acre (\$) (Non-drought years) | 1.38 | 1.01 |
| Net returns acre (\$) (Drought years) | 3.00 | $\mathbf{1 . 8 0}$ |

Heavy stocking causes desirable wildlife species such as white-tailed deer, bobwhite quail, and wild turkeys to decline or disappear since inadequate vegetation is available to meet their cover and food needs. They are often replaced with small rodents and jackrabbits that further degrade the range with their burrowing and foraging activities.

Lack of vegetation residue results in raindrops falling on unprotected soil. This causes dislodging of soil particles and reduces water infiltration into the soil profile. Low residue makes the soil more vulnerable to wind as well as water erosion.

Heavy stocking causes mortality of the more palatable plant species, and replacement with those that are unpalatable and often poisonous. Green plants, which are the primary producers on rangelands, use energy from the sun, carbon dioxide from air, and water and nutrients from the soil to produce food for maintenance and growth through the process of photosynthesis. Excessive removal of green plant leaves by grazing destroys the photosynthetic capability of the plant and will ultimately cause its death. However, green plants produce more leaf material than is needed for maintenance and growth. Therefore a surplus exists that can be grazed by livestock and wildlife.

Under moderate or light grazing levels the poisonous, unpalatable plants are at a competitive disadvantage because they invest part of their products from photosynthesis in poisonous compounds (alkaloids, oxalates, glycosides, etc.) and appendages (spines, thorns, stickers, etc.) that discourage defoliation rather than contribute to growth. In contrast the palatable plants use their photosynthetic products mainly for growth in the form of roots, leaves, stems, rhizomes, stolons, and seeds. Under excessive defoliation levels the photosynthetic capacity of the palatable plants is reduced to the point that they are unable to produce adequate carbon to maintain root systems, regenerate leaves, respiration, and reproduction. Over time, they are replaced with unpalatable plants that have had lower rates of defoliation.

Many ranchers and range professionals have held the belief residue was unimportant to key forage plants after completion of growth. However, research has shown that residue during dormancy plays a critical role in protecting plants from extreme temperatures, and destruction of the growing points in the crown by insects, rabbits, rodents, and pathogens (Sauer 1978, Sneva 1980). Heavy defoliation during dormancy reduces herbage production almost as much as during active growth (Cook 1971).

## STOCKING RATE INFLUENCES ON FORAGE PRODUCTION

Heavy stocking rate rapidly decreases forage production in desert areas and gradually reduces forage production in humid ranges. These effects are more reversible and lower in magnitude on humid ranges.

Van Poollen and Lacey (1979) reviewed the literature on grazing intensity influences on herbage production in the western United States. The average increase was $35 \%$ when continuous livestock use was reduced from heavy to moderate. An average increase in forage production of $27 \%$ resulted from switching from moderate to light. On some humid ranges forage production was actually less under light grazing than under moderate grazing. One of the cheapest ways to increase forage production on most ranges is to reduce stocking rate. On Chihuahuan desert range in New Mexico forage production increased from $160 \mathrm{lbs} /$ acre to over $600 \mathrm{lbs} /$ acres during a 25 year period under conservative stocking ( $30 \%$ use of key forages) (Holechek 1991, Smith 1993). After careful consideration of grazing studies in the central Great Plains, Klipple and Bement (1961) concluded that most of the improvement in forage production from light grazing occurs during the first 5 to 7
years. However, on desert ranges the benefits of conservative stocking tend to accumulate, and are greatest after a 5-10 year period (Holechek 1991) (Table 2). This is because rate of range recovery is strongly associated with amount of rainfall, and therefore, is relatively slow in the desert.

Table 2.
Range, cattle production, and financial characteristics for the 1968 to 1992 period on a conservatively stocked experimental ranch and surrounding more heavily stocked private ranches in the Chihuahuan desert of southcentral New Mexico (Source: Holechek 1991).

|  | College Experimental Ranch Surrounding Private Ranches |  |
| :--- | :---: | :---: |
| Average annual precipitation (inches) | 10 | $9-12$ |
| Average Forage Production, 1968-1992, lbs./ac. | 250 | 135 |
| Average Forage Production, 1988-1992, lbs./ac. | 572 | 174 |
| Acres/Animal Unit, 1968-1992 | 185 | 150 |
| Acres/Animal Unit, 1988-1992 | 110 | 150 |
| Forage Use, $\%$ | $30-35$ | $45-50$ |
| Calf crop, $\%$ | 80 | 75 |
| Calf weaning wt, lbs. | 460 | 420 |
| Death losses, \% | 1.0 | 3.5 |
| Supplemental feed cost per animal unit, $\$$ | 10.63 | 29.86 |
| Health care and pregnancy testing, $\$$ | 9.50 | 4.85 |
| Beef Production/acre, lbs. | 0.55 | 0.47 |
| Return per acre, $\$$ | 0.75 | 0.32 |

In arid shrubland ranges of the Southwest light grazing can be a useful means of improving forage production during early stages of range deterioration if desirable forages are present but in low vigor (Holechek 1991). However, light grazing has shown low potential for recovery of highly deteriorated, brush-infested ranges.

It is important to recognize that precipitation drives vegetation successional advance. If soil erosion has not been severe, recovery from severe overgrazing requires less than 10 years in the prairie country of the central and eastern United States, where precipitation averages over 20 inches per year. In the creosotebush areas of west Texas and New Mexico with less than 11 inches average precipitation per year, range recovery after severe degradation and brush invasion are slow to nonexistent (Beck and Tober 1985).

## GRAZING INTENSITY GUIDELINES

In most stocking rate studies in the western USA percent utilization of forage species has been used to measure grazing intensity. However from the standpoint of management decisions by ranchers, standing crop (dry matter basis) measurements are the most useful. Most managers can be trained to estimate standing dry matter ocularly to within $25 \mathrm{lbs} /$ acre (Smith 1944, Valentine 1970). On year-long ranges most decisions regarding adjustment in stocking rates are made at the end of the growing season in the fall. After the standing crop is estimated, animal numbers can be adjusted so that a minimum residue of dry matter remains just prior to the average time when growth is initiated the following year. The importance of maintaining minimum residues for soil, vegetation, and animal resources has previously been discussed. Some guidelines for minimum residues on the different Texas range types are provided in Table 3.
Table 3. Use and residue guidelines for different range types in Texas. These guidelines apply to ranges in good condition and may not be practical for those that are degraded.

|  | Average <br> Annual <br> PPT <br> (inches) | Forage Production <br> on Good Condition Range <br> (lbs./ac.) | Percent use <br> of key species <br> Ror moderate grazing | Suggested <br> minimum residue <br> to maintain range <br> (lbs./ac.) | Reference |
| :--- | :---: | :---: | :---: | :---: | :---: |

[^0]
## KEY SPECIES CONSIDERATIONS

The key-plant and key-area concepts have proven highly useful to managers in evaluating grazing effects on range vegetation (Holechek 1988). A key species is defined as a forage species whose use serves as an indicator to the degree of use of associated species, and because of its importance, must be considered in any management program (Society for Range Management 1989). Key management species are those on which management of grazing on a specific range is based. The key species and key area serve as indicators of management effectiveness. Generally, when the key species and key area are considered properly used, the entire pasture is considered correctly used.

In most cases one to three plant species are used as key species. These plants should be abundant, productive, and palatable. They should provide the bulk of the forage for grazing animals within the pasture. It is important to recognize the key species for one type of animal may be different for another type due to differences in food habits. As an example, sideoats grama is a key species for cattle on many Texas ranges but the key species for whitetailed deer is live oak. Sedge is important in sheep diets in the Edwards Plateau.

Under the key-species approach, secondary forage species such as curly mesquite and threeawn will receive light use, and key species (sideoats grama, Texas wintergrass, little bluestem) will receive moderate use.

The key area is a portion of range which, because of its location, grazing or browsing value, and/or use serves as an indicative sample of range conditions, trend, or degree of seasonal use (Society for Range Management 1989). Successful range management practices within a pasture are usually judged by the response of the key plant species on the key area.

When selecting the key area, parts of the pasture remote from water, on steep slopes, or with poor accessibility due to physical barriers should be disregarded. Proper use of these areas will generally result in destructive grazing of most of the pasture. These areas should be omitted when carrying capacity is estimated.

A number of qualitative guidelines have been developed for judging intensity of grazing on a range (Holechek et al. 1989). I have found that a simple categorization into heavy, moderate, and light use is most practical using the following criteria:

Heavy use. Range has a "clipped" or mowed appearance. Over half of the fair and poor forage-value plants are used. All accessible parts of the range show use, and key areas are closely cropped. They may appear stripped if grazing is
very severe. There is evidence of livestock trailing to forage.
Moderate use (proper use). About one-half of the good and fair forage-value plants are used. There is little evidence of livestock trailing. Most of the accessible range shows some use.

Light use. Only choice plants and areas are used. There is no use of poor forage plants. The range appears practically undisturbed.

On key areas average stubble heights of 12 to 14 in. for tall grasses, 6 to 8 in. for mid grasses, and 2 to 3 in . for short grasses are recommended minimums for proper use.

On some ranges livestock will differentially graze certain plants and reject others even though they are not poisonous. In the Chihuahuan desert of west Texas large areas of black grama and tobosa often grow in the same pasture. Under continuous grazing cattle will reject the tobosa and use the black grama. Burning and specialized grazing systems can be useful to overcome these types of problems. This subject is taken up in more detail by other papers in this symposium, and specific strategies are given by Vallentine (1980), Wright and Bailey (1982), Holechek et al. (1989), and Vallentine (1990).

## ADJUSTMENT FOR DISTANCE FROM WATER

Failure to adjust stocking rates for travel distance to water has resulted in considerable range degradation, particularly in the hot, arid rangelands of the southwestern United States. Several studies show that cattle make little use of areas farther than 2 miles from water (Valentine 1947, Martin and Ward 1970, 1973). In contrast, sheep and goats do not require water every day, and therefore, will readily use areas that are 2 miles from water.

Table 4 provides guidelines on adjustment in cattle stocking rates as distance from water increases based on research and experience.

Table 4. Suggested reductions in cattle grazing capacity with distance from water (Source: Holechek 1988).
Distance from Water (miles)
Percent Reduction in Grazing Capacity

| $0-1$ | None |
| :--- | :--- |
| $1-2$ | 50 |
| Over 2 | 100 |

Many ranchers in arid areas fail to recognize the influence of travel distance to and from water on livestock performance. Although livestock will travel great distances to water, this is not in the best interest of the animal or the range resource. Travel increases energy expenditure by the animal that otherwise would go into
production (weight gain, milk production) and takes away from grazing and resting time.

Research is lacking on how travel distance to water affects livestock performance on southwestern ranges. However, research from Australia and on cold desert range in Oregon indicates major reductions in cattle weight gains when the distance exceeds 1 mile (Table 5). Data from this study further supports the guidelines in Table 4.

Table 5. Average daily gain (lb) of cattle in southeastern Oregon as affected by trailing one mile to water and no trailing (Source: Sneva et al. 1973).

| Period | Trailing 1 Mile | Treatment |
| :--- | :--- | :--- |
| May 20 - Aug 17, 1970) |  |  |
| Cows | 1.11 | 1.32 |
| Calves | 1.68 | 2.05 |
| Ycarling | 1.10 | 1.37 |
| (April 16 - Aug 3, 1971) | 0.48 | 0.41 |
| Cows | 1.70 | 1.80 |
| Calves | 1.32 | 1.86 |
| Yearlings |  |  |

## ADJUSTMENT FOR SLOPE

Rugged topography is the second most important cause of poor livestock distribution on rangelands (Holechek et al. 1989). The reluctance of livestock to use steep slopes is not entirely undesirable since these areas are often fragile and valley bottoms can better withstand grazing. However, in many cases slopes serve as barriers to the use of benches and ridgetops above valley bottoms.

Livestock vary considerably in their willingness to use steep terrain. Large, heavy animals such as mature cattle or horses have difficulty in traversing steep, rocky slopes. Cattle make little use of slopes over $10 \%$ (Ganskopp and Vavra 1987). Because of their smaller size, greater agility, and surefootedness, sheep and goats use these areas more readily. On winter range in New Mexico, McDaniel and Tiedeman (1981) found sheep uniformly used slopes of less than $45 \%$, but utilization was sharply reduced on steeper slopes. Many rugged ranges can be better used by wild animals than by livestock.

Guidelines for stocking rate adjustment for slope with cattle are provided in Table 6. These guidelines are based on research and practical experience.

Table 6. Suggested reductions in cattle grazing capacity for different slopes (Source: Holechek, 1988).

| Percent Siope | Percent Reduction in Grazing Capacity |
| :---: | :---: |
| $0-10$ | None |
| $11-30$ | 30 |
| $31-60$ | 60 |
| Over 60 | 100 |
|  |  |

## RANGE RESOURCE GOALS

Ranchers generally fall into two categories when it comes to their management goals. These included those who want maximize financial returns from their livestock without damaging the range and those who want to improve their ranges from esthetic, vegetation, recreation, wildlife, and livestock standpoints but consider financial returns from livestock of secondary importance. These latter ranchers are often more interested in minimizing risk rather than maximizing income.

Stocking rate procedures are available that will accommodate each goal. The approach developed by Holechek (1988) is based on maximizing forage use by livestock while that of Troxell and White (1989) works well for range betterment and minimization of risk. After careful examination of long term stocking rate studies from various ranges in the USA, Holechek (1988) concluded that in years of average or above average precipitation about 50 percent of the current year forage production could be consumed by livestock in the more humid ranges such as the southern pine forest and the tall grass prairie. On the more arid mid-grass and shortgrass ranges about $40-45 \%$ can be consumed, and on desert ranges only $30-35 \%$ can be removed by livestock without rangeland deterioration. During drought ( $75 \%$ or less of average annual precipitation) his procedure requires partial or complete destocking to avoid breaching critical residues. On most Texas ranges, climatic records indicates this is necessary in 3 to 4 years out of every 10 .

Troxel and White (1989) have developed a simpler, more conservative procedure that allocates $25 \%$ of current year forage production to livestock, another $25 \%$ to natural disappearance (insects, wildlife, weathering) and $50 \%$ is left for site protection. Based on a comparison with the Holechek (1988) procedure it gives estimates about 15\% below maximum sustainable long-term stocking rates (Holechek and Pieper 1992). On most western ranges partial or complete destocking would be necessary in only about 3 to 4 years out of 20 with the Troxell and White (1989) procedure. Conservative stocking is particularly advantageous on desert ranges where plants can be damaged by one or two years of overuse but recovery may take 6-10 years even under light use (Cook and Child 1971).

A third approach to stocking rate selection is to use the guidelines developed by the Soil Conservation Service. The SCS guidelines are subjective and based mainly on practical experience. Holechek and Pieper (1992) found they over estimated stocking rate on desert range but it was underestimated on prairie range.

Both Holechek (1988) and Troxell and White (1989) procedures gave more reliable stocking rate estimates than the SCS guidelines.

## WAYS TO MAINTAIN MINIMUM RESIDUES

Regardless of what stocking approach is used, drought years will occur in which partial or complete destocking is necessary to maintain minimum residues and prevent a crash in livestock performance and financial returns. Four basic strategies can be used to deal with drought. These include sale of excess livestock, leasing of grazing land, confinement of livestock in drylot until the drought ends, and saving lands dominated by cactus or palatable browse as an emergency forage reserve.

## SALE OF EXCESS LIVESTOCK

Sale of excess livestock is usually the least desirable approach because droughts often occur over large areas and other ranchers are also forced to liquidate their herds. The high supply of livestock coming to market depresses prices. After the drought breaks everyone is trying to buy livestock so prices are high and quality, disease free animals are hard to find.

## LEASING OF GRAZING LAND

The problem here is that during droughts available grazing leases are generally considerable distances from the operator. Livestock transportation costs are high and livestock performance is often depressed from the stress of hauling and adjustment to a new area.

## LIVESTOCK CONFINEMENT

This approach has considerable potential as a cost effective means of dealing with drought. Confinement of cows during drought can relieve stress on plants and improve livestock production during drought (Herbel et al. (1984). The higher the price of calves and the lower the cost of feed, the more feasible partial confinement becomes. Confinement during drought does increase labor costs but reduces vehicle costs (Herbel et al. 1984). Stockpiling hay and other feeds during periods when prices are low for droughts when prices are typically high can enhance the financial benefits of partial confinement.

## CACTUS AS A DROUGHT FEED

In hot, arid climates in many parts of the world, cactus comprises a large part of the vegetation and can be an important animal fodder. Cactus has four- to fivefold greater efficiency in converting water to dry matter than that of most grasses (Kluge and Ting 1978). Nutritionally, cactus is low in protein but rich in digestible carbohydrates, water, and vitamins (Shoop et al. 1977). In many parts of the world, including the southwestern United States, prickly pear and cholla cactus are used as emergency drought food for cattle. Various propane torches, known as "pear
burners," have been used to singe the spines off cactus so that cattle can eat the pads. Based on recent figures from south Texas, it costs about $\$ 0.35$ per animal unit per day to maintain animals on prickly pear compared to $\$ 0.78$ if relief corn (government aid) is used or $\$ 1.09$ for alfalfa (Russell 1985). If cattle must be carried for an extended period, an additional $\$ 0.24$ worth of protein supplement (cottonseed) is required when cactus is fed.

Ranchers in Texas are now planting prickly pear in rows to increase the efficiency of burning spines (Russell 1985). Some ranchers are so pleased with the performance of their cattle on cactus that they are using it in normal years. Although spineless varieties of prickly pear are available, they are subject to considerable herbivore by wildlife. In New Mexico and west Texas, cholla cactus has been a useful emergency forage in drought. The reader is referred to Brown (1992) for a more thorough discussion of livestock management during drought on Texas ranges.

## BENEFITS OF RESIDUE DROUGHT

A point worth emphasizing is that the basic livestock herd should be based on forage production in years of average rainfall. Heavy grazing has the most severe impact on forage production in drought years when forage is already in short supply (Tables $1 \& 7$ ). Generally most droughts are broken by a period of heavy rainfall. Ranges managed to maintain critical levels of residue show quicker recovery after the drought than those that have been heavily denuded. This is particularly true on the more arid Chihuahuan desert ranges in west Texas.

Table 7. Herbage production (lbs./ac) on heavily and moderately grazed shortgrass prairie in Colorado during drought year compared to the 5 -year average (Source: Klipple and Costello, 1986).

| Grazing Intensity | Drought year | Five-Year average | Drought year as percent of average |
| :--- | :---: | :---: | :---: |
| Heavy <br> $54 \%$ <br> Moderate of forage | 312 | 595 | 52 |
| $37 \%$ |  |  |  |
| Light <br> $21 \%$ | 577 | 766 | 75 |

## STOCKING RATE VERSUS SPECIALIZED GRAZING SYSTEMS

It has been my experience that rangeland conservationists tend to overrate the benefits of rotational grazing schemes, such as short-duration or deferred-rotation, and underrate the benefits of a conservative stocking rate in conjunction with conventional livestock distribution practices, such as water development. Rotational grazing schemes in conjunction with heavy stocking rates adversely affect livestock performance and financial returns the same as under heavy continuous grazing (Holechek et al. 1989, Vallentine 1990). Studies in Texas that document this relationship include Taylor and Garza (1986), Thurow et al. (1988), Heitschmidt
(1986), Heitschmidt et al. (1990), Ralphs et al. (1990), and Taylor et al. (1993).

Although rotational grazing schemes can be effective means to improve livestock distribution and provide opportunities for range betterment, they are not a panacea for over-grazing problems. I agree with Pieper and Heitschmidt (1988), who, after careful consideration of available research, concluded, "stocking rate is and always will be the major factor affecting degradation of rangeland resources." In a comprehensive review of grazing management studies in the western U.S., Van Poollen and Lacey (1979) found herbage production on the average increased by about 13 percent when rotational grazing systems were implemented at a moderate stocking rate. However, increases were larger ( 35 percent and 27 percent) when continuous livestock use was reduced from heavy to moderate and moderate to light stocking rates, respectively. None of the more recent research on rotational grazing systems contradicts their findings. Although ranchers should be encouraged to use rotational grazing systems, these schemes should not be used as a justification for grazing practices leaving inadequate residues to maintain soil stability and vegetation productivity.

## STOCKING STRATEGIES AND THE ECONOMY

Many ranchers fail to consider the business cycle when making stocking rate decisions. However, the status of economy can have a great deal of influence on whether a maximum or conservative stocking rate is appropriate. Basically two approaches can be applied. These involve either maximization of production per land unit or maximization of production per animal unit. In the past conventional thinking within the range profession has been geared toward maximization of production per land unit. This strategy works well financially when the following conditions prevail: 1) Demand for meat and prices are expected to increase, 2) Costs (supplemental feed, labor, veterinary supplies, travel) associated with each animal are expected to be stable or increase at a lower rate than livestock prices, 3) Interest rates on borrowed capital are low relative to the rate of inflation. The above conditions prevailed during the 1970's with cattle prices peaking in 1979 (Table 7). Inflationary spirals, as in the 1970 's, caused by loose monetary policy by the Federal Reserve invariable causes commodity and land prices to move upward. Inflationary periods have always been favorable for farmers and ranchers. Since the turn of the century major inflationary periods occurred during World War I and World War II as well as in the 1970's.

Deflation, where land and commodity prices (meat) drop, invariably follows inflationary periods. This is because high prices lead to over supply, and during periods of rapid economic growth the Federal Reserve becomes more concerned about fighting inflation rather than unemployment. The tightening of monetary policy by the Federal Reserve that invariably follows inflationary spirals slows the economy and causes commodity prices to fall.

Maximization of production efficiency per animal unit is the most effective strategy when the deflationary phase of the business cycle prevails. Here the rancher is concerned with minimizing production costs as much as possible and avoiding debt. Keep in mind the high interest rates used by the Federal Reserve to control inflation in the early 1980's forced many leveraged ranchers out of business because their operating capital costs increased while cattle prices fell.

The most successful ranchers I know are those who keep one step ahead of the business cycle. They sell heavily during periods of high cattle prices and move into a conservative stocking strategy. When cattle prices start to bottom they begin building up their herds so they will have their ranges fully stocked when prices again peak. Historically these cycles have taken around 10 years from peak to bottom back to peak (Table 8). In humid areas such as the Rolling Plains and the coastal prairie of Texas, periods of conservative stocking when cattle prices are low permit the range to recover after being fully stocked under rising cattle prices. The strategy I've just outlined works particularly well for yearling cattle operations (Torell et al. 1991).

In arid areas flexible stocking has minor advantages over constant stocking at a conservative rate (Martin 1975). This is because forage crops vary more between years due to erratic rainfall, carry over residue plays a bigger role in meeting livestock nutritional needs, and there is greater risk of long term damage to the range if maximum stocking and drought coincide. Several studies indicate that drought coupled with heavy stocking has far greater adverse impact on livestock performance in arid compared to humid areas.

I find it regrettable that few ranchers conscientiously orient stocking rate, brush control, ranch expansion, and other decisions around the business cycle. The practice of buying low and selling high has just as much utility with livestock as it does with common stock on Wall Street. I suggest Stoken (1984), Schiller (1991), Pring (1992), and Holechek and Hawkes (1993) for more thorough discussions of the business cycle and how it can be used to improve ranching profits. The reader is referred to Whitson et al. (1982), Heitschmidt (1986), and Heitschmidt et al. (1990) for detailed information on the financial aspect of stocking Texas ranges.

## CONCLUSIONS

Generally moderate stocking is considered to be the maximum number of livestock the range could carry over an extended period of time (10 years or more) without degradation. Moderate stocking rates will maximize long term (over 5 years) financial returns and minimize risk compared to heavier rates. The concept of moderate stocking is somewhat vague to many ranchers because it has not been related to a level of residue necessary to meet the needs of livestock, wildlife, soil, and vegetation. Residue guidelines are now being developed for Texas ranges.
Table 8. Cattle prices in relation to the American economy for the period between 1970 and $1992{ }^{1}$.

| Year | $\begin{gathered} \hline \text { \% Change } \\ \text { in real } \\ \mathrm{GDP}^{2} \\ \hline \end{gathered}$ | Unemployment | \% Change in consumer price index | Prime interest rate, $\%$ | Real interest rate, \% | \% Gain S\&P 500 stock index | Nominal cattle prices, \$ | Real ${ }^{3}$ cattle prices, $\$$ | U.S. Beef cattle numbers ( 1000 's) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1970 | (0.3) | 4.9 | 5.6 | 7.91 | 2.31 | 0.1 | 28.40 | 70.12 | 43,120 |
| 1971 | 2.8 | 5.9 | 3.3 | 5.72 | 2.42 | 11 | 30.90 | 73.92 | 44,541 |
| 1972 | 5.0 | 5.6 | 3.4 | 5.25 | 1.85 | 16 | 35.80 | 80.63 | 45,794 |
| 1973 | 5.2 | 4.9 | 8.7 | 8.03 | (0.67) | (17) | 45.30 | 91.89 | 48,354 |
| 1974 | (0.5) | 5.6 | 12.3 | 10.81 | (1.49) | (30) | 36.70 | 68.22 | 51,234 |
| 1975 | (1.3) | 8.5 | 6.9 | 7.86 | 0.96 | 32 | 39.30 | 69.07 | 54,351 |
| 1976 | 4.9 | 7.7 | 4.9 | 6.84 | 1.94 | 19 | 36.30 | 59.90 | 50,943 |
| 1977 | 4.7 | 7.1 | 6.7 | 6.83 | 0.13 | (12) | 38.50 | 59.05 | 47,919 |
| 1978 | 5.3 | 6.1 | 9.0 | 9.06 | 0.06 | 1 | 52.90 | 72.87 | 44,596 |
| 1979 | 2.5 | 5.8 | 13.3 | 12.67 | 0.63 | 12 | 69.20 | 83.98 | 42,589 |
| X | 3.38 | 6.2 | 7.41 | 8.10 | 0.76 | 3.21 | 41.33 | 72.96 | $\overline{47,344}$ |
| 1980 | (0.2) | 7.1 | 12.5 | 15.27 | 2.77 | 26 | 64.30 | 70.74 | 43,049 |
| 1981 | 1.9 | 7.6 | 8.9 | 18.87 | 9.97 | (10) | 51.00 | 52.85 | 44,910 |
| 1982 | (2.5) | 9.7 | 3.8 | 14.86 | 11.06 | 15 | 46.99 | 46.99 | 45,837 |
| 1983 | 3.6 | 9.6 | 3.8 | 10.79 | 6.99 | 17 | 46.50 | 44.75 | 44,276 |
| 1984 | 6.8 | 7.5 | 3.9 | 12.04 | 8.14 | 1 | 46.00 | 42.75 | 43,677 |
| 1985 | 3.4 | 7.2 | 3.8 | 9.93 | 6.13 | 26 | 49.40 | 45.07 | 40,912 |
| 1986 | 2.7 | 7.0 | 1.1 | 8.83 | 7.73 | 15 | 48.50 | 42.69 | 38,781 |
| 1987 | 3.7 | 6.2 | 4.4 | 8.21 | 8.21 | 2 | 57.20 | 48.35 | 38,943 |
| 1988 | 4.4 | 5.5 | 4.6 | 9.32 | 4.72 | 12 | 62.30 | 50.77 | 38,432 |
| 1989 | 2.9 | 5.3 | 4.8 | 10.87 | 6.07 | 27 | 61.40 | 49.52 | 38,922 |
| $\overline{\mathrm{X}}$ | 2.67 | 7.3 | 5.16 | 11.90 | 6.74 | 13.1 | 53.34 | 49.45 | 41,774 |
| 1990 | 1.0 | 5.4 | 5.4 | 10.01 | 4.61 | (4.5) | 68.00 | 52.03 | 39,179 |
| 1991 | (0.6) | 6.6 | 4.2 | 8.00 | 3.80 | 28 | 63.92 | 48.75 | 39,205 |
| 1992 | 2.1 | 7.5 | 2.9 | 6.00 | 3.1 | 4.5 |  |  |  |

${ }^{1}$ Sources: National Agriculture Statistical Services 1945-1991; United States Department of Labor, Bureau of Labor Statistics; United States Department of Comerce, Consumer Price Index.
${ }^{3}$ Averged across classes of cattle and adjusted for inflation using 1982 as the base year.

Rancher goals are typically either to maximize income from livestock on a sustained basis or to emphasize wildlife and esthetics with income from livestock being of secondary importance. Stocking rate approaches are available that can be applied to obtain either goal. When maximization of income from livestock is the primary goal, about $50 \%, 40 \%$, and $30 \%$ of current year growth of the primary forages can be harvested by livestock on humid grassland (tall grass), semiarid grassland (mid-grass and shortgrass prairies) and desert ranges, respectively. When wildlife, esthetics, range improvement, and minimization of financial risk are major goals, harvesting $25 \%$ of the forage by livestock is a good approach.

Regardless of stocking strategy every rancher needs a plan to deal with drought. Temporary confinement of livestock in drought periods has proven to befinancially effective on New Mexico ranges and should work just as well in Texas. Ranchers who buy hay and protein supplements during periods when prices are low and store them for drought when prices are high should maximize benefits from the confinement strategy. Reserving areas with high amounts of prickly pear or cholla cactus for use in drought can also be effective.

It has been thought by many ranchers and range managers that heavy stocking could be used if combined with specialized grazing systems. Considerable research is now available that shows these systems are an effective means of improving livestock distribution and providing preferred forage species and areas with a recovery period. However, under excessive stocking rates, specialized systems give the same adverse impacts on vegetation, livestock performance and financial returns as heavy continuous grazing.

Many ranchers ignore the business cycle when making stocking rate and other ranch management decisions. However, partial destocking during periods of high livestock prices and gradually restocking when prices are low can reduce risk and greatly improve income, particularly on the more humid ranges and with yearling cattle. A better understanding of the national economy and factors influencing commodity prices and interest rates would enable most ranchers to more completely attain their goals.

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# MANAGING STOCKING RATES TO ACHIEVE LIVESTOCK PRODUCTION gOALS IN NORTH TEXAS AND OKLAHOMA 

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## INTRODUCTION

Proper stocking of rangeland should allow livestock to efficiently and economically convert forage to a marketable product on a sustained basis. However, it is difficult to determine the optimum stocking rate because the accuracy of the decision is determined by events that cannot be controlled - especially climate and markets. Optimal stocking rates vary among years, range types, ranches and groups of cattle. Management objectives, production costs, attitudes about risk and the ability to manage risk differ among managers and this further influences the decisionmaking process.

No single plan can be advocated for all. With this in mind, managers should be familiar with the long- and short-term impacts of stocking rates on rangeland stability, livestock production and enterprise economics, and be able to implement livestock and business management practices that will provide some insurance in a catastrophe and generate additional income in times of plenty.

## STOCKING RATES AND LIVESTOCK PRODUCTION

The general relationships among stocking rates, livestock production, and net returns per acre are illustrated in Figure 1. Table 1 is a partial summary of research trials conducted on rangelands similar to, or located in, Oklahoma and north Texas and gives some idea of the degree to which performance is affected by stocking rates. As stocking rate increases, individual animal performance decreases but, production per acre increases. At some point, production per acre will peak and then begin to decline. Net returns per acre reach a maximum at a stocking rate between the greatest production per head and the greatest production per acre. The stocking rate at which net returns are optimized is determined by variable costs of production, market value of products, and the response of livestock to changing stocking rates.

## PRODUCTION RISK

As stocking rate increases, risk increases due to wider fluctuations of weight gain by growing livestock and reproduction by breeding stock (Shoop and McIlvain 1971; Whitson et al. 1982; Heitschmidt et al. 1990; Gillen and McCollum 1992). Untimely marketing of livestock especially breeding stock, to adjust stocking rates to prevailing weather and forage conditions, and increased production inputs, such as purchased forage or concentrate feeds to substitute for inadequate grazing, also reduce net returns and add to instability of income.

Table 1. Performance of cattle grazing at different stocking rates on various rangetypes found in the plains and prairies of Oklahoma and northern Texas. ${ }^{a}$ LIVESTOCK OPERATION:YEARROUND COW-CALF

| RANGETYPE | ACRE/ | CALF | WEANING WEIGHT |  |
| :--- | :---: | :---: | :---: | :---: |
| (LOCATION) | HEAD | CROP, \% | LBS/COWS EXPOSED | LBS/ACRE |
| Sandsage | 22 | 89 | 457 | 21 |
| prairie | 17 | 92 | 443 | 26 |
| (NW Oklahoma) | 12 | 81 | 327 | 27 |
|  |  |  |  |  |
| Mixed grass | 18.8 | 89 | 417 | 22 |
| prairie | 12.5 | 89 | 401 | 32 |
| (N Texas) |  |  |  |  |
|  |  | 83 | 476 | 31 |
| Mixed grass | 16 | 83 | 466 | 40 |
| prairie | 12 | 80 | 439 | 45 |

## LIVESTOCK OPERATION:SEASONAL STOCKER CATTLE

| $\begin{aligned} & \text { LOCATION/ } \\ & \text { RANGE } \end{aligned}$ | $\begin{aligned} & \text { MONTHS } \\ & \text { GRAZED } \end{aligned}$ | $\begin{aligned} & \text { ACRE/ } \\ & \text { HEAD } \\ & \hline \end{aligned}$ | WEIGHT GAIN |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  | LBS/HEAD | LBS/ACRE |
| Tallgrass | 5 | 4.1 | 253 | 62 |
| prairie | 5 | 3.3 | 256 | 79 |
| (Oklahoma) | 5 | 2.8 | 249 | 90 |
|  | 5 | 2.5 | 233 | 94 |
| Tallgrass | 5 | 5.0 | 233 | 47 |
| prairie | 5 | 3.3 | 240 | 73 |
| (Kansas) | 5 | 1.75 | 219 | 125 |
| Sandsage | 5 | 9.0 | 290 | 32 |
| prairie | 5 | 6.0 | 268 | 45 |
| (NW Oklahoma) | 5 | 9.0 | 363 | 40 |
|  | 11 | 6.0 | 322 | 54 |
| Midgrass | 5 | 10.2 | 278 | 27 |
| prairie | 5 | 8.9 | 277 | 31 |
| (SW Oklahoma) | 5 | 6.8 | 254 | 37 |
|  | 5 | 4.6 | 241 | 52 |
| Shortgrass | 5 | 5.0 | 210 | 42 |
| prairie | 5 | 3.5 | 191 | 55 |
| (W Kansas) | 5 | 2.0 | 128 | 64 |

[^1] et al. (1982), Heitschmidtdt et al. (1990), Launchbaugh and Owensby (1978), Shoop and Mcllvain (1971).


STOCKING RATE, HEAD/ACRE

Figure 1. General relationships among stocking rates, livestock performance, production per acre, and net returns per acre.

Results from the Texas Experimental Ranch illustrate the variation in production and income that can occur at higher stocking rates (Heitschmidt et al. 1990; Figure 2). The width of the boxes represents the variability in stocking rate adjustments during the 6 -study and the height of the boxes represents the variability in production and income. Compared to the moderately-stocked continuous and deferred-rotation systems, the heavily-stocked continuous and rotational grazing treatments required more stocking rate adjustments and more supplemental feed (average $250 \mathrm{lb} / \mathrm{cow} /$ winter compared to $53 \mathrm{lb} / \mathrm{cow} /$ winter). Analysis of production and economics from 1960-1978 at this site (Heitschmidt et al. 1982; Whitson et al. 1982) produced similar conclusions.

From 1990-1992, estimated returns for stocker cattle grazing mid-grass prairie in southwestern Oklahoma varied from $-\$ 8.43 /$ acre to $\$ 19.33 /$ acre depending upon the year and stocking rate (Table 2; Gillen and McCollum, 1992). The margin between purchase and sale prices, in addition to performance, caused the variation among years. The heaviest stocking rate returned the most profit in 2 years but the loss in 1991 offset any short-term benefit of the heavy stocking. In contrast, the light stocking rate was superior in only one year and total returns for the 3-year period were lowest for this rate. A stocking rate of 6.3 acre/head would have produced the most cumulative income for the 3-year period even though it appeared that income would have been sacrificed in 1990 and 1992.


Figure 2. Range in annual stocking rates, production per cow exposed and per acre, and returns to land, management, and profit for heavy (HC) and moderate (MC) continuous grazing, deferred rotation (DR), and short duration grazing (RG) at the Texas Experimental Ranch, 1982-1987 (adapted from Heitschmidt et al. 1990).

Table 2. Variability of estimated income from stocker cattle grazing midgrass prairie in southwestern Oklahoma, 1990-1991(Gillen and McCollum 1992).

|  | YEAR <br> STOCKING RATE, <br> ACRES/HEAD |  |  |
| :---: | :---: | :---: | :---: |
|  | 1990 | 1991 | 1992 |

In this situation, maximum net returns were similar over a wide range of stocking rates. Stocking between 4.8 and 9.3 acres/head (68-133 head/section) would have produced net returns (\$/acre) within $10 \%$ of the maximum. Similar calculations for tallgrass prairie indicate that stocking between 2.2 and 3.8 acre/steer (168-291 head/section) would produce net returns within $10 \%$ of the maximum (Gillen et al. 1992). These examples demonstrate that by stocking conservatively, the long-term risks of heavy stocking can be avoided without sacrificing profit.

Whitson et al. (1982) noted that with greater market uncertainty and higher production costs, producers should use more risk management practices and alternative means of generating income such as retained ownership.



Figure 3. Relationships between stocking rate and (a) weight gain (lbs/steer/day) and (b) net returns (\$/acre) for stocker cattle grazing tallgrass prairie or midgrass prairie in Oklahoma.

## SITE DIFFERENCES

Results of studies on Kansas and Oklahoma rangelands indicate that livestock response to stocking rates varies with the type of rangeland. Figure 3a illustrates the weight gain response of stocker cattle grazing tallgrass prairie and midgrass prairie in central and southwestern Oklahoma, respectively. In order to compare the responses on similar scales, stocking rate has been expressed as steer days of grazing per ton of forage instead of head per acre. The decline in weight gain as stocking rate increased was about four times as severe on midgrass prairie as on tallgrass prairie (Figure 3c).

## STOCKING RATES AND LIVESTOCK NUTRITION

Stocking rates can alter both the quality and the quantity of forage consumed by livestock. Studies in Texas and Oklahoma suggest that heavier stocking rates can result in periodic reductions in forage intake and altered diet quality (Stuth et al. 1986; Pinchak et al. 1990' McKown et al. 1991; McCollum et al. 1993).

## DIET QUALITY

Diet quality is affected by the mixture of green and dead forage, the ratio of leaves and stems, and the species composition of the forage available for grazing. Generally, quality of available forage is higher on ranges with a history of heavy stocking because the plants will be at more immature stages of growth and less dead forage is present. On the other hand, a short-term increase in stocking rate on range that has been was previously grazed lightly or moderately may result in lower diet quality because of consumption of dead, standing forage.

During periods of rapid forage growth, stocking rate may have little if any impact on animal nutrition and performance because the relative abundance of preferred food items is high. Observations in the tallgrass prairie region (McCollum et al. 1993), post oak savannah of Texas (Stuth et al. 1986), and mixed grass prairie of northern Texas (McKown et al. 1991; Pinchak et al. 1990) have found little if any negative influence of stocking rates on nutrient intake by cattle during periods of rapid forage growth.

Insensitivity to stocking pressure during rapid growth periods is part of the basis for the intensive-early stocking (IES) systems used in Oklahoma and Kansas (Owensby et al. 1988; McCollum et al. 1989; Olson et al. 1993). Under IES, stocking density (head/acre) is double or triple that of conventional grazing but the grazing season is reduced to about half the normal time. Grazing at these densities does not impact weight gain unless there is a shortfall in forage production due to drought or late initiation of growth in the spring. This approach is an effective means of increasing the efficiency of beef production from range forages with fast dry matter accumulation rates and(or) short-lived quality.

Over the long-term, changes in the species composition of the plant community may affect diet quality and forage intake. Heavy stocking reduced the amount of Texas wintergrass on mixed grass prairie (Heitschmidt et al. 1989) and western wheatgrass on shortgrass prairie (Launchbaugh and Owensby 1978). These species are cool-season perennials that contribute to winter diet quality. Cattle consumed $35 \%$ less Texas wintergrass on north Texas prairies with a history of heavy stocking (Pinchak et al. 1990). However, cattle compensated and maintained the nutrient content of their diet by consuming other warm-season grasses and annuals. Coolseason annuals also increase with overgrazing and can contribute to winter and spring diets. But, in some instances the cool-season annuals may actually be detrimental because of the livestock losing condition as a result of "chasing" these green plants in the late winter and early spring. Finally, annual broomweed has been associated with poor livestock performance in north Texas (Kothmann et al. 1971; Heitschmidt et al. 1982). Annual broomweed infestations are related to climate in more arid areas and to overgrazing in more humid areas. The problem with broomweed is that the plant canopy impedes grazing and forage intake.

Although livestock performance is depressed by stocking rates during the growing season, winter appears to be the period of major impact on cow performance. On sandsage rangelands in northwestern Oklahoma, approximately $50 \%$ of the weight advantage on yearround steer programs was due to winter performance (Shoop and McIlvain 1971; Table 1). Similar effects would be expected with cows. On the Texas Experimental Ranch (Knight et al. 1990; Heitschmidt et al. 1990) the critical time for cows under heavy stocking regimens was the two to three months just prior to calving. During this time period, cows grazing heavily stocked pastures lost more weight and condition than cows under moderate stocking. This was associated with lower nutrient intake (Pinchak et al. 1990; McKown et al. 1991) on the heavily stocked areas especially when forage standing crop fell below $700-900 \mathrm{lb}$ /acre. Inadequate body condition at calving can delay return to estrous and reduce breeding success. Tools that insure cows are in adequate condition, and(or) remove stress on poor condition cows should be part of a management program.

In the fall and winter, livestock will search for the more desirable plants and plant parts. Because plant tissue is not regenerated until the following spring, the availability of preferred forage progressively declines through the winter and livestock must search longer and expend more energy, or consume less palatable forage. On rangelands with coarse forages, such as the tallgrass species, this is a major concern because the leaf:stem ratios are lower and quality is lower than short stature grasses. As stocking pressure increases, leaf removal increases until the available forage material is primarily stems and reproductive culms. Grazing management in the late summer, fall, and winter to maintain the leaf:stem ratio as high as possible should improve performance.

## SUPPLEMENTATION

Supplemental feed programs are a primary cost item for cow production and, with the development of new approaches and ideas, supplemental feeding of stocker cattle is becoming a yearround practice. Judicious use of supplements (hay or concentrates) is a vital part of managing livestock under any stocking rate scheme.

Under moderate-stocking regimens, supplements will be fed at minimal levels to achieve production goals - generally to maintain or improve cow condition or rate of gain by growing animals. The type, amount, and timing of supplementation will depend upon the species in the plant community, forage availability and the nutrient requirements of the animals. Strategic supplementation with small amounts of supplement augments the value of standing forage rather than replacing nutrients that are not present later in the production cycle.

On moderately-stocked rangelands with cool-season perennial species, winter supplement requirements are relatively low compared to other rangelands which have no dominant cool-season plants. Heavy stocking reduces cool-season perennial plants making livestock more dependent on warm-season grasses for winter nutrition and increasing the need for supplemental nutrients. Also, intensive stocking on mid- and shortgrass ranges may create an overall forage shortage and depress intake. Thus supplements may be required to replace forage protein and energy, maintain cow performance and reduce the year-to-year fluctuations in animal performance that can accompany an intensive stocking plan. Hence supplementation is a risk management tool (Whitson et al. 1982).

A key factor affecting the postpartum anestrous period in cows is body condition at calving. Some weight loss prior to calving can be tolerated if the loss will not draw body condition too low. Without supplement during the critical period just prior to spring-calving, condition losses can delay rebreeding and reduce calf-crop during a restricted breeding season or increase the number of late calves in a long breeding season. Failure to adequately supplement cows under limited forage conditions will affect the weaned calf crop for at least two years beyond the initial problem. In the sandsage prairie example (Table 1), cows on the three stocking rates were supplemented similarly in the winter (Shoop and McIlvain 1971). The lack of additional feed was apparent in the heavily stocked cows.

Ranchers should monitor cow condition closely and implement practices that maintain or improve body condition, or use other measures to improve reproduction. This is especially important for cattlemen intentionally utilizing intensive grazing practices and for cattlemen managing through dry periods. Condition of springcalving cows should be checked in July to determine if summer or fall supplementation, or early-weaning of calves will be necessary to allow the cow to gain condition prior to winter. Supplementing small amounts before the dormant season is more efficient and effective than supplementing large amounts on dormant forage. Condition should be checked again at weaning to assess the need for early
supplements. Additional checks a couple of months prior to calving and at the start of the breeding season will alert the manager to any changes in feeding or management that may be required. Fall-calving cows should be checked in the spring to determine when weaning should occur; additional checks should coincide with the same production stages as the spring-calving cows.

Early-weaning of calves is an effective tool for managing cows in less than adequate body condition that pose problems for winter feeding and threaten subsequent rebreeding success. If cows have not regained condition in the spring or summer, weaning calves two to three months early will reduce the cow's nutrient requirements and increase body condition entering the fall and winter. In addition, dry cows consume less forage than lactating cows, so under limited forage situations, available forage will be spared for future use. Early-weaned calves can be successfully grown on the ranch, moved to a backgrounding facility, or placed directly in the feedlot. Moving calves off the ranch will also spare forage.

If cows enter the breeding season in marginal condition (score $4-5$ on a 10 point scale), separating the calves for a 48 -hour period during the breeding season will stimulate a return to estrous. This is not a useful practice in cows of less than condition score 4. The only stimulus for these cows is to wean the calves.

## IN SEARCH OF THE OPTIMUM

It is difficult to predict the optimum stocking rate for any given year because of the unpredictable impacts of weather and markets. Equations such as the one shown in figure 3a can be used to predict performance and budgeting can be used to generate net return curves (Figure 3 b and 4 b ). This information can be useful in stocker programs to make adjustments to prevailing markets or changes in cost inputs. Research is being conducted in Oklahoma to further develop methods that aid with setting stocking rates and understanding how production inputs may impact these decision.

If equations are not available for a specific situation, an individual may be able to glean the information from ranch records and develop useful relationships. Grazing records (pasture size, days grazed, and head per pasture), pay weights, and sale weights are a starting point for developing these relationships.

## IS IT NECESSARY TO INCREASE STOCKING RATE TO ACHIEVE RANCH GOALS?

The primary reason for stocking at heavier rates is to increase ranch income. However, the additional income is accompanied by additional risk (Shoop and McIlvain 1971; Whitson et al. 1982; Heitschmidt et al. 1990). Research with stocker cattle in Oklahoma, has indicated that stocking conservatively will produce income within $10 \%$ of the maximum on tallgrass prairie and midgrass prairie. Research with cow-calf programs on mixed grass prairie in north Texas and sandsage prairie in
northwest Oklahoma indicated that heavily-stocked systems may have no real longterm advantages compared to moderately-stocked systems. Therefore, if ranch goals require more income generation, other avenues will need to be pursued.



Figure 4. A relationship between stocking rate and (a) weight gain (lbs/steer/day) and (b) net returns (\$/acre) for steers grazing midgrass prairie in southwestern Oklahoma.

## RETAINED OWNERSHIP

All cattlemen should include retained ownership as a segment of their operation. It may not be necessary to retain ownership routinely but retaining ownership beyond the ranch can provide a safety net in times of seasonal market downturns or poor forage conditions and animal performance.

Results of the Ranch-to-Rail (Texas Agri. Ext. Ser.) indicated that feedlot profits (net returns over costs including cattle interest) averaged just over $\$ 65.00$ and $\$ 120.00 /$ head for steer calves fed in 1991-92 and 1992-93, respectively. In a 22 year summary, which included approximately 8000 steers and 6400 heifers from and Oklahoma ranch, retained ownership through the feedlot increased net profits $\$ 30.97 /$ steer and $\$ 23.18 /$ heifer. This represents income back to the ranch that can be obtained without changing stocking plans.

Data from Heitschmidt et al. (1990; Figure 1) was used to illustrate the potential value of integrating a retained ownership program into the ranch business (Table 3). This illustration assumes that half of the heifer calves and all of the steer calves are fed and that a feedlot profit of $\$ 30 /$ head is realized. In this example,
moderate stocking combined with retained ownership would have generated $\$ 5.62$ /acre compared to $\$ 5.25 /$ acre for a heavily stocked system selling calves at weaning. Hence, by combining moderate-stocking with retained ownership, the same or higher level of ranch profitability could be achieved without the risks and additional inputs associated with heavy stocking. This example also illustrates the value of retained ownership for increasing profits and acting as a safety net on heavily stocked (intentionally or unintentionally) ranches.

Table 3. Potential for generating income with retained ownership of calves into the feedlot.

|  |  | STOCKING RATE <br> MODERATEHEAVY |  |
| :--- | :---: | :---: | :---: |
| ACRES/COW |  |  |  |
| \% CALVES WEANED |  |  |  |
| \% OF WEANED CALVES FED |  | 16 | 12 |
| CALVES FED/COW | 83 |  | 80 |
|  |  | 62 | 75 |
| NET RETURNS AT WEANING, |  |  |  |

## FORAGE ALLOCATION TO ACHIEVE GOALS

Reallocation of forage may produce a mixture of livestock enterprises that produces more income without increasing stocking rate. Allocating forage to a stocker program, as well as a cow-calf program, will improve flexibility for adjusting to short-term markets and weather fluctuations and may improve income. Altering heifer development and bull maintenance programs can potentially free some stocking capacity for cows or stockers that will generate immediate income.

Another means of reallocating forage is the intensive-early stocking programs mentioned earlier. These programs do not change stocking rate, instead the same amount of grazing is reallocated to a shorter period of time. On tallgrass prairie, this increases gain per acre about $30-40 \%$ without increasing stocking rate and can have significant impacts on the ranch economy (Bernardo and McCollum 1987). This approach may be useful on other rangelands.

## CONCLUSIONS

Proper stocking rates can be judged by evaluating individual animal performance and profitability, the presence of the major desirable grasses and forbs adapted to each range site, and a patchy covering of ungrazed forage remaining at the end of the growing season and at the start of the next growing season. Rangelands should be stocked at a rate that will maintain desirable, vigorous plant species from season to season. Efficiently utilize available forage by encouraging livestock to graze the range as evenly as economically feasible and allocating grazing to different classes of livestock.

Prior to increasing stocking rates, a manager should explore all means of increasing livestock income both on the ranch and beyond the ranch. If stocking pressure is increased, more intense livestock management will be necessary to stabilize production. Finally, a stocking plan should maintain the flexibility to capitalize on short-term benefits of increased stocking but also adjust to unfavorable conditions without suffering losses.

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# MANAGING STOCKING RATES TO ACHIEVE LIVESTOCK PRODUCTION goals on the edwards plateau 

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## INTRODUCTION

The Edwards Plateau is a very unique geological uplift located in southwest Texas between $98^{\circ}$ and $103^{\circ}$ west longitude and $29^{\circ}$ and $32^{\circ}$ north latitude. It covers approximately 23,000 square miles and includes all or parts of 28 counties. The region is bounded on the west by the Pecos River; on the north, northwest, and northeast by the physical limit of the Cretaceous rocks (limestone rocks formed from marine deposits during the Cretaceous period when a shallow sea covered this area); on the east by the Llano uplift; on the south and southeast by the Balconies fault system which forms a distinct boundary; and on the southwest by the Rio Grande.

Before Europeans brought permanent settlements and their domestic livestock to the plateau, the region bore a far greater resemblance to the vast, more northerly expanse of central North American grasslands than is the case today. In an attempt to address the topic of meeting livestock production goals through grazing management, namely managing stocking rates, it is important to understand the development of the early livestock industry of this region and the resultant changes in the vegetation and how that affects current livestock production. A brief historical perspective will be presented first and then a more detailed discussion of the principles and concepts of stocking rate will follow. Also, it should be stated that livestock production goals are generally made with specific short- and long-term goals in mind.

## HISTORICAL PERSPECTIVE

## Development of the Ranching Industry

For over a 150 years Edwards Plateau Ranchers have used domesticated livestock to harvest range vegetation. Although the purpose of this ranching activity probably has changed little over this time span (providing food and fiber for society), technology and rancher attitudes have undergone considerable change. Most of the early ranching period of the Edwards Plateau was characterized by the "open range" where livestock roamed free. This period followed the elimination of the buffalo and before fences and windmills were developed on the Plateau. Because of the lack of permanent surface water, the livestock industry was concentrated along streams and rivers and only developed later in the drier regions of the Edwards Plateau.

Most of the early ranchers were of European ancestry and they moved onto the Plateau from either humid farming areas east of the Plateau or they came directly from European countries characterized by mild climates and deep soils. The Edwards Plateau rangeland was a kind of land that was new to the overwhelming majority of settlers including educators and legislators. For the first time many were living in a semiarid environment on shallow rocky soils, and without previous ancestral experience to draw from, they had to contend with the complex and dynamic vegetation and climate found on the Edwards Plateau with limited knowledge about proper grazing management; many mistakes were made and centuries of farming had to be unlearned.

Important changes occurred in the use of these lands in the late 1880's with the development of windmills and barbed wire. This allowed ranchers to settle the drier regions of the Plateau and subdivide the region into pastures. This also marked the end of the "open range" and encouraged ranchers to purchase and develop their own land. About 1910 ranchers started building wolf-proof fences. This type of fence was constructed of woven wire with six-inch mesh, 42 to 52 inches high, attached to cedar posts, with a barbed wire on the ground (sometimes one on both sides of the posts at ground level), and two or three barbed wires above the woven wire.

The significance of these technologies cannot be overemphasized: they accelerated the private ownership of land; allowed ranchers to water stock over the entire Plateau within fenced boundaries; and, allowed ranchers to keep the Plateau relatively predator free. These conditions significantly increased the efficiency of ranching and set the stage for the development of a major livestock industry in the Edwards Plateau involving cattle, sheep and goats.

While the initial development of the livestock industry was a great success, it was apparent that Edwards Plateau ranchers faced many problems. One major problem was created by the continuous stocking of pastures at very heavy rates. Early records indicate that stocking rates in excess of 150 animal units/section yearlong were common in the early 1900's (animal unit equivalent has a demand rate of 17.6 pounds of forage per day). Because of these excessive stocking rates, the productivity of the rangeland resource was severely reduced. The more productive plants were mostly reduced or eliminated from the vegetative complex which exposed the soil and increased erosion rates and decreased water infiltration. Undesirable brush increased along with an increase in poisonous plants. Ranchers were loosing large numbers of livestock and they did not understand why. They did not have the necessary information to make an assessment of the inputs needed to meet their livestock production goals.

## SEARCHING FOR INFORMATION

The year 1914 had been extremely dry in Sutton and Edwards Counties and ranchers were loosing goats to some unknown disease. One Sutton county rancher (R.E. Taylor) who had suffered a significant death loss of his goats made a comment
to his neighbor (B.M. Halbert) "wouldn't it be nice if an experiment station was located in the heart of the sheep and goat industry to study our problems and recommend ways to improve our ranching operations". Mr Halbert suggested that they bring this matter up with their neighbors and seek support for their idea. This idea was later approved by the Texas Sheep and Goat Raisers's Association and with the help of Texas A\&M University and the Texas Legislature the Texas Agricultural Research Station was established between Sonora and Rocksprings.

These early ranchers showed a lot of wisdom and foresight in helping establish a research station that would address the problems involved in ranching in the Edwards Plateau. Most of the early research dealt with animal health and husbandry; however, there was concern that the range was being severely overgrazed. In 1920, a graduate student working on the Research Station reported the typical stocking rate for Sutton county. Here are his comments: "The year of 1920, in which this study was made, was above the average in rainfall, but there is no way to tell whether the ranges were over- or under-stocked. They were running in August of 1920 enough livestock to consume, on the average, the equivalent of 105 animal units per section. The Ranch Experiment Station, which may be taken as representative of the average range in the county, has tentatively adopted 104 carrying capacity units per section as the basis for stocking its pastures. Whether or not this is the true normal, only time can tell."

The stocking rates continued to decline on the Sonora Research Station and by the 1950's the recommended stocking rate was 48 animal units/section yearlong (Fig. 1). Over the last five years stocking rates have varied from 24 to 36 animal units/section on the Sonora Research Station depending on the kind of year.

## STOCKING RATE

Stocking rate is the most important grazing management decision of a ranching enterprize. Under stocking results in wasted forage and lower total animal production. Over stocking results in damage to the forage resource and lower individual animal production. Furthermore, the optimum stocking rate is not a constant but varies depending upon the current year's conditions. Since yearly rainfall in the Plateau is highly variable (Fig. 2) and moisture is the primary driving force for forage production, it is easy to see that balancing animal demand with forage supply is a difficult task. Obviously, principles are needed to guide stocking rate decisions.

Strong relationships exist between stocking rate and animal production. An understanding of these relationships is essential to the meeting the goals of livestock production. Stocking rate is a function of three things: 1) the land area, 2) the number of animals, and 3 ) the time that the animals graze on the land. Given these 3 factors and the demand rate for an animal unit equivalent ( 17.6 pounds/day), stocking rate can be determined and accurately expressed.



The law of diminishing returns governs the relationship between stocking rate and animal production. Forage may be considered as the basic resource and animals as the inputs. At low stocking rates, the production per animal is not affected by the addition of an additional animal. As the stocking rate is increased, the forage resource remains constant or begins to decline, and a point is reached where animals are competing with each other for food. The addition of another animal will reduce the production of each individual animal on the pasture, but the total animal production from the pasture will continue to increase. If enough animals are added to the pasture, individual animal production will decline to the point that total production will also decline. If you are stocked at this level, you are probably losing both money and forage resource (Fig. 3). Proper stocking will be greater than the point of maximum gains per animal and less than the point of maximum gains per unit of land.

Fig. 3. Conceptual model of livestock response to stocking rate.


## DIET QUALITY

Grazing animals exhibit a strong preference for green leaves over stems and dead forage; therefore, both animal production and carrying capacity are largely functions of the amount of green leaves that animals can harvest. Also, the level of forage quality required to meet the nutritional requirements of animals varies considerably among kinds and classes of animals. Forage quality requirements tend to be inversely proportional to the size of the animal; smaller animals having the higher requirements. Nutrient requirements are higher for lactating that for dry animals
and for growing than for mature animals. Pregnancy also increases nutrient requirements slightly. It is generally not good animal husbandry to graze animals having high nutrient requirements on forage with either low nutrient content or high in secondary chemicals. Either the feed bill will be high or the level of animal performance will be low! Selecting cows with high milk-producing potential may be good management if high quality pasture is available but will not be advisable on range that has a rough topography and supports mostly woody plants such as oak and juniper species.

## MULTI-SPECIES GRAZING

Multi-species grazing allows, within limits, an increase in stocking rate without adversely affecting individual livestock performance or the range resource. If is one of the few practices available for semi-arid rangelands to increase livestock production with positive economic returns.

If the use of rangelands by two or more species of livestock increases livestock production, then what can this increase be attributed to? In general it can be attributed to: 1) More efficient use of the total vegetative complex. This is possible because of the different preferences exercised by different kinds of animals. If grazing pressures are not excessive, less animal-to-animal competition for any one plant species will result, thus allowing for possible improved range condition and increased livestock production. 2) More efficient use of the available terrain by different species will reduce competition for forage. 3) Increased reproduction efficiency may result from using sheep and goats, both of which have greater reproductive potential than cattle. 4) Reduction of internal and/or external parasite infestations in the pasture may enhance animal performance. 5) Finally, mixed species grazing may reduce poisoning from toxic plants because of reduced grazing pressure on the preferred forage species.

The use of rangelands by two or more species of livestock can increase livestock production by increasing both animal performance and production per unit area. However, a deeper understanding is needed of the mechanisms by which livestock response is enhance by multi-species grazing. To accomplish this, one has to take into account the complex interactions between the different grazing habits of the animals species, the species composition and the stage of growth of the vegetation, and understand that these interactions may differ with stocking rates, animal species ratios and system of grazing.

In terms of livestock production, optimum stocking rate depends on the species of grazing animal. In the Edwards Plateau, Goat production is less affected by stocking rate and animal mix than sheep or cattle (Fig. 4). Even though their nutrient requirement are higher than other domestic livestock, goats are able to maintain a high level of efficiency because of their opportunistic foraging behavior. Goats also have a smaller rumen to body weight ratio than cattle or sheep which requires them to feed more selectively. A bipedal grazing stance (ability to forage
standing on their hind legs) and a prehensile tongue, provide goats the ability to select a higher quality diet.


Sheep production is less affected by stocking rate than cattle production. Sheep have a rumen volume to body weight ratio similar to cattle, but they have a much smaller mouth which allows them an advantage in terms of forage selection. This is especially true when animals are forced to select their diets from short or low growing vegetation as a result of excessive stocking rates.

Even though cattle have lower nutrient requirements, per unit body weight, than either sheep or goats, their productivity is more quickly and intensively affected at higher stocking rates. Cattle sweep forage into their mouth with their tongue where it is pinched between the upper plate and lower teeth and torn off. This type of harvesting mechanism prevents cattle from efficiently grazing either short forage or woody plants. On rangelands where long-term excessive stocking rates have eliminated most of the taller grasses and increased woody plants, cattle production may be severely restricted.

## MAXIMUM SUSTAINED LIVESTOCK PRODUCTION

One of the grazing management objectives frequently quoted throughout the years of grazing on the Sonora Research Station was maximum sustained livestock production. These words infer that livestock production is not adversely affected
over time. However, the problem with this philosophy is that management for maximum livestock production in the short term generally results in a false perception of sustained production. A more in depth review of the grazing management research on the Sonora Research Station will clarify what I mean by a false perception of sustained production.

In 1949 various grazing management research treatments were initiated. One of these experimental treatments included the 4 -pasture deferred-rotation grazing system. This grazing system was designed to reduce problems created by selective grazing and poor grazing distribution which were common on the continuously grazed pastures. Under this grazing system and with a moderate stocking rate, both livestock and vegetation were improved over continuous grazing. A 5-year analysis of the data indicated that a 4-pasture system "should be practiced to obtain maximum weight gains and wool and mohair production, as well as maximum vegetation improvement" (Merrill and Young, 1952). The researchers also concluded that a base stocking rate of 48 animal unit years per section was moderate. As these grazing treatments progressed over the years, vegetation composition continued to improve in pastures under the 4-pasture management. In 1959 a decision was made to increase the base stocking rate from 48 to 64 animal unit years per section. This decision was based on both vegetation improvement and an attempt to maximize livestock production on a sustained basis. The higher stocking rate was maintained until 1963, when it was reduced to 48 animal unit years per section because of decreased livestock production and a downward range trend. The increased stocking rate was justified because forage increased and there was a need to match animal numbers with forage production.

Another important factor was juniper encroachment. Because juniper was not perceived to be a great threat to current carrying capacity it was ignored (all of the juniper had been removed from the station in 1950). Instead of using the extra forage production as a justification for increasing stocking rate, this forage could have been used for fuel for prescribed burning to control the encroachment of undesirable brush. If the latter option had been chosen true sustained livestock production might have been achieved. Those same pastures have been managed under moderate stocking with the same 4-pasture deferred rotation management since 1948 and current carrying capacity is down to 24 animal unit years/section.

A critical flaw in grazing management research is that we sometimes try to keep grazing research separate and apart from other components of the range resource. In the Sonora research program, burning was not considered because it was not "grazing management research". This coupled with the desire of the researchers' goal of striving for maximum sustained livestock production in the short-term actually led to long-term instability. The purpose of this example is not to criticize previous research. These early researchers made significant contributions to understanding how range ecosystems function. In fact, because of their well designed experiments, we can develop sound alternative hypotheses. I'm sure that someone in the future will cast a critical view on our current grazing management research. My point is,
livestock producers often make mistakes because they concentrate efforts on those things they either enjoy doing most and/or have a better understanding of.

We could engage in a long debate about management needed to maximum sustain livestock production for the Edwards Plateau. However, regardless of our approach, a long-term view must be taken with system stability as a main priority. If stocking rates are excessive and the more desirable plants are over harvested then system stability declines. A shift in vegetation composition from midgrasses to shortgrasses and an increase in bare ground greatly increases the amount of erosion. Erosion but only exports nutrients needed for forage production but it reduces soil depth. As the water storage capacity of the soil decreases water availability decreases.

On the Sonora Research Station, livestock production can be severely reduced by poisonous plants. Sheep death losses to bitterweed poisoning occurred in 13 of the 21 years on heavy continuously grazed pastures stocked with sheep, and only 8 years under both moderate and light stocking rates. Death losses were greater for sheep and goats at the heavier stocking rates (Fig. 5).

## WHAT IS THE PROPER STOCKING RATE?

The correct stocking rate for a particular pasture involves more than obtaining the desired level of animal performance; it also includes the ability of the vegetation to withstand grazing pressure and the range improvement goals.

At Sonora, a $20-\mathrm{yr}$ cattle production study indicates that (steer gains) light (24 auy $/ \mathrm{sect}$ ), moderate ( 48 auy $/$ sect and heavy ( 72 auy $/ \mathrm{sect}$ ) stocking rates average 8.6 14.4 and 17.5 lbs per acre, respectively; while production per head averaged 262,225 and 179 lbs , respectively. Maximum production occurred at the heavier stocking rate (Fig. 6). A more recent study from the Texas Range Station at Barnhart has similar trends (Fig. 7). In both studies young growing animals were used to measure livestock responses to the different stocking rates. If reproducing animals had been used, the potential for a greater difference in livestock production between stocking rates might have been greater. If animals lost weight below a critical level during the breeding season, then reproduction would be significantly affected, regardless of subsequent forage conditions. During dormant periods with a year, animals in the heavier stocked pastures lost considerably more weight than animals in the lighter stocked pastures during dormant periods within a year. When forage conditions improved the animals that lost the most weight generally gained the most (i.e., compensatory gain). A harsh winter followed by an average summer, in terms of growing conditions, can result in little difference in per head production between stocking rates at the end of the study year (fall). There appears to be tremendous potential to increase livestock during above average rainfall years; however, inreality it is very difficult to harvest additional growth with increased stocking. One strategy might be to hold over offspring and use them to harvest the additional forage produced in a good year (i.e., maintain a base herd or breeding herd at $75 \%$ of the

Fig. 5. Average death losses (\%) of sheep and goats attributed to bitterweed and sacahuista from 3 stocking rates on the Sonora Research Station (21 years) 10



Fig. 6. Cattle production (iba/ac and hoa/hd) at light, moderite and heavy stocking racea.

normal carrying capacity and then use offspring to manipulate stocking rates up and down depending on forage conditions). In reality the most important question to ask is, "What is the most economical stocking rate?" Range economists report that maximum net income generally occurs at a lower stocking rate than maximum livestock production. Also resource stability is much greater at moderate than heavy stocking rates.

## CONCLUSION

Animal production is greatly affected by stocking rate. Livestock production on a per acre basis increases with increasing stocking rates to a maximum and then declines. Livestock production per head declines with increasing stocking rate. The stocking rate at which maximum production/acre is achieved varies as a function of rate of decline in individual/head production. Proper stocking will be greater than the point of maximum gains per animal and less than the point of maximum gains per unit of land.

If grazing can be controlled to prevent damage to the vegetation, higher stocking rates can be used to increase livestock production. However, be aware that as the stocking rate increases, the cushion of "reserve forage" decreases. This means that more frequent adjustments to stocking rate will be required to prevent overstocking in poor forage years. Also, even if heavy stocking does not accelerate the invasion of noxious plants such as juniper and prickly pear, heavy stocking will significantly reduce fuel loads and possibly eliminate the option of using fire as a brush control tool.

Again, let us emphasize, the higher the stocking rate, the greater the requirement for flexibility in stocking rate and the greater the risk!

# MANAGING STOCKING RATES TO ACHIEVE LIVESTOCK MANAGEMENT GOALS IN SOUTH TEXAS 

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## INTRODUCTION

Determining the number of animals to be placed on a range is the principal factor affecting the relative success of any grazing management strategy (Heitschmidt and Taylor 1991).

A rancher must balance both his finances and the range/livestock operation to be successful in the ranching business (Stoddart et al. 1975). It is often difficult to accomplish this balance when livestock numbers must be high to achieve a positive financial situation in the short run. In the long run, however, it is advantageous to the range and the financial situation of the rancher if the stocking rate is conservative, and if trend in range condition is upward.

Moderate to high range condition must be maintained to sustain a range livestock operation over the long term. Livestock production goals including high pregnancy rates, high calf crops, and high weaning weights can be sustained only under good range conditions. To sacrifice range condition for short-term gains can only lead to long-term failure. This situation is even more real in south Texas where rainfall is highly unpredictable, and droughts are common.

Lehmann (1969) presented his grazing philosophy for the Rio Grande Plain: "...In this region of widely fluctuating rainfall and hence of widely changing forage supplies, therefore, raising maximum quantities of quality grass -- and accomplishing efficient harvest -- involve much more than setting livestock populations 'safe' for 'normal' years. Substantial improvement actually requires developing practical systems for getting animal populations equal to the task of efficient harvest onto the ranges when grass crops are 'ripe' for harvest -- and for supporting domestic animals off major grass producing areas when harvest has been accomplished. ... In south Texas, however, orderly programs of range deferment break down during droughts when most pastures should not be grazed at all." The south Texas rancher must prepare for both the lean years and the good years in his range/livestock operation. Ranchers who stock lightly during droughts survive with more assets and less financial loss than those who stock heavily.

## Generalized Concept of Animal Production and Stocking Rate

The response of animal production to stocking rate generally shows high gains per animal at low stocking rates and high gains per unit of range at heavy stocking rates (Stoddart et al. 1975, Figure 1). Heavy or light stocking gives lower profits than moderate stocking. As stocking rate increases, production per animal unit declines and productivity per unit area increases. Lowered productivity is expressed as lowered weaning weights, lowered pregnancy rates, lowered calf crop percentages, and lowered seasonal cow weights. As stocking rate increases, animals tend to feed longer and travel more. Forage intake may be lower as stocking rate increases because forage becomes more scarce. With lowered stocking rate, diet and intake are not limited and animal productivity is increased.

Sarvis (1941, as quoted in Stoddart et al. 1975) conducted the classic experiment to measure the effects of stocking rate on animal production in North Dakota. On mixed shortgrass and midgrass prairie stocking rates were about 10, 7, 5 , and 3 acres per steer over a 5 -month grazing season. Gains per animal were successively lower, and gains per unit area were successively larger with increased stocking rate.


Figure 1. Optimum animal production is neither with maximum gains per unit area nor per head. Moderate stocking provides greater returns in the short run and assures continued high forage yields (Stoddart et al. 1975).

## The South Texas Experience

Few studies comparing different stocking rates have been conducted in south Texas. Chamrad et al. (1982) examined the efficiency and economics of grazing systems in the northern Rio Grande Plain during 1977-81. This study included a four-pasture, three-herd, deferred rotation (4PDR) system and a continuous, yearlong (CYL) system, both at 22 acres/animal unit (AU), and six-pasture, one-herd highintensity, low-frequency (HILF) system at 16 acres/AU. Calving percentage was highest on CYL, intermediate on HILF, and lowest on the 4PDR.

Calf weaning weights were higher on 4PDR. Per acre beef production was higher on HILF. Net income per acre was highest on HILF.

Stuth and Hanson (1988) examined diet selection and nutrient intake of cattle in the central Rio Grande Plain in a series of graze-out trials to determine community attributes that affect the ability of cattle to select nutrients as forage supply is depleted. Dietary browse consumption increased as residual herbage mass decreased. Intake of digestible energy increased as residual herbage mass increased.

In the Gulf Coastal Prairie, cattle performance remained high regardless of grazing treatment (Drawe 1988). All studies used a single moderate stocking rate of 12.5 acres/AU. Grazing treatments had no effect on spring or fall cow weights; however, calf weaning weights were lower under HILF (Table 1). Pregnancy rates, beef produced per cow, and net profit per acre were higher under CYL; whereas, calf crop sold and beef produced per cow were highest under 4PDR. Feedlot performance was best in calves from HILF.

Table 1. Average cattle performance over 7 years (1976-82) at one stocking rate ( 12.5 acres/animal unit) under three grazing treatments in the Texas Gulf Coastal Prairie. Numbers in the same row followed by a different letter are significantly different at $\mathrm{P}<0.05$.

|  | Continuous, <br> yearlong | Four- <br> pasture, <br> deferred- <br> rotation | High- <br> intensity, <br> low- <br> frequency |
| :--- | :---: | :--- | :--- |
|  |  |  |  |
| Spring cow weights (lb) | 895 a | 880 a | 880 a |
| Fall cow weights (lb) | 985 a | 960 a | 960 a |
| Pregnancy rate (\%) | 88 | 85 | 83 |
| Calf crop sold (\%) | 89 | 91 | 89 |
| Calf weaning weight (lb) | 512 a | 498 a | 476 b |
| Beef produced/acre (lb) | 43 | 45 | 28 |
| Beef produced/cow (lb) | 468 | 449 | 417 |
| Feedlot performance (lb/d) | 2.18 | 2.40 | 2.50 |
| Net profit/acre (\$) | 3.65 | 2.87 | 1.52 |

These data are indicative of the responses that can be expected from conservative stocking rates on native rangeland in the Texas Gulf Coastal Prairie. However, the per acre net profit is not impressive when compared to improved pastures. Neither is it impressive when compared to income from wildlife leases.

A follow-up study was conducted on the Welder Wildlife Refuge from 1983 through 1987 to determine the effects of (1) CYL grazing at two grazing intensities, heavy (H; 7 acres/AU) and moderate (M; 14 acres/AU), (2) 4PDR grazing at two grazing intensities, heavy (H) and moderate (M), and (3) cell-type, short duration grazing (SDG) at a variable heavy to moderate intensity upon vegetation and cattle (Drawe 1991). Cow weights, calf weights, calf crop percentages, pregnancy rates, expenses, and economic performance were monitored.

Cow weights were lower under SDG than on either CYL or 4PDR except for fall 1983. Comparing heavy stocking rates, cow weights on SDG were consistently lowest during spring and were lower on SDG in 3 of 5 years during fall. The treatment with highest spring cow weights occurred in heavy or moderate CYL or M4PDR across years (Table 2). Highest fall cow weights occurred in MCYL and heavy or moderate 4PDR across years (Table 3). CYL or 4PDR at either the heavy or moderate stocking rate had little effect on cow weights.

Table 2. Average spring cow weights on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge, 1983-1987. Within years, averages followed by a different letter are significantly different at $\mathrm{P}<0.05$ by Tukey's Studentized Range (HSD) Test. Number of animals comprising the average is in parenthesis following each weight.

| System |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Intensity | 1983 | 1984 | 1985 | 1986 | 1987 |
| Continuous, Yearlong |  |  |  |  |  |
| Heavy | 1008a(30) | 945a(30) | 907c(60) | 989c(60) | 1072b(60) |
| Moderate | 955 b (30) | 928a(30) | 933b(10) | 1064a(60) | 923e(60) |
| 4-Pasture, Deferred-Rotation |  |  |  |  |  |
| Heavy | 974b(30) | 886b(60) | 971a(30) | 982c(90) | 1048c(90) |
| Moderate | 996a(60) | 953a(90) | 976a(30) | 1029b(90) | $1113 \mathrm{a}(90)$ |
| Cell, Short Duration |  |  |  |  |  |
| Heavy to |  |  |  |  |  |
| Moderate | 911c(30) | 871b(30) | 895c(30) | $977 \mathrm{c}(30)$ | $991 \mathrm{~d}(30)$ |

Table 3. Average fall cow weights on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge, 1983-1987. Within years, averages followed by a different letter are significantly different at $\mathrm{P}<0.05$ by Tukey's Studentized Range (HSD) Test. Number of animals comprising the average is in parenthesis following each weight.

| System |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Intensity | $1983{ }^{1 /}$ | 1984 | 1985 | 1986 | 1987 |
| Continuous, Yearlong |  |  |  |  |  |
| Heavy | 981b(30) | 999a(30) | 1052b(60) | 1018c(60) | 1076b(60) |
| Moderate | 954c(30) | 1002a(30) | 1072a(60) | 1048b(60) | 1061bo(60) |
| 4-Pasture, Deferred-Rotation |  |  |  |  |  |
| Heavy | 1039a(60) | 935 b (60) | 1019c(90) | $1038 \mathrm{bc}(120)$ | $1048 \mathrm{~cd}(90)$ |
| Moderate | 1030a(90) | $993 \mathrm{a}(90)$ | 1044b(90) | 1076a(60) | $1114 \mathrm{a}(90)$ |
| Cell, Short Duration |  |  |  |  |  |
| Heavy to |  |  |  |  |  |
| Moderate | 982b(30) | $885 \mathrm{c}(30)$ | $945 \mathrm{~d}(30)$ | 973d(30) | 1031d(30) |

1/ Weights taken in June 1983.
Percent pregnancy was lower on SDG than on the other treatments (Table 4). On average the highest pregnancy rate was obtained from H4PDR. In 1984, percent pregnancy on SDG was $42 \%$. This extremely poor conception rate was attributed to poor nutrition on the cell-type, SDG treatment (Soltero et al. 1989). A short-term drought occurred during summer 1984, and forage slowly declined on all pastures and treatments. The most severe drought effect was observed in the SDG cell. As cattle were rotated from pasture to pasture on the 3-day schedule, forage steadily declined and eventually the pastures were bare. During the drought, forage intake and nutritional level of the cattle declined steadily (Soltero 1991). Cattle dietary crude protein averaged $9.1 \%$ and $9.7 \%$ under moderate and heavy CYL, respectively; heavy and moderate SDG had crude protein values of $8.9 \%$ and $8.5 \%$, respectively.

Average percent calf crop was highest under M4PDR (Table 5). Across years it was highest on MCYL or M4PDR. In 1984 SDG equalled M4PDR. In this instance calf crop is a reflection of the number of calves raised from $100 \%$ pregnant cows placed in the herd in September of the preceding year. In other words, after pregnant cows were placed in the cell, they raised almost as high a percentage of calves to weaning as on the other treatments. The last column in Table 5 is presented to show the percentage of cows exposed to bulls that raised

Table 4. Pregnancy rate of cows on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge, 1983-1987.

| System | \% Pregnant |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Intensity | 1983 | 1984 | 1985 | 1986 | 1987 | Avg |
| Continuous, Yearlong |  |  |  |  |  |  |
| Heavy | 92 | 84 | 89 | 77 | 69 | 82 |
| Moderate | 92 | 88 | 80 | 85 | 83 | 86 |
| 4-Pasture, Deferred-Rotation |  |  |  |  |  |  |
| Heavy | 92 | 88 | 92 | 93 | 83 | 90 |
| Moderate | 92 | 91 | 87 | 85 | 73 | 86 |
| Cell, Short Duration |  |  |  |  |  |  |
| Heavy to Moderate | 89 | 42 | 81 | 94 | 75 | 76 |

Table 5. Percent calf crop marketed from cows on three grazing treatments and two grazing intensities on the Welder Wildlife Refuge, 1983-1987.
$\left.\begin{array}{lllllll} & & & \begin{array}{l}\text { Average \% of } \\ \text { Calf Crop } \\ \text { Marketed from } \\ \text { Cows Exposed } \\ \text { to Bulls }\end{array} \\ \text { (Avg. Table } \\ \text { 4 x Avg. } \\ \text { Table 5) }\end{array}\right]$
calves to market age. Non-pregnant cows were sold after pregnancy testing in August each year, and only pregnant cows were on the treatments from August until calving in December-February.

Calf weaning weights were variable (Table 6). In 1983 the highest weaning weight was from M4PDR, and the lowest was from MCYL (Table 6). Conversely, in 1984 the highest weaning weight was from MCYL. In 1985 the highest weaning weight was in M4PDR. In 1986 the highest weaning weight was on HCYL, and the lowest was on SDG. Conversely, in 1987 the highest weaning weight was on SDG, and this weight was comparable to that from HCYL. These data show that CYL and 4PDR produce acceptable weaning weights in most years. The fact that SDG produced equally high weaning weights in 1983 was probably because this was the first year of study and the heavy stocking rate had not yet taken effect in the cell. After the 'crash' of the SDG treatment in 1984, the stocking rate was reduced, and by the last year of study the calves in the cell were as heavy as calves from CYL, and heavier than calves from 4PDR.

Table 6. Average calf weaning weights on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge. Number of animals comprising the average is in parenthesis following each weight. Within years, averages followed by a different letter are significantly different at $\mathrm{P}<0.05$ by Tukey's Studentized Range (HSD) Test.

| System |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Intensity | 1983 | 1984 | 1985 | 1986 | 1987 |
| Continuous, Yearlong |  |  |  |  |  |
| Heavy | 488a(80) | 505b(70) | 497c(115) | 525a(82) | 547ab(101) |
| Moderate | 445 b (25) | 517a(21) | 515b(21) | 506a(29) | (0)/1 |
| 4-Pasture, Deferred-Rotation |  |  |  |  |  |
| Heavy | 494a(81) | 468c(154) | 508bc(198) | 508a(185) | 535bc(170) |
| Moderate | 497a(85) | $512 \mathrm{ab}(132)$ | 532a(105) | 514a(63) | 526 c (100) |
| Cell, Short Duration |  |  |  |  |  |
| Heavy to |  |  |  |  |  |
| Moderate | 496a(67) | 460c(69) | 504bc(48) | 477b(24) | 554a(56) |

1/Missing data
Average pounds of beef produced per acre was greatest under heavy grazing: H4PDR produced the greatest, HCYL was intermediate, and SDG lowest (Table 7). Moderate grazing produced consistently lower weights on a per acre basis. In 1987 SDG produced the highest weight of beef per acre.

Pounds of beef produced per cow was consistently higher under M4PDR (Table 8). In 1983 and 1984 H4PDR was lowest. In 1985 HCYL was lowest, in 1986 MCYL was lowest, and in 1987 HCYL was lowest. Lowest average pounds of beef produced per cow was on HCYL.

Table 7. Average weight (pounds) of beef produced per acre on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge, 1983-1987.

| System | 1983 | 1984 | 1985 | 1986 | 1987 | Avg_ |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Intensity |  |  |  |  |  |  |
| Continuous, Yearlong | 60 | 57 | 60 | 57 | 56 | 58 |
| Heavy <br> Moderate | 39 | 33 | 35 | 28 | 23 | 32 |
| 4-Pasture, Deferred-Rotation | 84 | 86 | 73 | 61 | 53 | 41 |
| Heavy <br> Moderate | 49 | 46 | 44 | 42 | 41 | 44 |
| Cell, Short Duration |  |  |  |  |  |  |
| Heavy to Moderate | 61 | 59 | 46 | 50 | 62 | 56 |

Table 8. Average weight (pounds) of beef produced per cow on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge, 1983-1987.


Average net profit per acre was highest on H4PDR, followed by HCYL, SDG, M4PDR, and MCYL (Table 9). In 1983 MCYL produced the lowest loss and H4PDR produced the greatest loss. In 1984 H4PDR produced the highest net profit and MCYL the lowest. In 1985 H4PDR produced the highest net profit and MCYL the lowest. In 1986 and 1987 SDG produced the highest net profit and MCYL the lowest. All treatments lost money in 1983 because cattle purchases were not amortized over the length of the study.

Table 9. Net profit (\$) per acre on three grazing treatments and two grazing intensities on the Welder Wildlife Foundation Refuge, 1983-1987.

| Treatment Intensity |  | 1983 | 1984 | 1985 | 1986 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1987 Avg |  |  |  |  |  |
| Continuous, Yearlong |  |  |  |  |  |
| Heavy |  | - 7.51 | 5.33 | 12.14 | 16.62 |
| 9.36 | 7.19 |  |  |  |  |
| Moderate | - 5.01 | 3.43 | 6.81 | 8.67 | 4.643 .71 |
| 4-Pasture, Deferred-Rotation |  |  |  |  |  |
| Heavy |  | -10.33 | 7.34 | 14.64 | 17.69 |
| 9.82 | 7.83 |  |  |  |  |
| Moderate | - 5.63 | 3.80 | 7.97 | 10.02 | 7.194 .67 |
| Cell, Short Duration |  |  |  |  |  |
| Heavy to |  |  |  |  |  |
| Moderate | -8.67 | 6.21 | 9.67 | 18.00 | 10.197.08 |

## CONCLUSIONS AND RECOMMENDATIONS

Rainfall is highly variable in south Texas, and it is difficult to maintain any given stocking rate. To implement one on the basis of double stocking as was done in our SDG cell can be disastrous. Rainfall during 1982 was below average and 1983 was well above average, but in the third year, 1984, rainfall was below average. SDG did not work because we retained the double stocking rate for research purposes. Our work with cell-type, SDG has convinced us that double stocking is not applicable in all situations. The answer still seems to lie in using the more traditional systems, stocking moderately, and using a variable stocking rate to take advantage of excess forage.

The basic principle of proper stocking rate was essentially disregarded when double stocking was recommended by the Savory grazing method. It may be possible to exceed recommended stocking rates by 1.2 to 1.4 times, but to maintain double stocking is difficult if not impossible. Our economic comparisons indicate that SDG can be profitable, but not with double stocking. After we reduced the stocking rate cattle responses and economic comparisons improved.

Rather than recommending double stocking, we would advise south Texas ranchers to stock cows and calves conservatively at the recommended rate and to remove the excess vegetation with stocker animals or with prescribed burning in times of high rainfall (Drawe 1988). We would also advise a drought management plan. This plan could involve any number of approaches including destocking, use of ranch-raised emergency feed, use of plantings of emergency feed such as prickly pear, or other more innovative approaches.

Perhaps the best recommendation to south Texas ranchers with deteriorated ranges is to institute an SDG scheme at a moderate stocking rate until the desired level of range condition has been attained. This probably would take 10 to 20 years, based on the history of secondary plant succession on the Welder Wildlife Refuge, if no major weather shifts occur (Drawe et al. 1978). When the desired level of range condition is established, a change to 4 PDR or moderate CYL might be advisable.

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# MANAGING STOCKING RATES TO ACHIEVE WILDLIFE GOALS 

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## INTRODUCTION

Most livestock ranchers have heard the phrase "complementary forages." The classic example would be wheat pasture surrounded by rangeland. Complements "mutually supply each other's lacking" like the proverbial hand and glove. One partner (wheat pasture) provides crude protein and vitamin A which complements the energy contained in dry grass (rangeland). For many ranchers in Texas, wildlife complements (monetarily or aesthetically) livestock interests. However, managing for multiple species compounds (and confounds) the need for intelligent management decisions.

Aldo Leopold, as the "father" of wildlife management once noted that the same tools that had been used to destroy wildlife and their habitats, namely the "axe, plow, cow, and fire", could also be used to restore wildlife. Each of these tools influences plant succession, thus wildlife habitat.

If our discussion was based solely on livestock stocking rates and the impact on wildlife populations, this paper would be short, and the management implications might be general in scope. There are few data that relate wildlife responses to stocking rate changes, but there is information on the topic of grazing management impact on wildlife. In this article, we will 1) outline specific situations where wildlife responses to grazing management have been studied, 2) offer management recommendations that incorporate wildlife needs into stocking rate decisions, and 3) suggest a decision process that provides the land manager an opportunity to incorporate wildlife needs into management actions.

## ESTABLISHING WILDLIFE GOALS

The title of this presentation implies that management decisions are goal-driven, and that in this instance, incorporate both livestock and wildlife concerns. Based upon our experiences, wildlife goals of the Texas rancher can be defined in one of
the following four categories:

1. Interested only in livestock;
2. Livestock interests receive primary emphasis with wildlife incidental;
3. Wildlife interests receive primary emphasis, livestock interests secondary;
4. Interested only in wildlife.

This spectrum of goals may be viewed as a continuum (Fig. 1). On the left we might find the "traditional" rancher while on the right we might find the "absentee" landowner. Given this variety of goals, and perspectives, it becomes clear that phrases such as "good" range condition can assume different meanings. To the traditional cow-calf rancher, good range condition equates to an abundance of tall grasses, little if any brush, and few weeds. At the other extreme, such range would harbor few quail or deer, and thus would not be considered "good" range condition by the wildlife enthusiast.

## Interest relative to:

$\qquad$

$$
<- \text { Livestock }
$$

Figure 1. Strategic goals relative to wildlife and livestock are important when considering grazing management alternatives.

Aside from the two tails of this goal continuum, there is much to be said about the complementary values of both livestock and wildlife. Instances will be described where cattle grazing can benefit bobwhite habitat. On the other hand, there is ample evidence that the income generated from hunting can improve ranch cash flow and profitability.

Interjecting wildlife interests into a livestock operation usually means that the manager recognizes the importance of all plants. As Ralph Waldo Emerson noted "a weed is a plant whose virtues have yet to be discovered." Herbs like western
ragweed, doveweed, and broomweed are especially important plants for bobwhite quail, but usually viewed with disdain by traditional cattlemen.

If we assume that wildlife and livestock are compatible, we must accept this important axiom: while wildlife and livestock goals can be achieved simultaneously, one can never attain maximum livestock production and maximum wildlife production simultaneously. Once the manager recognizes that trade-offs are inherent, he can then begin to recognize problem areas and adjust strategies according to his location on the continuum of wildlife-livestock goals.

Strategic and tactical goals should be recorded. We ascribe to Specific, Measurable, Attainable, Related, Trackable (SMART) criteria when making management decisions. Example of goals that do not fit the SMART criteria are:

- raise more cattle and bigger calves,
- make more money, and
- enjoy life.

These strategic "goals" are defined poorly and could be enhanced with some critical thinking. For example, these goals might be refined and restated, incorporating a wildlife flavor as:

- retire debt load on ranch by the year 2003,
. use ranch-generated income to send kids to college,
. improve productivity of beef herd,
. increase wildlife density and diversity on ranch, and
. improve range and soil resources for descendants.
With a little recordkeeping, each of these strategic goals can be defined relative to the costs involved. Once costs are ascribed to each goal, SMART tactical goals can be listed. For example, goal II might require $\$ 10,000$ annually. The manager decides that traditional enterprises cannot cover these costs, so he pursues a hunting lease program with a goal of $\$ 10,000$ in mind. He may consider the following tactical goals:
- generate $\$ 6,000$ from deer hunts by incorporating archery and short-term leases during gun season;
- generate an additional $\$ 2,000$ for quail hunts during January and February;
- generate $\$ 1,000$ from spring turkey hunts during April; and,
- generate $\$ 1,000$ from feral hog hunts during February and March.

These tactical goals can be dissected to clearly define needs; such as generating the quail hunting revenue, developing wildlife habitat and managing hunts.

The inclusion of non-traditional enterprises will stimulate thoughts about how different land enterprises (grazing vs. hunting vs. minerals) interact. Once these
trade-offs are noted, managers can outline strategies to minimize competition and/or conflicts.

## HOW GRAZING AFFECTS WILDLIFE

Grazing or browsing can affect wildlife populations directly or indirectly (Figure 2).
Direct Effects Indirect Effects

Nest trampling
Interspecific competition
Behavioral changes

Structural changes
Plant species composition
Forage quality
Forage quantity
Landscape diversity
Vulnerability to predators
Seed/insect availability
Water availability
Associated activities

Figure 2. Ways which livestock grazing can impact wildlife.

## DIRECT EFFECTS

Direct effects are immediate and easily quantified but indirect effects occur gradually and accumulate with time. For example, quail managers might be curious about the impacts of specialized grazing systems, incorporating heavy stocking pressures, on the fate of quail nests. Intuitively, the more hooves present, the more likely a nest would be trampled. Research has shown that concern about livestock trampling on quail nests is minimal until some threshold stocking rate is reached (about 4 head/acre). Such high stocking rates would occur in Texas only on very productive sites under specialized management.

Interspecific competition (competition among different species) for food is seldom a problem with cattle and deer, but becomes more of a concern when sheep and goats are also present (Fig. 3). The potential for competition between species will increase proportional to their overlap in diets. Cattle and deer exhibit little overlap in diets. Sheep tend to have higher overlap with deer, while goats (especially Spanish goats) tend to have the greatest dietary overlap. Range condition can affect the degree of diet overlap among species. Overlap will be greatest in pastures that have low species diversity (usually Poor condition).

# Herbivore Diets Sonora Experiment Station 



Figure 3. Comparison of livestock and deer diets in the Edwards Plateau region of Texas.

Dietary overlap alone does not mean competition is occurring between (among) species. Competition occurs only when the resource in question (food in this case) is limiting. Along this "continuum of competition" is where stocking rates, of both wild and domestic grazers, become important. At "light" or "moderate" stocking rates (generally the SCS-recommended rates are moderate), cattle and deer exhibit little dietary overlap. However, at high stocking rates (especially on overgrazed ranges), cattle will consume more browse and forbs, and thus be more competitive with deer. The same is true for sheep and goats. Thus, the manager must be cautious that "common use grazing" (grazing with multiple species) does not degenerate into "common use overgrazing."

The mere presence of livestock may alter wildlife behavior, especially at the higher stocking densities observed with specialized grazing systems. Studies at the Welder Foundation in southeast Texas have documented that deer adjust their daily movements in response to the location of cattle in a short-duration grazing (SDG) system. Deer tended to avoid cattle and would move to adjoining paddocks when cattle were present. Deer behavior returns to "normal", 7 to 21 days after the cattle were moved. Turkeys may move to adjoining paddocks (at least initially) when cattle enter a paddock. Quail did not exhibit a conclusive trend. Some ranchers in the

Edwards Plateau maintain that deer move out of pastures stocked heavily with goats (especially Spanish goats), but such movements have not been quantified.

## INDIRECT EFFECTS

More subtle effects of livestock grazing occur cumulatively over time. Changes in structure (both at the macro- and micro-habitat levels), species composition, forage availability occur over months or years. The magnitude and direction of positive or negative impacts vary with species of wildlife, species of livestock, plant communities, and perhaps grazing systems, human activity, and topography.

The greatest effect of livestock grazing for gamebirds like bobwhites will be changes in habitat structure. Structural needs for quail include nesting sites on ungrazed bunchgrasses, intermittent feeding on grasses/forbs with ample bare ground, escape cover on moderately dense grass stands, roosting cover on short grass areas, and brooding areas in open grass/forb areas with overhead cover. The mosaic of micro-habitats that usually accompany grazing accomodates most of these cover needs. Effects stocking rate on insect availability might impact chick survival. Additional research on livestock grazing effects on foraging efficiency of quail should identify stocking rate effects on quail populations.

For other wildlife like deer, species composition changes may be more important than structural changes. Deer prefer forbs and browse when forbs are unavailable. Heavy cattle stocking tends to promote forbs, but similar stocking with sheep and/or goats will decrease forb availability. Cover diversity is important for deer fawning cover.

Different wildlife species prefer selected habitats (but "generalist" species) like deer and quail are more resilient to changes associated with grazing than species that are niche "specialists." Endangered species like the black-capped vireo and goldencheeked warblers are examples of niche specialists. These species, because of their narrow habitat tolerances and/or special needs, are more apt to be adversely affected by habitat changes.

The endangered black-capped vireo nests in parts of the western Edwards Plateau. The vireo prefers to nest in shrubby vegetation between 2 to 5 feet high. This seral stage is often found 10 to 15 years following chemical and mechanical brush control or fire. Species like shinoak, elbowbush, and littleleaf sumac are preferred. These species are preferred by angora and Spanish goats. There is concern about goat stocking rates and nesting habitat for vireos. It is possible that "prescribed goating" could be used to manipulate vireo habitat much like prescribed burning. However, such a hypothesis has not been tested.

Another indirect concern relative to endangered species involves livestock companions. Nest parasitism by brown-headed cowbirds appears to be one of the
limiting factors for golden-cheeked warblers in the Edwards Plateau. Accordingly, there is concern among warbler biologists that livestock grazing may be detrimental to warbler recovery plans. However, biologists at the Kerr Wildlife Management area have successfully used a mobile cowbird trap in conjunction with a cell-grazing system to reduce the abundance of cowbirds.

In southeast Texas, grazing management has been a concern for the endangered Attwater's prairie chicken and whooping cranes. While livestock grazing appears to be compatible, if not desirable, for the Attwater's prairie chicken, the issue is not as clear-cut for whooping cranes. Researchers have documented negative impacts of heavy grazing on insect and seed abundance; these are important food items for whooping cranes. The presence of fences may pose a threat to whooping cranes.

## GRAZING AND PLANT SUCCESSION

Most discussions of livestock grazing and wildlife focus on the detrimental impacts of overgrazing. Overgrazing is usually defined as a heavy long-term stocking and produces measurable negative impacts on species composition and soil stability. We will define such grazing as "absolute overgrazing." We do recognize however, that heavy stocking can occur in the short term without jeopardizing species composition or erosion. "Relative overgrazing" suggests that heavy grazing within constraints may be beneficial.

There are some situations when total livestock removal may be an appropriate management option. Resting pastures/paddocks for one or more years may be necessary to restore range condition. For example, a 150 -acre pasture at the Sonora Experiment Station has been rested for the last 10 years. Portions of this pasture have been burned at 6,3 , or 1 year intervals to study the impacts of fire on range improvement. In the presence of fire, and the absence of sheep and goat grazing, this pasture ranges from good to excellent condition. It also supports one of the highest quail population in the Edwards Plateau. Besides benefitting wildlife, these "grazing refuges" also serve as a "fodder bank" for emergency forage under drought conditions.

Before the whole pastures are overgrazed, some plants and areas within the pasture are overgrazed. This phenomena is usually apparent around watering facilities in more or less concentric circles. Non-uniform use (spot grazing) can be an important tool for managing vegetation structural diversity. Heavier grazing by livestock tends to promote some species (increasers and invaders) while limiting others (decreasers).

The terms decreaser, increaser, and invader are firmly entrenched in range jargon as a methodology for interpreting range condition. Range condition refers to the relative proportions of decreaser, increaser, and invader plants on the site relative to historic "climax" community for that site. As stocking rate increases, the most
palatable plants (decreasers) to livestock decrease. Examples of decreasers include big bluestem, sand lovegrass, Illinois bundleflower, and kidneywood. Less palatable plants (increasers) tend to increase initially, but may decrease in the long term if overstocking continues. Increasers are plant species that are present in the climax community but at lower frequencies. Examples include sideoats grama, goldenrods, and liveoak. Invaders are plants that increase with heavy stocking but, unlike "increasers", invaders were not originally present in the climax plant community. Ragweed, annual threeawn, and mesquite are examples of invaders on most sites.

Using the SCS range condition guides, sites dominated by ragweed, doveweed, lotebush, and mesquite would be in either "poor" or "fair" condition. The cattleman would concur with such a rating, but not the quail hunter. Current range condition classifications are designed for cattle rather than for wildlife. Low condition range usually provides more food and woody cover for gamebirds, while high range condition range provides better nesting cover. Fortunately for quail managers, grazed pastures have a mosaic of poor, fair, and good conditions because of preferential cattle grazing behavior.

The "optimum" range condition for wildlife depends on the selected species and site. On highly productive bunchgrass sites, bobwhites do best on poor or fair condition range. "Heavy" grazing tends to make such sites more habitable to quail by increasing bare ground, seed availability, and ease of travel. In more arid climates optimal quail conditions occur on good or excellent condition range.

As wildlife objectives become more important the rancher will modify stocking rate, class of animal, grazing distribution, and season of use. This will require management changes and the need to re-examine long-term goals.

## EFFECTS OF GRAZING SYSTEMS

In the last 15 years, there have been several studies to determine the impacts of grazing systems on wildlife. Rapid pasture rotation (SDG) provides greater flexibility to manage wildlife. For example, if the manager can overstock a pasture to stimulate invader forbs and lightly-stock another to preserve pasture nesting cover. No other grazing system offers this flexibility to the wildlife/livestock manager.

Deer, turkeys, and other wildlife are disturbed by cattle herds, but there is no direct evidence to suggest that reproductive cycles are affected. Studies at the Welder Institute suggest that deer move more and feed longer in an SDG vs continuously grazed (CG) pastures.

Over the last 30 years, range managers have been evaluating rotational grazing schemes to compare their value relative to range improvement, livestock performance, economics, and more recently, wildlife. In most of these trials, the grazing system under test fails to improve substantially upon a couple of old standbys:
(a) a moderately-stocked CG, or (b) a "slow" DR (usually a 4-pasture, 3-herd). As these methods usually result in the mosaic of ungrazed, lightly grazed, and heavily grazed areas as discussed earlier, it's likely that they will work as well for the wildlife manager as the most intensively-managed systems. The exception might be in those highly productive/high rainfall areas (e.g., Coastal Prairie) where range condition may reach levels beyond the optimum for a particular wildlife species. Because there is no rest per se for any portion of a CG pasture, it may be that stocking rate decisions may be important for wildlife considerations than in other grazing schemes where certain pastures/paddocks receive periodic rest.

## A DECISION-MAKING PROCESS

We propose the following series of questions when attempting to interpret the impacts of livestock grazing on wildlife species.

1. Is livestock grazing biologically compatible/appropriate for the species/habitat goal in question? Are there other tools that could do the same job more economically (e.g., burning)?
2. Given that grazing is useful, what kinds, classes, and numbers of livestock should be stocked, and at what seasons, to provide the desired result relative to target species' habitat requirements. How can livestock grazing be manipulated to optimize habitability for the wildlife species in question? Does the method of choice provide the manager flexibility to alter plans in case of drought, fire or other special circumstances (e.g., endangered species)?
3. What management actions (water and mineral locations, shade, fencing) need to be employed to improve structure (or other vegetative characteristics deemed important)? Are these actions deployed for the sake of uniform use (for livestock) or for non-uniform use (for wildlife)?

## CONCLUSIONS

Albert Einstein once noted that "for every action, there is a reaction." Einstein was an optimist. For every action, there are numerous reactions, some of which are very apparent, others more cryptic. Implementing any management scheme (grazing system, brush control, fire, etc.) will be accompanied by a host of reactions. Some will be positive, neutral, or negative, depending largely on the species of interest. If wildlife concerns are part of your strategic goals, you must consider such ecological trade-offs.

Whether your management interests revolve around cows or quail, steers or deer, the basics of range management revolve around 2 principles:

- know your plants, and
- know how to manipulate them.

Knowing your plants involves more than just the ability to identify prairie coneflower or Hall's panicum, it implies knowing when, how, and why each is important. The prairie ecologist, Dr. J.E. Weaver, proffered good advice to range/livestock/wildlife managers when he said:
"Nature is an open book for those who care to read. Upon each grass-covered hillside is revealed the history of the past, the conditions of the present, and the hope for the future."

Read, observe, learn, enjoy!

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# MANAGING STOCKING RATES TO ACHIEVE FINANCIAL GOALS 

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## INTRODUCTION

Most privately owned agricultural land in the United States is used in the production of marketable products. In areas where climatic and soil characteristics, or desires of the owner, make the land unsuited for cultivation, it is used to produce livestock and/or wildlife and related products through grazing. These livestock/wildlife production operations, commonly called ranches, are generally operated as businesses. In the ranching business the forage grown on the land supplies a significant portion, if not all, of the feed for the animals. The grazing land and animals are used in conjunction with labor, capital, management expertise, etc. to induce animal reproduction and/or growth which can be sold for currency. The currency can then be used to maintain and/or replace the resources used in the production process and provide income to support the rancher.

## RELATING GRAZING MANAGEMENT TO GOALS

The rancher, as a business manager, uses the resources available to accomplish the firm's goals and objectives. But what are these goals and objectives? The answer to this question varies with which rancher you ask and when you ask the question. However, in the context of a business firm, ranches included, it is generally agreed that one of the most important goals is to survive as a business. If this goal is achieved, then the rancher is assured of achieving at least some nonfinancial goals such as maintaining an occupation and lifestyle (Conner, 1984). Business survival generally requires that other supportive goals be achieved. That is, to survive the ranch must produce a profit in most years and in years when losses occur, they must not be so great as to eliminate the ranch owner's net worth. Over the long term then, the goal of firm survival requires that the rancher also achieve the goals of obtaining profits and avoiding catastrophic losses. To insure that these goals are achieved, most ranchers adopt yet another supportive goal; i.e., sustained growth in profits and net worth over time. The growth in profits and net worth provides an ever increasing cushion or margin of safety against business failure due to catastrophic losses. While these goals are stated in purely financial terms, it is implied that sustained growth provides the rancher an improved standard of living and growth in net worth to provide retirement security and/or family inheritance (Conner, 199 1).

Ranchers attempt to achieve their goals through use of the resources that are available to them. They accomplish this by selecting options from among all possible livestock production and/or wildlife enterprises and grazing strategies.

Selection of a grazing strategy is critical to goal achievement for the rancher because it relates directly to the goals of making profits, growth in profits and net worth over time and avoiding catastrophic losses. The relationship between the choice of a grazing strategy and the annual profits of the ranch business is through the cost of the grazing land used to provide part, or all, of the animal feed and wildlife habitat. Thus, the more saleable products that can be produced per unit of land, the greater the profit. Of course, this assumes that the cost of other resources like purchased feed and labor are not increased with the increased product sales to the extent that they off-set the decreased land cost.

This simple concept provides ranchers an incentive to increase stocking rates as a means of achieving their goals of making profits. As with most simple concepts, however, this one is not as simple as it seems. When stocking rates are increased beyond a certain point, food per animal becomes limited and production per animal begins to decline (Figure la). Carried to the extreme, production per animal will decline to the point that production per acres also declines. Before this happens, however, another complication factor arises. That is, costs of other resources like labor, vet supplies and supplemental feed begin to increase to the point that they offset the decreased land cost, thus eliminating the increased profits. Thus, to achieve the goal of maximizing annual profits, the rancher must usually choose a stocking rate that is less than the attainable maximum production per acre but greater than the highest stocking rate associated with maximum production per animal (Figure lb). Exactly what stocking rate within that range will result in maximum profits is determined by several factors, some of which will be discussed later.

The grazing strategy is also related to the goals of sustained growth in profits and net worth over time. The relationship is expressed through the impact that moderate stocking rates, and/or periodic deferment from grazing and /or more uniform distribution of grazing pressure can have on the ecological trend of the rangeland and associated production potential. In its simplest form, this concept states that as the rangeland trends upward in ecological succession its potential productivity increases, thereby allowing for increases in stocking rate while maintaining production per animal. Thus, if stocking rates can be increased with production per animal remaining unchanged, profits could be increased. The problem with this concept is the tradeoff, either real or perceived, between the goal of obtaining maximum current profits through relatively high stocking rates and the necessity of using reduced stocking rates and/or more costly grazing systems to induce an upward trend in ecological succession.

The grazing strategy also relates to the goal of avoiding or minimizing the impact of catastrophic losses. In this case, the relationship is expresses both through the buildup of net worth over time and the margin of safety that it affords, and as a forage reserve that would usually not be grazed, but during period of drought could be relied on to save the rancher from having to buy large quantities of supplemental feed, and/or sell large numbers of animals. A grazing strategy which provides a forage reserve for use only during drought or other emergencies contributes to the


Figure la


Figure lb

Figure 1. Relationship between production/animal, production/unit area of land, profit/unit area, and animal numbers/unit area.
goal of minimizing the impact of losses due to drought. This approach is consistent with the goal of sustained growth in profits and net worth over time because it facilitates improvement in range condition. During periods of good to normal climatic and market conditions, however, it is inconsistent with the goal of obtaining maximum annual profits which usually require higher stocking rates.

To this point, our discussion has focused on stocking rate as the primary component of a grazing strategy that relates to the rancher's financial goals. In reality, two other components, temporal and spacial allocation, are also important. The simplest grazing strategy; a one-herd, one-pasture grazed yearlong does not include spacial and temporal allocation. All other grazing systems include one or both.

The primary justification for grazing strategies (systems) which include spacial and temporal control lies in their ability to either induce improvement in ecological condition more rapidly than simpler strategies, or maintain or induce improvement in ecological condition at higher stocking rates than would be possible with simpler strategies. Thus, grazing systems involving temporal and spacial allocation may be viewed by the rancher as contributing to the goal of sustained growth in profits and net worth over time through improved ecological condition and range productivity. To the extent that a grazing system allows for maintenance of range condition with higher stocking rates than would otherwise be possible, it may be viewed by the rancher as contributing to the goal of maximizing annual profits.

The rancher's decision regarding the degree of control hinges on the tradeoff between the benefits expected to be gained in the form of current or future carrying capacity and the costs of additional fences, water facilities and operating labor required to implement and maintain the grazing system. Like most other decisions, the optimal combination of pasture size, length of rest or deferment period and stocking rate is unique to each rancher's individual goal hierarchy and set of resources. In addition, since goals and resources are likely to change through time, so will the optimal grazing strategy.

In addition to grazing strategies, ranchers may also select among alternative classes and kinds of grazing animals as a mean of accomplishing their goals. A rancher's annual profits may be enhanced by selecting a kind or class of grazing animal that can most efficiently utilize his particular forage. For example, if browse makes up a large component of the forage base, the rancher might be able to safely stock more animal units of goats than cattle per unit area because goats utilize browse more efficiently than cattle. Often, particularly if the forage base is diverse, a combination of two or more types of grazing animals can utilize the forage more efficiently than a single species. In this case, the total animal units per unit area can be increased with a combination of livestock over the number of animal units that could safely be stocked with either species alone.

Combinations of livestock may also enhance a rancher's ability to avoid catastrophic losses because the probability of simultaneously suffering economic losses in any given year in two ore more diverse enterprises is much less than the probability of experiencing losses in any given year for a single enterprise. This risk management strategy, known as investment diversification, has long been an accepted business practice.

Choosing an alternative class or kind of grazing animal, or a combination of grazing animals, is often made difficult because of differences in production requirements, costs and product prices associated with the different animals. Fences, for example, that may be well suited for cattle production may be totally inadequate for goats. In this case, changing from a single cattle enterprise to a goat enterprise or a combination of cattle and goats would require a significant increase in fencing costs which might more than off-set any gains in income that might result from the more efficient utilization of the forage base.

## RANGE CONDITION, STOCKING RATES, AND FINANCIAL GOALS

This portion of the paper will address the influence of stocking rate on range condition, forage production and subsequent opportunities to achieve the financial goals of ranch firms. Examples will be used to illustrate different scenarios where stocking rates are significant to range product yields for traditional livestock operations, as well as white-tailed deer, northern bobwhite quail and a combination of these potential income sources.

## SECONDARY SUCCESSION, RANGE CONDITION AND STOCKING RATE

The long-held belief that as range ecological condition increases (a rating based on percentage of the natural potential plant community present in current vegetation composition) forage quantity and quality increase is generally true with respect to cattle and perhaps sheep (Figure 2). It is not necessarily true, however, for other animals such as goats, native deer, exotic wildlife species, or quail. The value of range forage often depends on the specific plants and the animals in the equation. For example, many of our South Texas range sites are estimated to have had a very high percentage of graminoid species compared to shrubs, forbs, and cacti, a plant composition that would not, in many cases, be the favorite selection of biologists or land managers promoting a wildlife component for a ranching firm.

Using a sandy loam range site in the 19-31 PE Zone of the South Texas Plains for the purpose of illustration, the site is approximated to support $90 \%$ grass and grass-like species, $5 \%$ woody plants and only $5 \%$ forbs when in the highest ecological condition. Only a trace of pricklypear is estimated to be present in the climax vegetation (USDA SCS 1972). This site in "excellent" ecological condition with reference to the climax vegetation would probably not provide ideal habitat for deer or quail, and certainly not for javelina.


Figure 2. Classical interpretation of the effect of improving range ecological condition on range forage quality and quantity.

The manipulation of grazing animals to induce secondary succession, subsequent range condition improvement, and an increase in range carrying capacity is practiced by many range managers. Assuming that the range has the capacity to produce greater amounts of different kinds of plants than are represented in the current composition, the ones increased depends in large part on grazing management. The first principle of grazing management is correct stocking rate. Stocking rate refers to the balance between animal demand for forage and the supply of forage from the range. However, more is involved than just total forage resources.

In order to improve range condition, that is to increase the proportion of plants present in the natural potential vegetation for a range site, utilization of plants by livestock must allow certain plants to increase at the expense of others - no small task, but possible. Stated simply, those plants in the current composition of range vegetation that represent a higher ecological order (higher percentage of natural potential vegetation), or key species, must be encouraged to replace those plants that are invaders or low order increasers (opportunist species). To accomplish this, grazing animals must be controlled to the degree that the key species are not defoliated to levels that reduce their competitive position with associated, less desirable plants. This usually means removal of no more than about $40 \%-60 \%$ of the leaf area during the growing season; defined as range proper use. What makes this a not-so-easy task is that those plants most often targeted for increase in relative percentage of total forage are also those that are selected first and most by grazing animals. Theoretically, the correct stocking rate should permit the key species to respond to proper use and increase in the plant composition. In grassland ecosystems, these higher order species have the ability to aggressively compete when grazing pressure allows retention of minimal growing point and leaf area requirements. Limiting the use on key plant species requires allowing more of them to survive on the range in relation to the selective grazing of animals. The less key species in the total plant composition, the lower the stocking rate must be to maintain or improve range ecological condition. For example, a sandy loam range site in South Texas would have a recommended stocking rates of about 14 and 21 acres per animal unit yearlong for excellent and fair range condition, respectively. Excellent condition means that there is more than $75 \%$ of the climax vegetation remaining on the site, while fair condition equates to only $26-50 \%$ climax vegetation remaining.

In the classic view, as the percentage of plants approximated to make up the natural potential vegetation of a range site increases, the production of the site increases; which in turn allows higher stocking rates and an opportunity for increased income per unit area of land (Figure la). Typically, the quality of vegetation should increase concomitantly with production so that individual animal performance will increase. This is the sequel to the belief that forage quantity and quality are related to range condition; that as forage quantity and quality increase, grazing animal production per unit of land area also increases (Figure 3). Again, whether or not this is true depends largely on the match between range vegetation and the grazing animals.


Figure 3. Classical interpretation of the effect of improving range forage quantity and quality on grazing animal production per unit of land area.

If highly preferred key species make up only a very small percentage ( $<10 \%$ ) of range vegetation, the stocking rate required to practice proper use on these plants would require a financial sacrifice most ranchers could not tolerate. This is when other practices, such as revegetation, grazing systems, and/or brush and weed management are usually considered. Lack of sufficient percentage of the key species may also dictate acceptance of the need to base grazing use on a lower order species, but with seasonal deferments or other strategies to promote the more preferred plants. Considerable patience is usually required to manage rangeland from low to high ecological condition by manipulating livestock grazing to promote secondary succession.

Many landowners in South Texas and other land resource areas, such as the Rolling Plains, now have viable hunting populations of white-tailed deer associated with an increase in woody plant distribution and density; a movement away from the natural potential plant communities described for their range sites. In some cases, land managers may prefer the presence of "leasable" populations of deer, quail and turkey to a higher ecological condition of the range.

Over the past 30-40 years, with the increasing importance of multiple use of rangeland resources, the view of a "best mix" of rangeland vegetation to achieve financial goals has changed. In earlier times we essentially "grew grass to produce beef to make money." This general objective still holds true on many ranches, while on others it is still important, but not the dominant view of what vegetation the range should furnish. Even when cattle are the primary livestock involved in determining the best mix of range vegetation, there are some important elements of diet furnished by plants other than grasses. For example, Huston et al. (1981) and Varner and Blankenship (1987) concluded that diversity of range plants provides a greater overall opportunity for high quality diet selection. High quality range forage should equate to high levels of range animal product yield and increased opportunity for financial success. What constitutes "quality" range? It depends.

Hanson (1987) and Mastel (1987) found that steers and cows in South Texas selected $10 \%$ or less shrub species in their diet until herbaceous plants provided less than an average of about 750 pounds per acre of forage. This level of residual herbage approaches the threshold of physically limiting cattle access to remaining forage, contributing to their inability to reach gut fill using herbage only in their diet. In both studies, cattle suffered nutritional stress when herbage reached levels that forced them to eat high quantities of woody plants. Conversely, Warren et al. (1984) found that spanish goats on similar range sites in South Texas selected diets that averaged greater than $50 \%$ shrub species across all seasons. Arnold and Drawe (1979), Walsh (1985), Chamrad and Box (1968), Everitt and Gonzales (1979), Drawe (1968) found that white-tailed deer utilize a high percentage of forbs, shrubs and cacti in their diets. Arnold and Drawe (1979) reported $21 \%$ of annual white-tailed deer diets in Jim Hogg County were composed of cactus, while Everitt and Drawe (1979) found that cactus consumption reached $61 \%$ in the Rio Grande Plains during winter.

These studies did not address the physical value of woody plants for cover screen (McMahan and Inglis 1974), travel lanes (Walsh 1985) and other amenities brush furnishes in deer and quail habitat. They present clear evidence, however, that the potential for increasing income from rangeland must relate to the grazing animals being used, as well as their manipulation to cause vegetation composition changes.

In view of all these qualifications, range condition may a useful concept for rating present vegetation compared to plant species and associations of species and to project yield of a range site at the ecological potential. However, vegetation of the climax plant community may not be the most suitable for all range management objectives (Smith 1979), including financial goals. Kinds of grazing animals, wildlife habitat, or even the economic feasibility of significantly raising ecological condition may point to a more practical plant mix. The concept of best vegetation mix for management objectives must be constrained, however, by the need to provide satisfactory protection of the soil resources from losses to erosion or long term physical condition or fertility reduction.

## NORTHERN BOBWHITE QUAIL

Assuming there is a best mix of range plants for achieving financial goals, the obvious question becomes, how does stocking rate influence creating and maintaining the optimal vegetation composition? This question cannot be answered without defining "best plant mix." For example, if northern bobwhite quail are an important economic asset to a ranch firm, what is the best mix of plants for good quail habitat, and what is the role of stocking rate in influencing this mix? Guthery (1986) and Bidwell et al. (1992) state that bobwhite quail are highly favored by diverse habitat features, including a large number of plant species; a large number of cover types, small blocks of cover well mixed with small blocks of different types of cover, great edge area, and brush and trees of several ages. Guthery recommends that brush component of South Texas bobwhite quail habitat should be about 5 to $15 \%$ canopy cover, mostly one to five feet tall and two to eight years of age. Heavy litter and thick grass blades near the ground make it difficult for northern bobwhites to move through the cover in search of food, although some heavy cover has value for nesting. Ideal travel and screening cover has a mixture of low plants and tall plants, grasses and forbs, and plenty of bare ground for easy movement and seed finding. Several authors agree that bobwhite quail have an affinity for low successional habitats with diversity of vegetation types, densities and stature. Bobwhite quail are "successional species" (their abundance depends on the successional status of plants), with lower successional levels preferred over higher successional levels (Hanselka and Guthery 1991).

Assuming that maximizing quail populations was the objective of management, it is quite possible that stocking rates of grazing animals would need to be purposely heavier than recommended for promoting secondary succession from lower to higher levels. Higher stocking rates benefit quail habitat on a productive site because cattle consume and trample dense plant growth to which bobwhites are not adapted.

Moderate to low stocking rates are better on less productive sites because maintenance of ground cover is a primary concern (Hanselka and Guthery 1991). In other words, very dense stands of tall grasses, such as those typically associated with the Coastal Prairies in South Texas when in good and excellent ecological condition would not be good quail habitat and quail populations could be expected to decline.

Guthery (1986) developed guidelines for grazing management decisions affecting quail habitat. In 20 to 30 inch rainfall zones, stocking rates should be light in pastures with $5 \%$ brush cover or less. They should approach moderate as the coverage and diversity of brush increase. In 30 to 40 inch rainfall zones, stocking rates should be moderate with $5 \%$ brush coverage or less. They can approach heavy as the coverage and diversity of brush increase. As Guthery points out, stocking rates based on SCS range condition determinations and range site descriptions may be too light to provide the best habitat for quail because of the conservative nature of these stocking rate guides.

## WHITE-TAILED DEER

White-tailed deer are a well recognized source of significant financial income and a very stabilizing factor contributing to retention of ranch ownership in many parts of Texas. How does stocking rate affect the financial equation when deer are a primary source of ranch income?

Deer have much higher nutritional requirements than cattle. For example, protein ranges of 13 to $16 \%$ are required for successful growth, antler development and reproduction (Richardson 1990). The components of range vegetation capable of producing this level of protein are primarily forbs. Therefore, the forbs are the "quality, level, and bonus" components described by Huston et al. (1981). Deer are also successional animals, preferring a level of succession where forbs and woody plants may be greater in the composition of vegetation than grasses and grass-like plants. Grasses of the Edwards Plateau could have maintained deer rumen function during the growing season ( $6-7 \%$ crude protein), but could not nearly meet growth, reproduction and development requirements.

Everitt and Gonzales (1981) found the average crude protein content of 14 common South Texas shrubs was 17.4 percent during spring, $15.0 \%$ during summer, $15.7 \%$ during fall and $13.9 \%$ during winter. Mean crude protein values of forbs for the same four season were $13.8,14.6,14.5$ and 13.8 , respectively. Varner and Blankenship (1987) found that deer diets included less than $5 \%$ grass in any season and other studies have shown protein levels of the dominant warm-season perennial grasses to be well below these averages for forbs and browse plants. There are exceptions, of course, such as range sites that contain a high percentage of cool season grasses and areas in deep South Texas that may not receive winter temperatures to cause dormancy in warm season plants (Meyer et al 1984). Still, it is clear that the woody plant and forb components on rangeland are important to
animal nutritional status, particularly to deer that have mouth parts that allow "nibbling" use of high quality components of shrubs. Therefore, livestock stocking rates that reduce forb populations or remove the nutritious growing ends (terminal buds) from key woody plants can be critically competitive to deer, especially when reproduction and antler development occur.

There is a caution worth mentioning when considering the use of winter-spring stocker grazing programs. In these operations cattle density is usually high because stockers are grazed only 6-8 months and then sold in late spring-early summer. Even though stocking rate may be appropriate for the total forage base on the ranch, high stock density causes these animals to compete with deer in the critical late winter early spring period when all forage components are usually least abundant. Deer would suffer more than the stockers from this extra heavy level of competition, particularly as they needed high quality forbs and browse to meet nutritional requirements. Even though the use of steers is generally considered positive because it allows stocking rate flexibility in case of drought and often provides growing season deferments, the presence of high numbers of these animals on the range in critical periods can be detrimental to deer nutrition (Inglis 1985).

Interspecific competition occurs when different species such as deer and domestic livestock compete for resources that are in short supply. Competition does not occur simply because two species are consuming the same types of food plants. It is possible for sheep, goats, cattle and deer to occupy the same range without competition if the animals are present in low numbers and there is a diversity and abundance of forage plants (Richardson 1990). "Numbers" is a key element in this scenario, and can be controlled by stocking rate decisions by land managers. However, numbers are not the only ingredient needed to successfully manipulate range vegetation to the benefit of white-tailed deer.

In many instances, there is an imbalance of the different components of vegetation, grasses, forbs, woody plants and cacti on Texas ranges to provide the best mix for management objectives. If an area that has this diversity of vegetation types is stocked with cattle only, there is a limitation to the pressure that can be brought to bear on woody plants that are increasing in proportion beyond optimal limits. This is particularly true when species such as honey mesquite (Prosopis glandulosa var. glandulosa) or other less preferred species are present in the composition. Increasing stocking rate with goats, on the other hand, could help control woody plant increase, but rates should be carefully controlled so that key browse species continue to be adequate for deer requirements. Most Texas ranges with significant infestations of woody plants ( $>30 \%$ canopy cover) that have reached heights above the browse line of goats, will need some form of brush management before grazing practices can effectively manipulate composition. Archer's (1989) diagram of threshold changes in community structure shows a shrub driven succession that cannot be reversed without energy inputs (Figure 4).


Figure 4. Diagrammatic illustration of the chronosequential development of shrub clusters on fine loamy upland in the Rio Grande Plains, Texas. These landscapes may be moving from the present two-phase configuration - discrete woody clusters scattered throughout the continuous grassland matrix - towards a monophasic woodland, as new clusters are initiated and existing clusters expand and coalesce (from Archer et al. 1988).

Perhaps the greatest influence of stocking rate on white-tailed deer production parameters is competition for the high quality range components, primarily the perennial and annual forbs. Low stocking rates of livestock may help save forbs and key browse for deer, but a better approach would be flexible stocking to provide deferments as needed during periods critical for deer nutritional requirements. Even at low stocking rates, domestic livestock seek out and utilize highly preferred plant species. Stocking density (the number of animals per unit of land at a point in time) could be the most important factor in preserving key forage for wildlife.

## COMBINATION STOCKING

What is the best stocking rate strategy to optimize the production for income potential from rangeland when livestock and wildlife are both important economic components? We do not have an answer to this question, but a step in the right direction may be the "Multi-Species Stocking Calculator" or POPMIX decision aid. POPMIX is a component of the Grazing Land Applications (GLA 2.0.1) decision support system (RSG 1993). POPMIX allows the manager to describe the current wildlife population (density/AUE demand) and the desired livestock demand ratio; for example, $80 \%$ cattle, $20 \%$ goats. A transect that quantifies the vegetation in the area being evaluated is linked to specified multi-species mix and the program computes a recommended stocking rate based on preference, status of the forage, and demand by animal composition. Wildlife population needs are addressed first and the remaining forage species are allocated among livestock, and allocation is based on a stated level of harvest efficiency.

POPMIX is essentially a vegetation budgeting procedure. The livestock, which may include more than one kind, are allowed to utilize the remaining herbage and browse based on preference values (preferred, desirable, undesirable, nonconsumable and toxic plants) assigned to each plant for each kind of animal. For example, many grasses would be preferred by cattle (selected in a greater percentage in the diet of the animal than the percentage of the plant in the field), and would be undesirable for deer (selected in a minimal percentage when preferred and desirable plants are not available). Other plants may be desirable (selected in approximately the same percentage as they are in the field) to one kind of animal and nonconsumable (a plant that is armed [thorns] or that has noxious characteristics) to another. Preference values for plants can differ not only by animal species, but in some cases, by seasons of the year.

POPMIX generates an overall stocking rate (Ac/AU) with an AUE equal to 26 pounds of dry matter consumption per day to meet the desired composition of demand. Stocking rates for each kind of animal are also computed. The program provides an estimate of each animal's diet composition and a habitat score for the transect used in the analysis. The user can run various stocking compositions and apply the results to budget analyses to determine which combination results in the greatest economic returns.

## RESEARCH EXAMPLES

## ROLLING PLAINS, 1982-87

Research was conducted at the Texas Experimental Ranch located on the eastern edge of the Rolling Plains Region of Texas (Heitschmidt et al., 1990). Grazing treatments were: yearlong, continuous-stocked at heavy (HC) and moderate (MC) rates; 3-herd, 4-pasture deferred rotation (DR) stocked at a moderate rate; and 16paddock, l-herd rotation (RG) stocked at a very heavy rate.

The four grazing strategies were analyzed for economic returns using annual values of the stocking rates, amounts of supplemental feed, and production levels reported for 1982 to 1987 . For purposes of estimating operating costs and returns, each grazing strategy was analyzed as if it were a single enterprise being operated on 3000 acres of land. Prices and costs used were representative of those that prevailed from 1983 through 1986.

All four strategies were evaluated with average cow death losses of $2.6 \% / \mathrm{yr}$ with $10.4 \%$ of cows culled each year and enough heifer calves retained each year to equal $13 \%$ of the cow herd. Standard enterprise budgeting techniques were used to produce estimates of annual net (residual) returns to land, management, and profit. A separate budget was developed for each strategy for each year, then average annual returns were determined for each treatment for the 6-yr.

Over the $6-y r$ study, average residual returns (i.e., net returns to land, management, and profit) per cow averaged $\$ 60.81, \$ 69.57, \$ 93.12$, and $\$ 62.72 / \mathrm{yr}$ in the HC, MC, DR, and RG treatments, respectively. Net returns per acre averaged $\$ 5.25, \$ 4.46, \$ 6.47$, and $\$ 6.63$, respectively. Returns per cow were significantly greater in the DR than HC and RG treatments. There was no difference in returns per cow between the MC and the other three treatments. There were no differences between any treatments in the net returns per acre when averaged across years.

Net returns varied significantly among years in that returns in 1985 (\$17.46/cow and $\$ 1.26 /$ acre, averaged across all treatments) were significantly less than all other years, which averaged $\$ 82.37 /$ cow and $\$ 6.62 /$ acre. All other contrasts among years were nonsignificant. However, there was considerable variation in returns among years and treatments (Figure 5), thereby indicating that economic risk varied as a function of grazing treatment. For example, net returns ranged from $\$-1.26 /$ acre and $\$-18.34 /$ cow to $\$ 8.43 /$ acre and $\$ 95.78 /$ cow in the HC treatment while in the DR treatment the range was only from $\$ 3.55 /$ acre and $\$ 50.95 /$ cow to $\$ 8.80 /$ acre and $\$ 124.07 /$ cow. Thus, economic risk was least in the DR treatment and greatest in the HC treatment. This agrees with previous economic analyses (Whitson et al., 1982) of the HC, MC, and DR treatments from 1961 through 1974.

The data from the study show that stocking rate was the major factor affecting livestock production and economic returns because, as stocking rate was increased,


Figure 5. Range in annual stocking rates and residual returns to land, management and profit in the heavy continuous (HC), moderate continuous (MC), deferred rotation (DR), and rotational grazing (RG) treatments during the 6-yr study.
average production and residual returns per cow declined, whereas average production and residual returns per acre increased. Moreover, the results show that annual production stability also tended to decrease as rate of stocking was increased except at the highest stocking rate (RG), whereby livestock production was continually depressed. Quite simply, the results show that in semi-arid and arid rangelands grazed yearlong, it is not possible to continually stock at heavy rates without encountering increased financial risk because of the need to periodically destock or provide a substitute feed in the absence of sufficient amounts of forage.

## SIMULATION OF STOCKING KATE ADJUSTMENT TACTICS

Riechers et al. (1989) used simulation to assess long-term effects of alternative tactics for adjusting stocking rate in accordance with variations in forage production and to simultaneously include the impacts of variations in forage production and cattle prices on the outcome. Simulation provides the alternative tactics to be monitored to determine which tactics create the greatest variance in cattle numbers and how these changes impact the mean and variance of net returns to the rancher's capital, land, and management.

The economic consequences of 3 different stocking rate tactics were simulated on a total land area of 3,000 acres, using 36 years of weather data from Throckmorton and studies of standing crop and livestock production by Heitschmidt et al. (1987). The first tactic set stocking rate at a maximum limit of 250 head. The second tactic set the maximum limit at 333 head and no maximum was set in the third tactic. No minimum levels were set for any of the simulated tactics.

With the unlimited stocking tactic, the yearly average number of cows was 78 per section. Annual average cow numbers for the 2 limited tactics were 58 and 47 per section for the 333 and 250 head limits respectively.

The average annual net returns and their standard deviations are presented in Figure 6. Average net returns increased as the maximum allowable stocking rate increased. When the average stocking rate was changed from 47 to 58 cows per section, annual net returns increased about $24 \%$ and relative variation increased $8 \%$. Comparing the differences between the 58 and 78 head per section stocking rates, annual returns increased by $9 \%$ and variation increased $18 \%$.

Stochastic dominance with respect to a function was utilized to rank each of the stocking rate adjustment tactics at different levels of risk aversion. The results (Figure 7) indicate that if a producer is not averse to risk (risk neutral) or only slightly averse to risk, then the heavy stocking rate (unlimited stocking rate tactic) would be preferred because it offers higher average annual net returns. However, as aversion to risk increases, the moderate stocking rate becomes preferred. In fact, at the highest levels of risk aversion examined in this study, there was little difference in relative preference between the moderate and light stocking rate strategies despite the fact that the moderate tactic offered $24 \%$ greater average annual net returns.


## Average Annual Stocking Rate $\longrightarrow$

Figure 6. Mean and standard deviation of annual net returns for three stocking rate levels over the 36 year period simulated.


Risk Aversion $\rightarrow$

Figure 7. Relative preferences for three stocking rate levels over four levels of risk aversion.

An analysis by Whitson et. al (1982) of data from the Texas Experimental Ranch in the Rolling Plains for the period 1961-1974 indicated that for the entire period of time, heavier stocking rates produced greater net income. However, when only the last five years of the study were evaluated, a moderately stocked system produced only slightly less net income than the heavier stocked system (Figure 8). Sustainability of income over a longer term planning horizon became increasingly important over time. That is, the longer period of time that heavier stocking rates were utilized, the greater the negative impact on vegetation and income. Thus, time in a planning period became an extremely important component of selecting a particular stocking rate (Figure 9).

One additional finding of this study was the role that supplemental feeding during the winter had on income as well as the stability of income from year to year. Supplemental feeding, with high stocking rates, resulted in increasingly more stability in net income over time. Moderate stocking rates had a similar stabilizing impact on income.

The importance of net income stability over time should be considered in the development of ranch plans. The greater the potential negative impact from losses in any one year, the more important the development of plans that will reduce or minimize annual income fluctuation becomes; even if these plans result in somewhat lower average annual income.

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Figure 8. Actual total costs ( $\$ / \mathrm{ha}$ ) from alternative grazing systems on the Texas Experimental Ranch, 1961-1974.


Figure 9. Net returns (\$/ha, 1979 dollars) from alternative grazing systems on the Texas Experimental Ranch 1961-1974.

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# MANAGING STOCKING RATES TO PREVENT ADVERSE ENVIRONMENTAL IMPACTS 

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## Introduction

Watersheds are important reservoirs and sources of water for agricultural, industrial, and human uses. Population growth and expansion are expected to make increasing demands on water resources. To meet this increasing demand, a major environmental concern is focused on the physical impacts of watershed management practices that may impact the hydrologic cycle (Figure 1). Recently, concerns of nutrient and bacteria contamination have also become important to the public. The impact of livestock grazing on watershed parameters has become a national resource management issue. Often the information is based on emotion or misinterpreted data. This paper will assess the impacts of livestock grazing on watershed parameters.

Improperly managed grazing animals can indirectly cause contamination of water by damaging vegetation to a degree that erosion occurs. This nonpoint-source pollution could have a major impact on quality of the state's water supply because grazing lands make up a large portion of the watersheds in Texas. Rangeland accounts for about 60 percent of the Texas land area ( 40 million ha). In addition, grazing land classified as pastureland, which receives more intensive management than rangeland, includes 11 percent of the land area ( 7.2 million ha).

Livestock grazing affects watershed properties by altering vegetation properties and by the physical action of the animals' hooves. Reductions in the vegetation cover may: increase the impact of raindrops; decrease soil organic matter and soil aggregate stability; increase surface soil crusts; and decrease water infiltration rates.

## Vegetation Properties

Plant cover and litter are important because they reduce or redirect the erosive force of rainfall impact and surface runoff. Good vegetative ground cover significantly reduces surface runoff and erosion because it softens raindrop impact on soil and improves infiltration of water into the soil. Thus, more water moves into the soil and reduces the amount of surface runoff and erosion potential. Vegetation slows water movement as well, serving as a physical barrier to surface runoff. Thus,


Figure 1. A simplified diagram of the hydrologic cycle.

## VEGETATION TYPE



Figure 2. Influence of vegetation type on sediment loss, surface runoff, and rainfall infiltration from four inches of rain in 30 minutes. (Adapted from W.H. Blackburn et al. 1986)
more of the sediment is deposited on the grazing land rather than carried into streams or water impoundments.

Removal of the vegetation results in a decrease in above-ground biomass which eventually reduces the amount of organic matter being returned to the soil. Organic matter is important in soil aggregate foundation and stability of the aggregates. Root biomass is also reduced by excessive grazing. The roots are important in maintaining pore spaces in the soil and for addition of organic matter.

Changes in species composition are also related to grazing intensity. The type of vegetation has a strong influence on infiltration rates (Wood and Blackburn 1981, Pluhar et al. 1983, Thurow et al. 1988). Perennial bunchgrasses generally have higher infiltration rates and lower sediment production than sodgrasses, annuals or bareground (Figure 2). Long-lived, perennial bunchgrasses have a deeper root system than sodgrasses. A deep root system creates an environment more conducive to water infiltration than a shallow root system. Thus, sites with vegetation composed of deep-rooted perennial bunchgrasses generally have a higher rate of infiltration than similar sites occupied with perennial sodforming grasses. Annual grasses are short-lived and shallow-rooted. A site with vegetation composed of annual grasses has a lower rate of infiltration than a similar site with a cover of perennial grasses.

Species composition of vegetation is a strong indicator of hydrologic condition. As stocking rates are increased on midgrass and tallgrass rangeland, the composition shifts to a shortgrass dominated association (Rhodes et al. 1964) with very dramatic shifts associated with very high stocking rates (Thurow et al. 1988). Midgrasses or bunchgrasses generally are more desirable, so the animals repeatedly graze these plants. The repeated grazing stresses the plants causing a decline in total foliar and basal cover. This causes a shift in range condition from good to fair and eventually poor if the heavy grazing is continued (Figure 3). Moderate or light stocking rates generally have little effect on vegetation composition (Ellison 1962, Blackburn et al. 1982).

Vegetation and litter cover should be maintained to reduce raindrop impact on the surface soil, give maximum infiltration rate and allow minimum surface runoff (Figure 4). Thurow et al. (1988) showed that total organic cover was strongly associated with infiltration rates. Total above ground biomass was strongly associated with sediment production (Figure 5). Managing rangelands to maintain a minimum vegetation cover or biomass is important in reducing runoff and erosion problems.

Pastures evaluated in 1976 at the Sonora Research Station represented: (a) a heavily stocked continuously grazed pasture (4.6-5.4 ha/AU), (b) one pasture of a Merrill 4-pasture, 3-herd deferred rotation grazing system (5.2 ha/AU), and (c) a livestock enclosure that had been ungrazed for 28 years. All pastures were heavily stocked, continuously grazed before 1948.

## RANGE CONDITION



Figure 3. Effect of vegetation cover on runoff and erosion. (Adapted from R.W. Bailey and O.L. Copeland, Jr. 1961)


Figure 4. Relationship of infiltration rate with total organic cover (\%) for the Edwards Plateau. (From Thurow et al. 1986)


Figure 5. Relationship of the Log,, sediment production with total above-ground biomass ( $\mathrm{kg} \mathrm{ha}^{-1}$ ) for Edwards Plateau, Texas. (From Thurow et al. 1986)


Figure 6. Mean infiltration rates of field capacity soil moisture for various grazing practices at the Sonora Agricultural Experiment Research Station. (From McGinty et al., 1978).

Terminal infiltration rates for the pasture in a 4-pasture deferred-rotation grazing system at Sonora and a 27 -year exclosure were similar (Figure 6) (McGinty et al. 1978). The heavily, continuously-grazed pasture exhibited less than one-half the infiltration rate of the deferred-rotation pasture and exclosure. Soil loss was higher from the continuously-grazed pasture ( $211 \mathrm{~kg} / \mathrm{ha}$ ) than the deferred-rotation pasture and exclosure ( 134 to $160 \mathrm{~kg} / \mathrm{ha}$, respectively).

## Soil Factors

Grazing animals also reduce infiltration rates and increase sediment production by trampling the soil. Savory (1978) promotes a "herd action" from having livestock concentrated on small areas for short periods. The hoof actions associated with the concentrated animals are supposed to enhance infiltration rates even at doubled stocking rates (Savory 1983). No research conducted to date has supported the theory that infiltration rates are increased at higher stocking rates (Warren et al. 1986). Trampling of soil when it is dry has a lower impact than when the soils are wet (Figure 7).

Clayey soils are impacted more severely when wet because the soil aggregates are easily broken down and bulk density is increased. A study conducted by Warren et al. (1986) looked at various levels of trampling on both wet and dry soils (Table 1). Infiltration rates were decreased and sediment production increased following trampling typical of intensive rotation systems. The harmful effects increased as stocking rate increased. Thirty days of rest are not enough to allow recovery of the soils to pre-trampled conditions. Increased numbers of compacted trails are also associated by intensive rotation systems (Walker and Heitschmidt 1986). These trails, although no related to stocking rates, can have very harmful effects on the overall system because of channelization of overland flow. The channelization promotes gully formation.

## Riparian Areas

Riparian areas are lands adjacent to creeks, streams and rivers where vegetation is strongly influenced by the presence of water. Riparian areas may comprise less than $1 \%$ of the area in the western United States, but they are among the most productive and valuable of all lands. The presence of water and green vegetation makes riparian areas attractive and important to domestic livestock grazing adjacent, drier uplands. Many other values of riparian areas are not well known, and commonly are misunderstood. While occupying relatively small areas of land, riparian areas can strongly influence how watersheds function. By influencing the timing and quality of water produced, the condition of riparian areas can have significant, far-reaching, economic and environmental consequences.

TRAMPLED


Figure 7. Conceptual architecture of a soil aggregate and the changes in soil aggregate structure caused by trampling under wet and dry conditions. (From Taylor et al. 1993) Table 1.

| Trampling intensity | Infiltration Rate ( $\mathrm{mm} \mathrm{h}^{-1}$ ) |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Trampled dry |  |  | Trampled moist |  |  |
|  | Before trampling | After trampling | Mean | Before trampling | After trampling | Mean |
| 0 | 166 | 166 | 166 | 160 | 160 | 160 |
| 1X | 147 | 132 | 140 | 133 | 130 | 133 |
| 2 X | 137 | 106 | 121 | 115 | 83 | 99 |
| 3X | 134 | 101 | 117 | 109 | 82 | 96 |
| Trampling intensity | Sediment Production ( $\mathrm{kg} \mathrm{ha}^{-1}$ ) |  |  |  |  |  |
|  | Trampled dry |  |  | Trampled moist |  |  |
|  | Before trampling | After trampling | Mean | Before trampling | After trampling | Mean |
| 0 | 976 | 976 | 976 | 2007 | 2007 | 2007 |
| 1X | 1829 | 3824 | 2827 | 2998 | 2752 | 2875 |
| 2 X | 2272 | 4605 | 3438 | 3542 | 5048 | 4274 |
| 3X | 2211 | 7078 | 4788 | 4057 | 7465 | 5861 |

Diversity of vegetation is an important characteristic of riparian areas in good condition. Woody and herbaceous plants slow flood flows and provide a protective blanket against the erosive force of water. Their foliage shields the soil from wind and sunlight, which keeps soil temperatures low and reduces evaporation. They produce a variety of root systems that bind the soil and hold it in place. Riparian vegetation filters out sediment which builds stream banks and forms productive wet meadows and floodplains and reduces sedimentation of water supply and hydroelectric reservoirs. Riparian areas in good condition slowly release water to stream channels, thus increasing seasonal quantity and quality of water.

The deterioration of western riparian area began with severe overgrazing in the late nineteenth and early twentieth centuries. Native perennial grasses were virtually eliminated from vast areas and replaced by sagebrush, rabbitbrush, mesquite and juniper, and by exotic plants or shallow-rooted native vegetation less suited for holding soils in place. Concerns with riparian management in Texas have been minimal because most of the state is private land. Management of riparian areas may be regulated in the future, even of private land. Some areas are already regulated under the federal wetlands regulations. Riparian areas may also be important habitats for endangered species, both plant and animal.

Proper grazing management can restore the long-term productivity of most riparian areas and associated uplands. However grazing and the gap between shortterm costs and long-term benefits of improved management, all present significant obstacles to changes in grazing practices.

## Nonpoint Source Pollution

The nonpoint source provisions of the Clean Water Act bring a new dimension to monitoring of grazed watersheds. States will systematically monitor and evaluate chemical, physical and biological water quality indicators such as sediment load, temperature, dissolved oxygen and fish populations. The results will be used to ensure compliance with state programs adopted to achieve the act's mandata to attain and maintain designated beneficial uses such as drinking water, agricultural water supplies and fish and wildlife production.

Although the vast grazing lands have a great potential for nonpoint source pollution, the water runoff currently is not a major source of water pollutants. However, in localized situations, water quality problems may exist. Because of the extensive area covered by grazing land and potential problems with runoff, the management of these lands to prevent nonpoint source pollution is very important.

Generally, pollutants from grazing land watersheds impact surface water more than groundwater. The Edwards aquifer, a sole source aquifer, is susceptible to pollutants carried by surface runoff because it is cavernous and contains numerous faults that allow direct recharge from surface runoff.

Most rangeland in Texas receives low rainfall. Surface runoff from these areas may be infrequent. However, when runoff does occur, it is usually the result of a high intensity thunderstorm that may create significant surface runoff. These intense rainfall events can cause considerable sediment movement particularly if vegetation cover is poor.

Sediment carried by surface water runoff is the primary water pollutant from grazing land. Other less abundant pollutants include chemicals adsorbed on the sediment particles and organic matter. Streams adjacent to areas grazed by livestock may show increased concentrations of bacterial indicator organisms such as coliforms and streptococcus. However, it should be recognized that if watersheds have been severely overgrazed, instituting a moderate continuous or specialized grazing system may not reduce sediment losses. Bacteria or nutrients as potential pollutants from livestock grazing do not appear to be a problem on areas not included in riparian zones (Buckhouse and Gifford 1976, Gifford et al. 1976). However, properly managed rangeland and pastureland usually have no pollution problem from animal waste. Their impact on the vegetation is the major concern.

## Summary

Hydrologic impacts of livestock grazing result primarily from the interactions of climate, vegetation, soil, and intensity and duration of livestock use. Thus, grazing impacts will vary naturally from area to area due to the normal variability of these factors. Few studies have attempted to account for these natural variations. What is described as moderate grazing intensity in one study may be the same as heavy grazing in another study. Grazing cover affects nonpoint source pollution because of its impact on falling raindrops and surface runoff. The impact of raindrops on the soil surface dislodges soil particles and may move them a considerable distance. This splash erosion creates a suspension of soil and water, which is moved in surface runoff. Water infiltration is reduced when soil pores get plugged with suspended soil particles. Standing vegetation and mulch on the soil surface intercept raindrops and reduce their splash effect. Nonpoint source pollution from the vast Texas rangelands and pasturelands may be minimized by proper vegetation management. Application of grazing management principles will be necessary to achieve the level of vegetation management needed.

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# DETERMINING CARRYING CAPACITY ON RANGELAND FOR SETTING PRODUCTIVE STOCKING RATES 

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Every rancher faces the problem of deciding the stocking rate for his pastures how many animals for how long. If he fails to make the right decision, the problem will inevitably face him and be compounded by continuing indecision or inaccurate decision.

Proper use is the range management practice upon which the success of all the others depends. Defined as "stocking according to forage available for use, always leaving enough for production, reproduction, and soil protection," it is easier said than done. Other factors, such as the species of livestock and wildlife to be grazed, the proper distribution of grazing and the grazing method employed, are important in obtaining proper use, but a key concern is setting and adjusting the stocking rate as determined by carrying capacity.

Experience and research have surfaced several means by which the grazing land manager may estimate and/or calculate carrying capacity of range and tame pasture in order to make more accurate and timely stocking rate decisions and adjustments. Use of several different methods simultaneously gives several different "looks" that help improve judgment and increase accuracy.

For many years the U.S.D.A. Soil Conservation Service has used range site and condition to determine carrying capacity and has developed range site descriptions and range condition guides for almost every area of privately owned rangeland in the U.S. The safe starting stocking rates derived by the S.C.S. are fairly conservative, as they should be to avoid recommendations that might cause trouble.

A range site is a distinctive kind of rangeland of relatively homogeneous climate, soils, and topography which will in turn support a typical group of plants and level of production. Range condition refers to the current productivity of range relative to what that range is naturally capable of producing in climax condition. Range condition class is determined by the percent of climax plants present and usually is expressed as excellent, good, fair, and poor by 25 percent increments. For each condition class there is a corresponding carrying capacity or safe starting stocking rate range expressed in acres per Animal Unit Year Long or Animal Unit Month. The range allows for varying forage production from year to year within a given condition class.

Climax plants include decreasers, which are those plant species dominant in the original climax vegetation that decrease in relative amount with continued overuse. Increasers are secondary climax plants that increase for a period of time as decreasers decline under overuse, but they in turn will decrease under continued overuse. Invaders are those plants absent or present in very small numbers in the climax situation that come to cover bare ground as the climax plants decline and therefore are not counted for range condition classification.

For many years S.C.S. range condition estimates were based on a visual estimate of percent ground cover (basal density and/or canopy cover) of climax plants, with any amount of decreasers counted and with no greater percent of increasers counted than were estimated to be present in climax condition. This system was easy for both range technicians and ranchers to learn and use and provided a reasonably accurate track of changes in plant composition if recorded year after year. (Appendix A)

In an attempt to refine that system in recent years, S.C.S. range condition guides assign a percentage of each plant or group of plants similar in production and reaction to grazing pressure. The percentage present is determined by estimating the pounds of air dry forage per acre of these plants or groups divided by the total pounds per acre. (Appendix B)

This system is much more difficult and complicated to learn and use and confuses annual forage production, which fluctuates widely from year to year, with actual changes in plant composition, which are much slower to change, so that neither is tracked accurately and separately. For these reasons, the present system in practice appears to be more complicated and time consuming, less useful, and no more accurate than the former. After going to this trouble, the estimate of total forage production per acre is not used per se in estimating the carrying capacity.

For the past twenty years, the author has developed and used a third method, proven accurate in practice, which is fast and easy to learn and use in yearlong grazing area. It is based on estimating the total forage production per acre in the fall at or near the end of the growing season to determine the carrying capacity through the dormant season. The pounds of forage per acre may be estimated by site and totaled for the whole pasture or estimated as an average per acre for the whole pasture. In either case the pounds per acre is multiplied by the number of acres to determine the total forage available in the pasture.

In order to determine the amount of forage available for animal intake, the total forage present should be divided by four to allow for the amount already grazed during the growing season, the amount lost to weathering and trampling, and the amount that should be left for soil protection to achieve proper use at the end of the grazing season before the following year's growth is initiated. To determine the amount of usable forage required per animal unit, multiply 30
pounds per day (three percent of body weight) times the days to be grazed (dormant season plus 30 to 45 days to allow for late spring, or a shorter period if livestock are to be rotated). If the pasture is being grazed year long, the winter stocking rate will approximately equal the yearlong stocking rate.

The eye of the technician or rancher can be set for visual estimates by clipping all the forage from a 21 inch radius circle and weighing in grams times ten to determine pounds per acre and adjusting for moisture content to arrive at air dry forage per acre. The adjustment can be made from S.C.S. tables related to forage type and stage of growth or by heating (carefully to avoid fire) in the kitchen oven and adding ten percent back to get air dry. Usually, only two or three clippings are necessary to set the eye to typical areas before proceeding with visual estimates. This procedure comes very naturally to those accustomed to estimating livestock weights. (Appendix C)

A fourth method of estimating carrying capacity involves using the total forage production per year required to support an animal unit, while providing for forage loss and soil protection in areas of differing annual rainfall, divided by the actual total annual forage production per acre as determined by clipping or ocular estimate to determine acres per animal unit on a yearlong basis. This method was developed independently by Hershel Bell, H.L. Leithead, and a number of other workers based on their field observations and experience. A table published by the Texas Agricultural Extension Service follows:

## Forage Requirement per Animal Unit of Domestic Livestock

Average Annual Rainfall Annual Forage Requirement

| More than 30 inches | 30,000 pounds |
| :--- | :--- |
| 20 to 30 inches | 24,000 pounds |
| 15 to 20 inches | 20,000 pounds |
| Less than 15 inches | 15,000 pounds |

A fifth method of annually setting or adjusting stocking rate is used by Dick Whetsell on the Oklahoma Land and Cattle Company in the Osage area of northeastern Oklahoma in an area of 32 to 34 inch average annual rainfall. Since no one can predict future forage production accurately, he bases his adjustments on the previous year's forage production. In an area where on the average 8 acres is required per animal unit yearlong, if the previous year has been above average in forage production, the allowance would be reduced by one acre to seven acres. If another good year followed in succession, the allowance would be reduced to six but never below six. If that succeeding year had been average, the rate would remain at seven; if below, it would have returned to eight. In years of reduced forage production, reductions would be made in one acre increments. To
adjust this method for areas of less rainfall larger increments of adjustment would be needed. An area requiring 16 acres per animal unit would require adjustment in two acre increments.

A sixth method uses the net energy method to estimate carrying capacity by balancing animal energy needs with energy available in the amount of forage per acre with energy provided by supplements deducted to arrive at the number of acres required per animal. (Appendix D)

A seventh method, simple and widely used, is making adjustments of stocking rate based on degree of use and overall range trend. The present degree of use is the first indicator of range trend, followed by plant vigor, production and reproduction, with litter, organic matter, ground cover, and livestock production following. A stable trend would indicate leaving livestock numbers as they are with concomitant additions of livestock if trend is upward, and decreased numbers if trend is down.

Data for all these methods can be obtained rather rapidly for the purpose of original inventory or subsequent monitoring by moving through each pasture and recording data in abbreviated form site by site and/or pasture by pasture on aerial photographs or other maps. Site can be noted by initials, as can condition class ( $\mathrm{E}, \mathrm{G}, \mathrm{F}$, or P), the amount of forage present in pounds per acre, current degree of use (L, M, or H for Light, Moderate or Heavy) and trend (,$+ \mathbf{0}$, or - to represent upward, stable, or downward). An example map notation follows:

Fair condition
J-Moderate Use
Deep Upland Site $\longrightarrow \mathrm{DU} / \mathrm{F} / 2500 / \mathrm{M} /$
2500 pounds of forage--—T $T$ Upward trend
Calculations of an example by methods one and three might be done as follows:
North pasture - 328 acres November 1 Observations

(30\#/A.U./DA. x 180 DAS. $=5400 \# /$ A.U.)

If your stocking rate the previous year had been 35 A.U. and this had been an average forage producing year with a total forage production of 3500 pounds per acre, a crosscheck by method four would indicate 38 A.U. and by methods five and seven would be 35 A.U. With these calculations as background, you might confidently decide to stock on the basis of 37 A.U. in that pasture.

Before determining the number of domestic livestock to be grazed, be sure to deduct the animal unit equivalent of grazing wildlife, if numbers are significant. Species and classes of livestock should be chosen according to forage and water resources, topography, markets, facilities and knowledge available. Stocking rate usually can be increased if rotation grazing and/or multiple species are used to increase efficiency.

Animal unit equivalents guide
Kind and classes of animals Animal-unit eauivalent
Cow, dry ..... 1.00
Cow, with calf ..... 1.00
Bull, mature ..... 1.25
Cattle, 1 year of age .....  60
Cattle, 2 years of age ..... 80
Horse, mature ..... 1.25
Sheep, mature .....  20
Lamb, 1 year of age .....  15
Goat, mature .....  15
Kid, 1 year of age .....  10
Deer, white tailed, mature ..... 15
Deer, mule, mature .....  20
Antelope, mature .....  20
Bison, mature ..... 1.00
Sheep, bighorn, mature .....  20
Exotic species ..... (to be determined locally)

Stocking rate calculations are exactly the same situation as calculating feed ration. They are used to decide on a reasonable course of action, which is followed by continuous close observation of results, in this case response of both forage and livestock, and adjustment as necessary to achieve the desired results. No amount of calculation can take the place of good judgment, keen observation, and timely action, but used properly, it certainly can contribute to wiser decisions and less costly errors.

Since subsequent years are seldom alike in forage production, good ranchmen need to plan for adjustments in stocking rate as needed to match forage available
without wrecking breeding management, cash flow, and tax management. Understocking, overstocking, and even constant stocking at the same rate increases costs and reduces profitability. A conscious, constant, and knowledgeable effort to stock properly will pay good dividends.

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## Appendix A

SCS TECHNICAL GUIDE TO RANGE SITES AND CONDITION CLASSES
Work Unit: Fort Worth

| KEY CLIMAX PLANTS. | Plant Percent | Allow | by Sites | INVADING PLANTS |
| :---: | :---: | :---: | :---: | :---: |
|  | DU | RP | VS |  |
| Little bluestem |  |  |  | Annuals |
| !! ! bluestem |  |  |  | Texas orama |
| Trujiangrass |  |  |  | Tumblcorass |
| Sivi tchorass |  |  |  | Huiry tridens |
| Pcrennial wi idrye |  |  |  | Scribner panicum |
| Sidcosats oramo | 10 | 15 | 0 | Fall witchorass |
| Hini ryuropsced |  | 5 |  | Hal iscanicum |
| Vine-mcsqui te | 5 | 5 |  | Sand drooseed |
| Mc.300w oropseed | 5 | 15 |  | Roemer senna |
| Silvar blucstem | 5 | 10 | 15 | Gray colaaster |
| Texas wintergrass | 10 | 5 | 5 | Dvschori ste |
| Fexas cupqrass | 5 | 5 |  | Buckwineat |
| Muffalograss | I" |  |  |  |
| ,. | $\overline{5}$ | 10 | Cur I y nunweed |  |
| i'hite tridens | 5 | 5 |  | Mea 1 ycunsace |
| aepruhly | Inv. | 5 |  | Hightshaos |
| Tall hai ry orama | Inv. | 5 | 10 | Mi1 kiveeds |
| Pnuoh tridens |  | Inv. | 15 | Western ranwead |
| Ferennial threcawn | Inv. | Inv. | 10 | Baldwin iron:sed |
| C iimar forbs | 5 | 5 | 10 | Texas sti llinoia |
| Wontv carooy * | 5 | 5 | 5 | Prickly Dear |
|  |  |  |  | Mesouite |
|  |  |  |  | Yucca |
|  |  |  |  | Suriac |

M:iximum Total
Lllourble_lnereascrs 20

| Rance Condition |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Excel lent | 7 | 10 | 16 | 76-100 |
| Good | 9 | 12 | 20 | 51-75 |
| li,jir | 14 | 16 | 26 | 26-50 |
| Poor | 20 | 23 | 35 | O-25 |

## LEGEND

| Blank | $=$ Not significant |
| :--- | :--- |
|  | $=$ |
| Decreaser: all allowed |  |
| 5, etc. | $=$ Increaser: allowable percentage |
| Inv. | $=$ Invader |

Range Sites and liajor Soils:
DU= Deep Upland (GP) 2-San Saba clay; 2X-Denton, Krum clay; Lewisville clay loam.
$R P=$ Rolling Prairie (GP) 18 c -Denton-Tarrant complex; 18 -Denton clay, shallow phase.
$V S=$ Very Shallow (GP) $24 c$-Tarrant stony ciay, unfractured substrata.

Useopen canopy method to determine percentage of all brush species. On Savannah sites, determine range condition by the percentage comoosition of undcrstors vegetation. To estimate available grazing, reduce the acreace in the site by the percent that climax brush exceeds the indicated allowable. On-prairie sites, estimate percentage of invading brush species by loosely compacting the canopy to simulatetotal shading. The percentage figure thus obtained is "counted" against range condition.

Appendix B
FROM SCS GUIDE TO RANGE SITES AND CONDITION CLASSES
Page 2
Clay Loam
Section II-E
November 13, 1972

## RELATIVE PERCENTTECE

| Graseses $\quad 0 \%$ | Woody | 2\% | Forbs $5 \%$ |
| :---: | :---: | :---: | :---: |
| Little bluestem 35 | Elm |  | Fragelmanndaisy |
| Eig bluestem 20 | Eackberry | 5 | Ifaxmilian sunflower |
| Indiengrass 15 | Pecan Plum | 5 | Yellow neptuni |
| Switcheress | Ifveoak | T | briar |
| Virginia and | Iureoak | 1 | Prairie clover-s |
| Canada wildrye |  |  | Scurfpeas |
| Sideoats grema to |  |  | Heath aster |
| Texas wintergress 10 |  |  | Trailing ratany |
| Tail dropseed |  |  | Blacksamaon |
| Vine mesquite |  |  | Wildbeans |
| Texas cupgress |  |  | Tickclovers |
| White tridens 5 |  |  | Gayfeather |
| Silver bluestem |  |  | Prairie bluets |
| Eairy greas |  |  | Bundleflower |

b. As retrogression occurs, big bluestem decreases rapidly followed by Injiengrass, little bluestem, and swítchigress. Sidsoats grame, tall dropseed, and Texas wintergrass increase initially and then decrease as retrogression continues. Buffalograss, Tixas grama, tumblegress, red threeawn, westam ragweed, Baldwin ironweed, queensdoligint, mesquite, sumac, lotgbush and common honeylocust invede the site.
0. Approximate total annual yield of this site in excellent oondition ranges from 3000 pound per acre in poor years to 6500 pounds per acre of edr-dyy vegetation in good years.
4. WILDLTFE NATIVE TO THE SITB: Dove and quail inhabit this site.
5. GOIDE TO RIIRIML STOCKINTS RiTRT:

| Condition Class | Climax Vegetation | $\mathrm{Ac} / \mathrm{AD} / \mathrm{XL}$ |
| :---: | :---: | :---: |
| Excellent | 76-100 | 6-9 |
| Good | 51-75 | S-12 |
| Fair | 26-50 | lo-16 |
| Poor | o-25 | 14-20 |

b. Introduced Species

Species
King Range bluestem
Common bermuderrass Eleingrass

Percent of the Area Established

| $\frac{100-76}{8-10}$ | $\frac{75-51}{10-14}$ | $\frac{50-26}{14-18}$ | $\frac{25-0}{18+}$ |
| :--- | :--- | :--- | :--- |

$\begin{array}{llll}7-10 & 10-13 & 13-18 & 18+\end{array}$
$\begin{array}{llll}7-10 & 10-13 & 13-18 & 18+\end{array}$


## Appendix C Cont'd.

Percentage of Air-Dry Matter in Harvested Pl ant Material at Various Stages of Grouth

| Shr ubs | New I eaf and twig grouth until leaves are full size | Ol der and full-size green l eaves | Green fruit | Dry fruit |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Ever green. $\qquad$ <br> bi $\mathbf{g}$ sagebrush <br> bi tterbrush ephedra al gerita gal I ber ry | $\frac{\text { Percent }}{55}$ | $\frac{\text { Percent }}{65}$ | $\frac{\text { Percent }}{35}$ | $\frac{\text { Percent }}{85}$ |  |
| Deci duous snouberry rabbi tbr ush snakeweed Ganbel oak nesquite | 35 | 50 | 30 | 85 |  |
| Yucca and yucca-like pl ants. <br> yucca <br> sot 01 <br> saw pal netto | $55$ | 65 | 35 | 85 |  |
| Forbs | Initial grouth to fl owering | tl oweri ng to seed maturity | ```Seed ripe; leaf tips dry``` | Leaves dry; stens dryi ng | Dry |
| Succul ent. <br> vi ol et <br> wat erl eaf <br> buttercup <br> bl uebel Is <br> oni on, lilies | $\frac{\text { Percent }}{15}$ | $\frac{\text { Percent }}{3 \mathrm{~s}}$ | $\frac{\text { Percent }}{60}$ | $\frac{\text { Percent }}{90}$ | $\frac{\text { Percent }}{100}$ |
| Leaf y. . . . . . . . . . . . . . . . . . . . . <br> I upi ne I espedeza compasspl ant bal samroot ti ckcl over | 20 | 40 | 60 | 90 | 100 |
| Fi brous leaves or nat. <br> phl ox <br> nat eriogonum pussytoes | $30$ | 50 | 75 | 90 | 100 |
| Succul ents | New grouth pads and fruits |  | O der pads |  | Od grouth in dry years |
| pricklypear and barrel cactus cholla cactus......... | Percent |  | Percent |  | Percent |
|  | $\begin{aligned} & 10 \\ & 20 \end{aligned}$ |  | $\begin{aligned} & 10 \\ & 25 \end{aligned}$ |  | $\begin{array}{r} 15+ \\ 30+ \end{array}$ |

## Appendix D

From TAES B-1043


Figume n. Estimutins annunl disestible curcre irquiroments for a row and her calf (2 milrs travel).


Use your overoge com weight cand 7 month call weght ond determine the digestible entrgy requirements from figure o.

range analysis and management handbook
*- b. Distribution of livestock may be poor, and will usually be evident by a patchy grazing pattern on primary range. When distribution is the problem, a reouction in stocking makes the area of heavy use smaller but does not totally correct the situation. Theoretically, there will continue to be an area of over-use until all livestock are removed or the distribution problem is solved.

The grazing capacity is the maximum stocking rate possible without inducing damage to soils, vegetation or related resources. Stocking rate may equal grazing capacity, but should never exceed it.

Foraqe Production and Utilization. A comparison of current stocking rate with forage production and utilization on primary range forms a good basis for checking estimated capacity (Chapter 22.34).

Comoare with other Allotments. No two allotments are similar, and management is seloom similar. Direct comparisons are limited, therefore, actual stocking on a properly stocked allotment with similar vegetative type, soils and suitable areas may-. be used as a check against the allotment on which the grazing capacity is being determined.

When managment and distribution of livestock on an allotment improves to where utilization is below that considered as proper and there is forage which should be utilized, re-calculate the capacity and aajust the stocking rate according to new production and utilization figures and the guidelines above.

This adjustment formula may be used anytime during the grazing season when percent use to date and AUM's of use to date are known.

## Estimated <br> Current stocking AUM x Desired $\%$ Utilization $=$ Stocking Rate Current \% Utilization <br> AUM's

Make changes in stocking rates and recalculate grazing capacity based on records over a period of 4 to 5 years. Conai tions affecting capacity, such as rainfall, change too frequently for records of one to two years to be accurate. Record grazing capacity estimates on Form R8-2200-17, Allotment Acreage by Vegetative Type and Grazing Capacity Estimate (Exhi bit 6).
+-R-8 FSH1l/83 AmEND 3-f
Animal Unit (A.U.) is defined as the amount of forage to feed a 1000 pound cow.
Animal Unit Month (A.U.M.) is the required forage for a 1,000pound cow for one month.
Animal Unit Year (A.U.Y.) is the required forage for a $\mathbf{1 , 0 0 0}$ pound cow for one year.
CARRYING CAPACITY EOUIVALENTS
AUM per Acre Acres per AUY Acres per AUM
15-------------------0. $80---------------0.067$
14-----------------0. 86 ..... 072
13-----------------0. 92 ..... 077
12------------------1. 00 ..... 083
11------------------1. 09 ..... 091
10------------------1. 120 ..... 100
9------------------1. 33 ..... 0.110
8------------------1. 50 ..... 0.125
7-----------------1. 71 ..... 0.143
6------------------2. 00 ..... 0.167
5------------------2. 40 ..... 0.200
4------------------3.00 ..... 250
3------------------4.00 ..... 330
2-----------------6. 6.00 ..... 0.500
1------------------12.00 ..... 1.000
$0.8------------15.00$ ..... 250
0.6 --------------20. 20.00 ..... 670
0.48 --------------20. 25.00 ..... 080
0.40 -------------30. 30 ..... 500
$0.34-2--------35.00$ ..... 920CONVERSION FACTORS
Acres per AUY $=12$ months - AUM's per Acre Acres per AUM $=1$ - AuM's per Acre aUMbs pertacibe $=12$ ma-riAcres~-per AUY AuM's per Acre - 1 - Acres Der Aum

Acres per AUM $=$ Acres per AUY -12

Acres per AUY $=$ Arces per AUM X 12
Prepared by Darwin C. Hedges
Range Conservationist Pauls Valley, Oklahoma5/23/73

# GRAZING MANAGEMENT CONSIDERATIONS 

Kim Flowers<br>Flowers Cattle Company<br>Miami, TX

Flowers Cattle Company operates family owned ranches in Roberts and Hemphill Counties of the Texas Panhandle. The ranch in Hemphill County is 6,565 acres and the ranch in Roberts County is 8,362 acres. Both ranches are strictly cow/calf operations. We run about 450 cows. We have used rotational grazing on the Roberts County ranch for the last two years and the Hemphill County ranch for one. I live on the Roberts County ranch and am responsible for the day-to-day operations.

The Roberts County ranch was purchased in 1946. At that time it had only four pastures. Since then, the ranch has been crossfenced and now has 15 pastures. We still have five pastures larger than a section or 640 acres. However, due to the fact that windmills are so deep and expensive to operate we have been reluctant to reduce pasture size. I made the decision in the fall of 1991 that I was going to implement rotational grazing on my place using existing fences and water sources. Water is the limiting factor in my grazing system. All water comes from windmills and overflow ponds. There have been 40 erosion control dams built but we do not rely on them for water.

To determine the stocking rate, I started with the SCS forage inventory and suggested stocking rates. Their numbers were based on 1,000 pound cows. Our cows average about 1,100 to 1,200 pounds. I set a target of $80 \%$ to $85 \%$ of their numbers. Their suggested stocking rate was 292 animal units and I set a range of 234 to 248. I started last November with 232 cows and 12 bulls.

We use a 60 -day calving season for cows. About $75 \%$ of our calves are born in the first three weeks. Heifers on a 45 -day calving season and start a month after the cows. Calving starts December 10 . Cows are calved out in the pasture. Heifers are calved out in the lot. We usually calve out in seven pastures within a mile and half from the house. From December 1 until branding in March, the cattle stay in the same pastures. They are grouped according to age for calving. Old cows and problem cows are kept near the house. All cows are number branded. Records are kept on each individual cow. Calving date and sex of calf are recorded along with any other information we feel is important. Calves are evaluated prior to weaning and assigned a ranking. Calving intervals are calculated for each cow and for each age group of cows. Cows have to back up to stay in the herd.

My primary consideration in developing a grazing system was to give each pasture a minimum of 60 days continuous rest during the months of May, June and July. I feel that about $75 \%$ of our grass is grown during this period of time.

I put all of the cows with heifer calves together. They are rotated through four pastures with a total of 3,546 acres from March until October 1. The cows with steer calves are placed in a group and rotated through pastures with 2,885 acres. First calf heifers and old cows, if any, are rotated through the remaining pastures of the ranch. We put our cows with steers on our best country.

We sell our steers off of the cows in mid-September weighing around 750 pounds. We work our cows, sort them and then take them to pastures on the outer edge of the range until December 1. We then bring in our cows with heifers. The cows are worked, sorted and taken back to pasture on the outskirts of the ranch. All heifers are weaned. Keeper heifers are sorted off. All heifers are placed on a 30-day preconditioning program. Keeper heifers are vaccinated and started on $20 \%$ cubes. The rest of the heifers are vaccinated, wormed and placed on a starter ration and fed in feed bunks. We will send these heifers to the feedlot around November 1 weighing around 700 pounds. All cows are rotated through pastures on the outer edges of the ranch from weaning until December 1. We save our pastures closer to the headquarters for calving and to run the cows on until branding.

We keep detailed records by pasture on the number of head placed in a pasture and dates the pasture was grazed. We have a maximum number of days we want to be in a pasture for a year. We keep these records on a May 1 to May 1 of the next year basis. We feel this follows our grass growing seasons better than other time frames such as January 1 to January 1.

We keep precipitation records and moving 12-month average of the moisture. If it was a hard rain or slow and if we had runoff or not. If the snow was on the level or drifted. We try to get a feeling on the effectiveness of the moisture received. We want to go into the spring months with grass and litter left so that when it does rain we can keep it from running off.

There are approximately 100 pairs in each of the rotations. Cattle are moved horseback by one person. We feel that it is important to monitor grass condition horseback. We feel we get a better idea of the condition over the entire pasture. We also think that we see the cattle better by checking them horseback.

As long as we are in normal or near normal rainfall, we continue on. As we begin to fall behind in rainfall, we rank our cows based on the individual records we have kept. Older cows and lower producing cows would be first to go along with cows with an attitude problem. We group them in truckload lots and get ready to go with them. As long as conditions are good and our cows are holding up, we wean calves at about $81 / 2$ months. If conditions warranted, we would wean our calves earlier and send them to the feedlot. We would keep few, if any, keeper heifers.

If we felt we were getting into a problem with forage, we would get SCS to help us determine how much forage we had available so we would know exactly where we stood.

We grow and purchase grass hay for feeding in winter only. We feed first calf heifers, old cows and cows raising second calves a limited quantity of hay daily from calving through March. We feed hay if the ground is covered with snow or ice or if the weather really gets cold. We watch our cows closely to see how they are holding up. That determines when and how much we feed hay in cold weather. We feed only small square bales. We feel that this is more efficient use of the hay.

We begin to get ready to ship cows if we have not received spring rains by May 15 - June 1. We also look closely at September 1 moisture conditions. If we are very dry, we cut back on number of keeper heifers and possibly cull more cows.

In summary, our stocking rate depends primarily on rainfall amounts and trigger dates to have received rainfall, available forage and SCS recommendations to set stocking rates.

# STOCKING RATE CONSIDERATIONS ON THE BRIGGS RANCHES 

Joe Jones, General Manager<br>Briggs Ranches<br>Bloomington, Texas

The Briggs Ranches have Divisions in Bloomington (Traylor Division) and Catarina (San Roque) in Texas and in Poteau (Oklahoma Division), Oklahoma. The physical location of each of these ranches under different climates and soils mandate distinctly different management strategies on each. This paper will discuss our general grazing philosophy with a focus on the Traylor Division near the Texas Coast.

The Traylor Division is located near Bloomington in Victoria County, Texas, on the Coastal Prairie. It consists of 8000 acres with 1000 acres devoted to farmland and 400 acres of cool-season annual pasture. The remainder is largely Gordo and Medio bluestem with some acreage in Coastal bermudagrass and some in native grasses. The ranch has problems with mesquite, huisache, and macartney rose invading the grass pastures. A gallery forest of bottomland hardwoods exist along the Guadalupe River bottom. All soils are tight, heavy Victoria clays.

The cattle enterprises are a registered Santa Gertrudis and commercial crossbred (cow/calf) operation. The ranch has both spring and fall calving seasons. A stocker operation, primarily through retained ownership of ranch-produced calves, provides flexibility in production.

The basic managerial philosophy is to "get the most out of what we have". The long-range management goal is to support 600 mature animals ( $\pm 13$ acres/cow). Heifers and stocker steers are used during periods of excess forage. Seventy= five replacements are retained annually.

Our pastures vary in size and in strength so they also vary in carrying capacities. We have to know the strengths and weaknesses of each pasture so stocking rates can be set and adjustments made. Many of these decisions are based upon rainfall records. Also, records of the number of cows in each pasture, the time they are in each pasture, and breeding sheets and conception rates in each pasture are kept.

Monitoring is an on-going process. Frequent (at least weekly) checks of cow condition and grass quantity and condition in each pasture are done by getting out of the truck and walking through the pasture(s). If grass availability begins to drop and stress is occurring, we move heifers and yearling to other pastures, ranches or we sell. If conditions continue to deteriorate we move mature cows.

Fluctuations in carrying capacity by season and by site force fluctuations in animal numbers accordingly. Since we have a target nucleus herd of 600 cows we adjust numbers by decision deferment of pastures. Thus, stocking rate adjustments are basically time controlled. We try to keep at least one pasture deferred at all times so we have a place to go with cattle if we have to move. These pastures may be deferred only a few weeks but it is usually enough time for forage renewal and improvement in plant vigor.

The ranch plants 400 acres of oats and ryegrass each year. We try to match preparation of the land and seeding of cool season grasses with fall precipitation. These are grazed in an "on and off' fashion by combining herds during the winter. The herds are usually moved onto native pasture during the winter months.

This method of stocking rate adjustment and grazing management has worked very well for us. The combinations of improved pasture, native range, and winter pasture has allowed high livestock carrying capacities for much of the year. Frequent monitoring of pastures and adjustment of animal numbers allows us to more closely match forage availability and animal demands, and we optimize cattle production from our pastures.

# IMPROVING STOCKING RATE DECISIONS USING FORAGE SURVEYS 

Larry D. White<br>Professor and Extension Range Specialist Uvalde, TX<br>\section*{INTRODUCTION}

Livestock and wildlife grazing and trampling removes forage and cycles nutrients from plants back to the soil. The amount and quality of forage removed, and when and where the forage is obtained have major impacts on the current forage supply, future forage production, animal performance, financial returns, resource sustainability, and achievement of short and long term ranch goals. The grazing impact is directly related to the amount of forage removed in relation to supply and how much forage is left ungrazed to protect the resource and grow next seasons forage.

Ranchers monitor changes in forage supply and livestock condition to determine needed stocking rate adjustments. The expected amount of forage harvested in a year provides a calculation of the minimum needed forage supply. By comparing the needed forage supply with the actual forage supply, shortfalls or excess can be predicted and critical decision points established. Historical records and experiences help establish a realistic planned stocking rate; however, each year is different and appropriate monitoring using forage surveys followed by corrective action must be implemented if resources are to be sustained or improved.

## MONITORING AND ADJUSTING STOCKING RATES

Ranchers use visual appraisal to determine if pasture conditions require decisions on rotation and adjustments in stocking rate. Often these observations are coupled with awareness of recent rainfall, general growing conditions, available forage, and animal appearance. Because such observations are not quantified, experience is necessary for the rancher to reasonably predict what is likely to happen. Decisions are often delayed until a potential crisis becomes reality or opportunities are missed. Quantifiable information coupled with visual observation and "gut-feeling" can improve most grazing decisions.

Ranchers having rotation grazing programs have an advantage over those using continuous grazing. Because livestock are concentrated in a few pastures while other pastures are ungrazed, rotational grazing allows more visible observation of forage disappearance and regrowth. However, quantification of decision criteria to improve visual appraisal and calculated projections provides evaluation of risk and establishment of decision dates and needed adjustments.

The forage survey method determines how much forage is available and calculates how long the supply will last (White and Richardson, 1991). A rancher
can then reasonably estimate current and future forage requirements by pasture and for the ranch. The planned or current stockflow and grazing schedule identify stocking rate for the grazing system (forage demand), an expected monthly forage production (when growth should occur), the amount of forage needed and where and when the forage is to be grazed. These calculations provide a rancher quantifiable forage information throughout the year for each pasture.

Visual surveys indicate if the needed quantity of forage is available to meet current and future needs. Experience and accurate records improve interpretation and decisions on appropriate management action. Judging the amount of forage requires practice but is not difficult to learn (White and Richardson, 1990). Developing photoguides of known quantities of forage for your ranch can improve confidence and accuracy.

## MAKING STOCKING RATE ADJUSTMENTS A CASE EXAMPLE

Grazing management decisions are complex and require careful analysis of total ranch impact before decisions are implemented. The short- and long-term impact of stocking rate should not be taken lightly. Monitoring changes in ranch resources and comparing forecast alternatives requires quantification and logical estimation of potential impacts and identification of adjustments needed to avert crisis (White and McGinty, 1992).

A ranch management goal of sustaining or improving range resources while maximizing livestock production with annual stocking rates should optimize profits. The rancher, however, must be prepared to make seasonal adjustments in grazing pressure among pastures and for the entire ranch when forage supplies dictate. Balancing forage demand with forage supply requires planning and correcting imbalances following forage production.

The recommended approach for "putting it all together" can best be illustrated using an example ranch. The example will illustrate continuous grazing of a single pasture and a 1 herd:5 pasture rotation system grazed by a cow/calf enterprise (Table 1). The ranch consists of rangeland adequately watered and fenced for efficient livestock production and rotation of livestock without grazing distribution problems.

Table 1. Characteristics of example pastures and desired threshold residue amount.*

| Pasture <br> Name | Total <br> Area <br> $(\mathrm{Ac})$ | Ungraz- <br> able <br> $(\%)$ | Graz - <br> able <br> Area <br> $(\mathrm{Ac})$ | Desired <br> Residue <br> $(\mathrm{lb} / \mathrm{ac})$ | Total <br> Residue <br> (lbs.) | Stock <br> Units <br> Grazed |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1 | 394 | 7.9 | 363 | 628.8 | 228250 | 24 |
| 2 | 358 | 13.4 | 310 | 633.9 | 196500 | 22 |
| 3 | 595 | 10.9 | 530 | 477.4 | 253000 | 38 |
| 4 | 714 | 8.8 | 651 | 493.4 | 321200 | 46 |
| 5 | 633 | 6.2 | 594 | 542.3 | 322150 | 36 |
| Total | 2565 | --- | 2448 | --- | 1321100 | 166 |

*Pastures are evaluated by range site to determine percent ungrazable and establish desired threshold residue goals. Weighted average is calculated by site and summed for pasture totals.

## ANNUAL PLANNING AND MONITORING

The principle governing stocking rate decisions is to "take half and leave half." This means that of the total forage produced during the year, half should remain ungrazed (residue). Of the half that is available for livestock consumption, half of that amount ( 25 percent of total) will be lost to insects, weathering, trampling, other animals and decomposition. Thus, only the remaining 25 percent of the original total forage is actually consumed by livestock. This 25 percent is considered to be a moderate "harvest efficiency" (HE) on rangelands that are properly stocked and to be the level most ranchers should strive for (White and McGinty, 1992).

Research and experience indicate that 35 percent of the annual forage production can be consumed under careful management (heavy harvest efficiency). However, most ranchers should utilize a moderate harvest efficiency (HE) of 25 percent. This harvest efficiency leaves adequate ungrazed forage (threshold residue) to protect the soil resource. The recommended general threshold residue guidelines for shortgrass, midgrass, and tallgrass plant communities are 300-500, 750-1000 and 1200-1500 pounds per acre dry matter, respectively. Only grazable area should be considered when planning and monitoring stocking rate.

With the current stocking rate of 166 stock units grazed (Table 1), a desired minimum threshold residue of $1,321,100$ pounds, 2,448 acres grazed and a desired harvest efficiency of 25 percent, the minimum annual forage supply required (FSR) can be calculated. A stock unit utilizes 19.6 pounds of dry matter per day (Troxel and White, 1990). The forage available for harvest is the amount in excess of threshold residue. The amount of harvestable forage that is consumed equals 2 times the harvest efficiency ( 2 x HE ) and is called consumption efficiency (CE). If moderate grazing pressure is used (i.e., a HE of $25 \%$ ) then desired consumption efficiency equals 0.50 ( $2 \times .25$ ),

## CONTINUOUS GRAZED

If we assumed pasture 1 (Table 1) was continuously grazed by 24 stock units (in this case equal to 22 head), the monthly forage demand and needed forage supply can be calculated. The annual minimum forage supply needed is 228,250 pounds of residue plus $(24 \times 19.6 \times 365 \div 0.50)=571,642$ pounds or 1,575 pounds per acre.
Table 2. Projected monthly stockflow for 152 mature cows and bulls (3 months) (adapted from Troxel and White, 1990).


* Cow weights determined first day of each month
** Gain or (loss) for that month
*** SUE based on beginning weight, production stage and gain for month (Table 4)
**** Daily forage demand = \# head x SUE X 19.6
NOTE: $\quad$ The average SUE per cow for the year $=1.07$ or $21.0 \mathrm{lb} \mathrm{DM} /$ day

```
= 1,321,100 + (166 x 19.6 x 365 \div 0.5)
= 3,696,228 pounds or 1,510 pounds per acre
```

Annual forage production cannot be realistically measured by ranchers, hence, the needed forage supply is estimated to compare needs with research results and other studies to determine if it is realistic and what plant species should be present. However, seasonal monitoring of forage supply and projection of how long the forage supply will last relative to a seasonal stockflow forecast provides an estimate of needed changes in stocking rate and potential crisis conditions. These adjustments during the year based on forage surveys help the rancher balance forage demand with actual forage supply.

Following evaluation of each pasture, summary of last years grazing record and evaluation of financial needs, a rancher must select the planned stocking rate, but realize future forage production is unknown and seasonal adjustments may be necessary (White and McGinty, 1992). If a pasture was grazed closer than desired, stocking rate may need to be decreased or adjusted among pastures for next year or season.

## SEASONAL PLANNING AND MONITORING

Seasonal planning, monitoring and adjustments require more detailed information on livestock forage demand and forage supply. A stock flow plan projects the number of head, their weights, expected performance, and physiological conditions so that a stock unit equivalent (Table 2 and 3) can be determined (Troxel and White, 1990). Then, the number of head times the SUE times the daily intake per SU equals the herd's daily forage demand (FD).

This daily forage demand can be used to determine the needed forage supply at any point in time and the total forage supply needed for various graze periods or for the year. Rainfall information and experience can be used to project the "normal" monthly forage production needed. Kothmann and Hinnant (1993) used a monthly rating approach to calculate a weighted percentage of annual production for a given month. For example, consider the rainfall for Uvalde, Texas (Table 4).

The expected forage production is highest during April through June and September through October when temperatures are moderate, in July and August high air temperatures restrict growth and evaporation is high, frost and cool weather during November through March allow little growth to occur, hence adjustments are based on the median rainfall percentages and corresponding growth curves for a normal year. If 1,510 pounds per acre is annually needed and the normal monthly forage production percentage is realistic, then each months forage production can be calculated (Table 5):

Example, January production $=0.02 \times 1510=30.2$ pounds

Table 3. Stock unit equivalents of beef cattle based on NRC (1984) metabolizable energy requirements (Troxel and White, 1990).

| Body Weight <br> $(\mathrm{lbs})$ | Lactating <br> cow | Mature Cows |
| :---: | :---: | :---: |
| 900 | 1.02 | 0.94 |
| 1000 | 1.09 | 1.00 |
| 1100 | 1.15 | 1.05 |
| 1800 |  | Bull at maintenance |
| 1.33 |  |  |

Table 4. Percent of annual median rainfall ( 17.84 inches) and expected percent of annual forage production by months for Uvalde, TX.*

| Months | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Median |  |  |  |  |  |  |  |  |  |  |  |  |

*based on 83 years of records (1904 through 1986) analyzed using rainfall analysis software (White, 1990).

Table 5. Expected monthly forage production needed to produce 1510 pounds per acre (dry matter) of annual production near Uvalde, TX in 1987.

| Months and Forage Production (lb/acre) |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Jan | Feb | Mar | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Tota |
| 30.2 | 30.2 | 60.4 | 181.2 | 256.7 | 211.4 | 105.7 | 135.9 | 181.2 | 211.4 | 60.4 | 45.3 | 1510 |

The monthly forage production needed is as follows:
(lb/ac)

| Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | N o v | Dec |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 31.5 | 31.5 | 63.0 | 189.0 | 267.8 | 220.5 | 110.3 | 141.8 | 189.0 | 220.5 | 63.0 | 47.3 |

Forage surveys should be conducted in March, June and October to determine if forage supply will last until regrowth is expected (White and Richardson, 1991). However, the stockflow can be used to estimated forage needs for different graze periods so that visual inspection of the pasture has quantifiable criteria to judge if the current supply is adequate. For this example, (Table 1) 24 SU would be 22 head of mature cows that would require the following daily forage intake (demand), from Table 2 , $(3,426 \div 152 \times 22=496)$ daily FD for herd $\div$ \# head in herd $\mathrm{X} \#$ head in pasture 1:

Months, Days in Month, FD/Day (in lbs)

| Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | N o v | Dec |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 |
| 496 | 496 | 470 | 470 | 470 | 453 | 453 | 444 | 440 | 431 | 457 | 457 |

On March 1, the rancher planned to visually appraise this pasture to determine if available forage will support 24 stock units through June 1, or when regrowth should accumulate for summer grazing. This planning/forecast period is for 92 days (March through May). Calculate the total FD for the entire period from the above stockflow:

|  | March |  | $\underline{\text { April }}$ | $\underline{\text { May }}$ |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| FD/day | 470 |  | 470 |  | $\underline{\text { Total }}$ |
| Days/Mo. | 31 | 30 | 310 | $\underline{\text { for }}$ |  |
| Total FD | 14570 |  | 14100 |  | 14570 |

The minimum required forage supply in pasture 1 without regrowth that maintains desired threshold residue would be:

FSR $\quad=(43,240 \div 0.5)+228,250$ (residue desired in pasture 1$)$
$=314,730$ pounds or 867 pounds per acre ( 363 grazable acres in pasture 1)

Because of low quality, supplement would probably be required to maintain adequate intake and obtain satisfactory conception rates. Visual appraisal of the pasture using photoguides or experience would indicate if more than the needed amount of forage is available. If excess is noted, stocking rate would be maintained,
if in doubt or less forage is observed a detailed survey should be undertaken to determine appropriate change.

Assume a forage survey was conducted in pasture 1 and only 700 pounds per acre was currently available. Rainfall risks analysis will help evaluate probability of receiving adequate precipitation (White 1990 software) in the next 3 months. How long would this forage supply last?

Calculate the pounds of forage available for consumption: 700-629 (residue from Table 1) $=71$ pounds per acre available for consumption but only 35.5 pounds per acre can be eaten (total of 12886 pounds; $35.5 \mathrm{lb} / \mathrm{ac} \times 363 \mathrm{ac}$ ). March forage demand is 14,570 pounds or 470 pounds per day. Thus, the forage would last through March 27th (approximate date) $(12,886 \div 470=27)$

In this case delaying a decision will mean grazing desired residue or purchasing feed in April and May. This calculation can be performed at any time of year. As the year progresses, the rancher should record actual conditions to compare with the current plan and use this information to improve next years plan.

## ROTATIONAL GRAZING

The proper days of grazing per pasture in a rotation system can be calculated using information on pasture performance or production criteria. Historical records of stock unit days, range condition (McGinty and White, 1991) or forage surveys can be used to determine a production rating relative to other pastures in the grazing system (Table 6). This weighted average approach is used to adjust grazing pressure among pastures and compensate for differences in pasture size and production. Grazing pressure is adjusted by varying the days of grazing after selecting the appropriate length of rest.

The planned and actual graze schedule provides basic information to aid in the development of grazing strategies (Table 7). The forage production can be replaced with expected monthly forage production followed by an actual rating at the end of each month. Similarly, the plan may indicate grazing of pasture 1 for 16 days in January, but due to actual conditions the graze period was changed.

The number of head grazed is obtained from the planned or actual stockflow (Table 2). This stockflow information is used to calculate forage demand. Each graze period requires an initial forage supply and the manager is expected to leave a minimum threshold residue. A rancher plans and frequently updates to quantify a minimum forage supply. Actual forage supply notes help to improve planning, readjustment among pastures, and changes in stocking rate.

During dormant periods regrowth is unlikely, hence, the accumulated projected forage demand per pasture during the dormant period is used to determine needed forage supplies at the end of each growing season to compare with actual forage supplies. June, October and March are recommended, however, anytime visual surveys indicate a possible need to adjust stocking rate, a survey should be conducted. The potential cost of an incorrect decision determines if a rancher exerts the effort to actually sample the forage supply using the double sampling method (White and Richardson, 1991). For example, pasture 1 is scheduled to be grazed $7 / 20 / 87,10 / 30 / 87$ and $2 / 19 / 88$. How much forage is needed in this pasture on $7 / 19 / 87$ to last through February and March of 1988 ? The calculations are as follows:

| Dates of <br> Grazing | Graze Period <br> Forage Demand | Desired <br> Residue | Minimum Forage <br> Supply Reauired |
| :--- | :---: | :---: | :--- |
| $7 / 20 / 87$ | 50,048 |  | 228,250 |

" $3426 \mathrm{lbs} / \mathrm{da} \times 16 \mathrm{da}=54816$ ( $3,426 \mathrm{lbs}=$ daily forage demand from Table 2)
Thus, on $7 / 19 / 87$ a forage supply greater than $1,485 \mathrm{lb} / \mathrm{ac}$ is needed to last through the winter, if regrowth does not occur. In each pasture the rancher visually determines if the forage supply is adequate, deficient, or excessive. A survey in October would reevaluate the situation. Appropriate adjustments would be made in the grazing schedule and stocking rate. Expected forage production can be subtracted from the FSR to determine a corrected FSR if regrowth occurs as expected. Decisions can be made before crisis situations severely impact ranch resources through the use of forage surveys to balance forage demand with forage supply.

Adjustments in grazing pressure and rotation schedule may be needed to benefit preferred forage species, especially if less preferred or undesirable species dominate. Close use of key plants and/or sites may dictate shorter graze periods or longer rest periods which may require reduced stocking rates or strategic rotation to protect the resource. The forage surveys could be modified to sample key species rather than all herbaceous plants. Soil protection may occur because plants such as tobosa grass are unpalatable much of the year. Forced use of the less preferred plants will result in abuse to preferred plants unless special precautions are undertaken.

Table 6. Potential graze periods (days) for 5 pastures grazed in rotation with different rest period strategies.

|  | Pasture | Grazable Acres | Production Rating | Adjustment ${ }^{2}$ | 30 | 45 | 60 | 90 | 120 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 363 | 24 | 0.723 | 5 | 8 | 11 | 16 | 22 |
|  | 2 | 310 | 22 | 0.663 | 5 | 7 | 10 | 15 | 20 |
|  | 3 | 530 | 38 | 1.14 | 9 | 13 | 17 | 26 | 34 |
|  | 4 | 651 | 46 | 1.39 | 10 | 16 | 21 | 31 | 42 |
| W | 5 | 594 | 36 | 1.08 | 8 | 12 | 16 | 24 | 32 |

${ }^{1}$ Production rating is a quantifiable measure of each pasture's productivity in relation to each other. Total stock units per pasture can be used for the production rating (see Table 1).
${ }^{2}$ Adjustment ratio is the comparison of each pasture to the average pasture, i.e., total production rating for a pasture compared to the average total production rating for all pastures e.g. $24 \div 33.2=0.723$.
${ }^{3}$ Graze period equals the average graze period times the adjustment factor, e.g. average graze period $=$ (days of rest $\div$ number pastures resting)(adjustment factor). For example: ( 60 days rest $\div 4$ pastures resting) x $0.723=10.85$ or 11 days graze period.

Table 7. Planned graze schedule for 1 herd: 5 pasture rotation.*

|  | $\underline{\text { Pasture }}$ | Grazable <br> Acres | Graze Days | Head Grazed | Forage Demand (lb) | Forage <br> Supply <br> Required <br> (lb/ac) | Planned <br> Rest <br> Period <br> (days) | Forage <br> Prod. <br> Stage | From | Through | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 1 | 363 | 16 | 152 | 54816 | 704 | 90 | Dormant | 01/01/87 | 01/17/87 | Grazed by |
|  | 2 | 310 | 15 | 152 | 51390 | 717 | 90 | Dormant | 01/18/87 | 01/31/87 | Mature Cows |
|  | 3 | 530 | 26 | 152 | 89076 | 561 | 90 | Dormant | 02/01/87 | 02/27/87 | and Bulls |
|  | 4 | 651 | 31 | 152 | 100657 | 571 | 90 | Dormant | 02/28/87 | 03/27/87 | Only |
|  | 5 | 594 | 24 | 152 | 77928 | 608 | 90 | Slow Growth | 03/28/87 | 04/21/87 |  |
| \# | 1 | 363 | 11 | 152 | 37433 | 680 | 60 | Rapid Growth | 04/22/87 | 05/02/87 |  |
|  | 2 | 310 | 10 | 152 | 34030 | 689 | 60 | Rapid Growth | 05/03/87 | 05/11/87 |  |
|  | 3 | 530 | 17 | 152 | 57851 | 532 | 60 | Rapid Growth | 05/12/87 | 05/29/87 |  |
|  | 4 | 651 | 31 | 152 | 101804 | 572 | 90 | Slow Growth | 05/29/87 | 06/24/87 |  |
|  | 5 | 594 | 24 | 152 | 76944 | 607 | 90 | Slow Growth | 06/25/87 | 07/19/87 |  |
|  | 1 | 363 | 16 | 152 | 50048 | 698 | 90 | Dormant | 07/20/87 | 08/05/87 |  |
|  | 2 | 310 | 15 | 152 | 46035 | 708 | 90 | Dormant | 08/06/87 | 08/19/87 |  |
|  | 3 | 530 | 26 | 152 | 79014 | 552 | 90 | Dormant | 08/20/87 | 09/15/87 |  |
|  | 4 | 651 | 21 | 152 | 63819 | 542 | 60 | Rapid Growth | 09/16/87 | 10/04/87 | Cows Palpated |
|  | 5 | 594 | 24 | 152 | 71496 | 603 | 90 | Slow Growth | 10/05/87 | 10/29/87 | Open Cows |
|  | 1 | 363 | 16 | 152 | 50528 | 698 | 90 | Dormant | 10/30/87 | 11/15/87 | Replaced with |
|  | 2 | 310 | 15 | 152 | 47370 | 710 | 90 | Dormant | 11/16/87 | 11/29/87 | Bred |
|  | 3 | 530 | 26 | 152 | 82108 | 555 | 90 | Dormant | 11/30/87 | 12/26/87 | Replacement |
|  | 4 | 651 | 31 | 152 | 106206 | 575 | 90 | Dormant | 12/27/87 | 01/24/88 | Heifers |
|  | 5 | 594 | 24 | 152 | 82224 | 612 | 90 | Dormant | 01/25/88 | 02/18/88 | (2nd calf) |

*Table 2 show monthly stockflow grazed in rotation and Table 1 pasture characteristics.
$* * \mathrm{FSR}=($ Forage demand $\div 0.5)+$ Residue $) \div$ Grazable acres

## SUMMARY

Unrealistic expectations of above-average precipitation, the reality of drought and excessive stocking rates cause deterioration of range resources and reduced animal and financial performance. Planning, evaluation, monitoring and controlling grazing pressure with due consideration of risk can improve stocking rate decisions. The use of calculated responses to sustain or improve the range resource followed by forage surveys to compare actual conditions to the plan can provide early warning of potential crisis situations. A rancher can hope forage supplies are adequate and that tomorrow's rain will grow additional forage or plan and adjust to actual conditions to improve chances of success. It takes effort and purpose to succeed in todays competitive markets and variable environmental conditions.

Making stocking rate adjustments before forage shortfalls provides more management options and time to determine the "best" alternative. For example, a projected forage shortfall in three months provides time to evaluate what and how many livestock to cull to maintain desired residue, maintain adequate animal performance, reduce direct costs, maintain herd genetics, pre-condition animals for sale, lease additional grazing, consider tax consequences, and market culls to best advantage. A Total Ranch Management plan (White 1987, White, Troxel, Pena, and Guynn 1988a, and White, Troxel and Craddock $1988^{\text {b }}$ ) incorporates the proposed stocking rate adjustments is revised to determine over all impact of "best" alternatives including effect on subsequent years. This allows time to adjust other aspects of the ranch operation, eg. personnel, overhead/family expenses, renegotiate loans, delay investments, etc.

The greatest harm to ranch resources occurs during crisis situations. Protecting the resources for the future is a successful strategy. Restocking should lag behind recovery to insure recovery following each drought and before the next drought.

Proper stocking rate decisions should achieve realistic range, animal, and financial goals. The process for selecting an appropriate stocking rate is outlined by White and McGinty (1992). We suggest forage surveys to quantify actual and estimated conditions with a decision process that includes understanding potential impacts and assumptions.

Our approach provides quantifiable criteria ranchers can use with current visual pasture appraisals and livestock to judge forage supplies. A reliable technique for sampling has been developed to provide accurate estimates of forage supply and how long the forage will last in advance of crisis situations. Calculations and plans will seldom match actual conditions but are realistic estimates that provide guidelines for management decisions and grazing policy. This method requires a planning and monitoring effort that many ranchers currently do not use but decision criteria are identified so that visual appraisal is more specific. Several years of use will improve accuracy and interpretation of results. Monitoring plans versus actual conditions and results achieved and documented evaluation of alternatives prepares the land manager for more future decisions.

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# THE GRAZING MANAGER: AN OPERATIONAL LEVEL GRAZING MANAGEMENT DECISION AID 

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## INTRODUCTION

Grazing managers face the difficult problem of balancing livestock forage demand with forage production which varies in response to environmental conditions. Animal demand also varies as animal numbers change, as animals grow, and as they change physiological status such as lactating or dry. Since current technology cannot reliably predict future environmental conditions, managers find it difficult to develop grazing plans that balance forage supply and demand. Under-utilization of forage reduces total animal production. Over-utilization can deteriorate the forage stand and reduce animal performance and/or increase the need for feed. When forage demand exceeds the forage supply, excess animals should be removed from the pasture. Thus, the manager must monitor both forage supply and demand and project these values through the annual planning cycle. Most managers use an intuitive approach because quantitative techniques are either not available or are too time consuming and tedious. TGM provides an effective quantitative decision-aid to balance forage demand with current year's production so that stocking rate can be managed more effectively to: (1) maintain or enhance forage production, (2) achieve targeted levels of animal production, (3) reduce feed costs, and (4) reduce economic risk.

## DECISION AID DESCRIPTION

A decision aid, The Grazing Manager (TGM) was developed to assist managers in making timely stock adjustments. Our goal in developing this decision aid was to keep it as simple as possible in both design and execution and to provide flexibility so that it can be utilized with many types of pastures. TGM relies on the "on-site" manager's expertise and ability to analyze and integrate responses such as monthly forage production and use ratings. It does not require inputs that are complex or difficult to obtain. A rancher should be able to obtain all inputs with reasonable effort and training.

TGM was designed to develop and analyze grazing plans and to monitor grazing for management units which may contain a single pasture or a group of pastures. It utilizes the animal-unit concept to monitor forage production and demand (Scarnecchia and Kothmann, 1982; Scarnecchia, 1985). Information required for development of the initial plan includes: number of acres in each pasture and an estimated average carrying capacity, monthly forage production coefficients, and the
grazing plan. It provides monthly and annual analyses of forage production for a "normal" or average year, adjustments for current year's forage production, and forage demand by livestock. TGM is divided into a resource inventory component and a grazing plan and monitoring component.

## Resource information

The first step in defining resources is to list all available Grazing Management Units (GMU). GMU consist of one or more pastures treated as a distinct unit. A GMU may be the whole ranch, a single pasture or a group of several pastures. There are several reasons to have more than one GMU. You might have two different grazing systems applied to the ranch, such as several pastures grazed continuously and a group of four pastures in a deferred rotation grazing system. The only constraint to grouping pastures into a GMU is that the major forage component begins growth in the same month. Generally, this means separating cool season pastures (small grain or winter legumes) from warm season pastures. Species composition and seasonality of forage production may differ among pastures within a GMU as long as the annual forage production cycle begins in the same month.

Pasture information describes the forage resource on a pasture basis. The pasture is named, and a GMUcoef number (a unique combination of GMU and a set of seasonality coefficients) is assigned. The number of acres in the pasture must also be entered. The next variable which needs to be entered is an initial estimate of average carrying capacity. The program accepts this input as acres/animal-unityear, animal-unit-days/acre, animal-unit-months/acre and animal-unit-year/section. British units were used (not metric units) since the objective was to construct a management oriented decision aid and the potential users of the decision aid in the USA are more familiar with the British system. The decision aid, by default, assumes that the user desires to make full use of the pasture. The manager may enter a value other than full use as a target use rating, such as light, moderate or close use, to achieve a desired management objective. The manager might, for example, want to graze a pasture lightly to provide fuel (excess forage) for a burn.

The acres and average carrying capacity are used to calculate the total animal-unit-days (AUD) of forage available to be grazed on an annual basis. Animal-unitdays are calculated for each pasture and summed across GMU and the whole ranch. The monthly forage production coefficients are scaler values entered to obtain a relative rating of forage production for each month for each forage type present. Producers find it easier to rate the relative levels of production by month than to estimate percentages that must add to 100 . The decision aid uses these values to calculate the percent of carrying capacity produced each month. The proportion of production per month is multiplied by the total AUD of carrying capacity to obtain AUD of forage production per month. These values are summed to create a cumulative production value.

An animal numbers estimator is available to facilitate calculation of the numbers of animals that the unit will support. It is based on the estimated annual AUD of forage produced and a herd structure input by the manager. The herd structure consists of the kind and class of animal, AUE, ratio, and days that the class will be present during the year. The ratio is the relative number of animals for each class in a herd; for example, to obtain a $25: 1$ cow to bull ratio, one could enter a ratio of 100 for the cows and 4 for the bulls. After you have defined your herds, you must allocate a percentage of the carrying capacity of each GMU to one or more herds. The program generates the percentage of forage demand, the number of animal-units and number of head for each class based on the AUD of carrying capacity allocated to the herd.

Substitution feeding, unlike supplemental feeding, may affect forage demand, especially large quantities of feeds like hay. Feeding protein supplement usually does not reduce demand for forage. Feeding hay or an energy feed such as corn or breeder cubes can reduce demand on grazed forage. For each herd, enter the total monthly quantity of feed you plan to use, separated into three types: (1) Protein, (2) Energy feeds, (3) Hay. Select the efficiency for feeding hay. Grain-based breeder cubes should be considered an energy supplement. The pounds of energy feed and pounds of hay, reduced by the efficiency factor, are divided by 17.6 to calculate the AUD provided from feed. These AUD are added to the carrying capacity allocated to the herd through the GMU allocation before estimating the numbers of animals that can be supported. These values are only used in the planning phase. Actual kinds and amounts of supplement fed will be entered in the Grazing Plan and Monitoring section.

TGM produces numerous reports which may be sent to the screen or printed to provide a copy of entered information and to provide calculated results.

## Grazing plan and monitoring

Only after all resource information is entered, may a grazing plan may be entered. All possible combinations of pasture-herd-class are provided by TGM in the grazing plan and monitoring section. The grazing plan is entered as the numbers of livestock by kind and class, Animal-Unit-Equivalent (AUE), and the day-in and dayout for each pasture. Supplemental feeds should be entered as lb/head/day. These inputs are used to calculate AUD of forage demand. AUD from supplement are subtracted from AUD of forage demand to calculate the actual stocking rate for the pasture. The cumulative AUD of production and demand are used to determine the forage deficit or surplus. Graphic output can be generated for each pasture and each GMU to aid in evaluation of the plan (Figs. 1 and 2). TGM is also used to monitor grazing and provide an analysis of the current and projected forage balance for each management unit and the whole ranch (summed across pastures). This will assist the manager in making stock adjustments in response to seasonal fluctuations in forage production.


Figure 1. Grazing record for headquarters-4 pasture (178 acres) with average carrying capacity of 10 acres/animal-unit-year. Variables are discussed in the text.


Figure 2. Grazing record for headquarters-2 pasture ( 97 acres) with average carrying capacity of 12 acres/animal-unit-year. Variables are discussed in the text.

Data entry required during the monitoring phase includes: corrections to the grazing plan, monthly forage production adjustment coefficients, and a field estimate of the degree of use on the unit. These will adjust the estimates for both forage production and forage demand in response to actual conditions. The adjustments to animal numbers and days of grazing reflect the difference between the grazing plan
and the actual grazing applied. The forage production adjustment coefficients are relative values used to adjust the monthly AUD of forage production based on devia tions from average conditions. A value of one represents normal; whereas, 0.5 would represent $50 \%$ of average and 1.5 would represent $150 \%$ of average.

## Pasture Use Rating

Calibration of the decision aid is based on matching monthly use ratings generated internally with those estimated in the field. If field estimates do not match the use ratings calculated by the model, inputs to the decision aid should be reexamined. The final input to examine is the estimated average carrying capacity. If necessary, it should be adjusted to obtain appropriate fit. The result is a more accurate estimate of the average carrying capacity for the management unit. TGM is used to predict forage balance, but unlike a regression model, the inputs to the decision aid are updated monthly to account for the current year's conditions. This provides accuracy and increases monthly and seasonal forecasts of end-of-year forage deficit or surplus. Thus, the manager can make adjustments to stock numbers and modify forage consumption.

The pasture use rating is a key component of TGM. The use rating generated by the decision aid is calculated as (forage demand / forage production) $\times 3$ and is based on a O-6 scale. Zero represents no use and 6 represents total or extreme use. A rating of 3 represents full use. Full use is normally the maximum use desired on rangeland. Tame pasture or annual forage on cropland may have a greater target use rating because these types of pastures can sustain greater harvest efficiencies. The use rating may vary monthly during the year because the rates of forage production and demand are seldom balanced. A descriptive guide is provided with TGM to assist the manager with visual estimation of the use rating. Some training may be required for accurate estimation of use ratings in the field.

## DECISION AID MODIFICATIONS AND APPLICATIONS

TGM has been evaluated on several ranches across Texas for 5 years. Modifications and additions made to the decision aid based on user feed-back include: a feed component which interacts with forage demand, a flexible starting date for the forage production cycle, the animal numbers estimator, and space for user comments to be inserted.

The kind and amount of supplemental feed provided to animals on pasture will affect their demand for grazed forage. In operations that included hay feeding or significant amounts of grain based feeds, we reduced the forage demand. A feed component was added with inputs of the amounts of protein, energy, and hay fed on the management unit per month. Protein does not affect forage demand in the model. Energy feeds (grain based) reduce forage demand on a $1: 1$ ratio. Hay reduces forage demand, based on the feeding efficiency of the hay. The user estimates the intake efficiency of hay. This value can be adjusted if needed. The

AUD provided from feed are calculated and subtracted from the animal demand for the unit. Experience on ranches has supported validity of this approach.

The flexible starting date was essential for the use rating to work correctly. Forage production and utilization on pastures operate on an annual basis. Harvested forages may be carried over, but there is little opportunity to carry standing forage from one year to the next. Carrying capacity is evaluated based on the annual forage production and the appropriate harvest efficiency. While forage cannot generally be carried over between years, there is considerable flexibility in the season and timing of use within a year. The use rating is based on cumulative forage production and forage demand within a year; therefore, it is essential that the decision aid initiate calculations at the beginning of the forage production cycle. The user selects the month to begin. For rangelands in Texas, this would generally be March or April. For a cool-season annual pasture like oats or wheat, the cycle would initiate in September.

The animal numbers estimator was implemented to assist with planning for changes in the forage or herd. It can be used to asses the impact of alternatives such as increasing or reducing the carrying capacity and changing herd composition or management on the numbers of animals that can be supported. For example, "What would be the impact of keeping replacement heifers versus purchasing replacement cows?" Or, "What would be the effect on a registered cattle operation with respect to the number of sale bulls and heifers produced from increasing or decreasing the land base in the operation?" One of the ranchers evaluated the impact of dropping a leased ranch and scaling the operation down to only owned property. It is also useful when planning a grazing system to estimate the animal numbers that can be supported based on its carrying capacity.

A comment area was added to several screens in the decision aid to allow the user to insert notes and documentation. Users found it helpful to document model inputs and management decisions within the decision aid rather than having to keep a separate $\log$ or print the data and write the documentation on the printed copies.

Two examples will be presented to illustrate graphic output from the model and some of its applications for analysis of grazing management (Figs. 1 and 2). Each figure presents four variables. The monthly carrying capacity is derived from the product of the average carrying capacity and the proportion of production per month. Normal carrying capacity is the cumulative sum of monthly carrying capacity. Actual carrying capacity is the cumulative sum of the product of normal monthly carrying capacity and the forage production adjustment coefficient. Animal demand is the cumulative forage demand based on the grazing plan entered. The acres, average carrying capacities, and grazing plans differ, but the forage production adjustment coefficients are the same for the two pastures. In both examples, the forage production cycle is set to begin in March and end in February. In this example, forage production was near normal from March through July, but August-

November were below average. This resulted in the actual carrying capacity being lower than the normal carrying capacity.

In Figure 1, the Headquarters-4 pasture was grazed for 9 months. No grazing occurred in April, May and December. The stocking was set to achieve moderate use ( $2 / 3$ of full use) during an average year. Because the year was below average, actual use obtained was a little less than full use. This grazing plan would provide benefit to the range vegetation because of the delayed moderate use. Livestock performance should be near maximum with the exception of January and February. During these two months, animal demand greatly exceeded the monthly carrying capacity; however, because of the overall moderate use, there should be ample standing dead forage. Animals will almost certainly require supplemental protein during these months. The amount and kind of supplement will depend on the quality of the standing dead forage and the requirements of the animals. If greater animal production per acre is desired, grazing should be increased during April-September and reduced during the dormant season. If greater emphasis is desired on range improvement, grazing should be deferred longer during the peak growth and reproduction periods for the vegetation.

In Figure 2, the Headquarters-2 pasture was grazed during March-May to maintain a use rating of 3. Following deferment from June-August, the use rating on the pasture fell to near 2. Intensive grazing from September-December increased the use rating to greater than 4 (close use) by the end of the forage cycle (February). This grazing plan should enhance animal production during the spring and provide pasture recovery and improvement during the summer. However, during the fall, intensive grazing stresses animals and reduces animal performance, and there is a need for supplemental feeds. Heavy grazing will reduce vegetative cover, may damage sensitive plants, and reduces watershed protection. Adjustments could have been made to the grazing plan by early October to prevent the excessive use based on below average forage production during both August and September.

The graphic presentation of the forage production and demand variables facilitates the analysis of a grazing plan. Most individuals can work with visual concepts easier that with numerical data. The combination of visual and numerical presentations make evaluation of several alternative plans relatively easy.

## ACKNOWLEDGEMENTS

The authors thank the Extension Range Specialists and ranchers who cooperated in the testing of this decision aid. Special thanks are extended to Debbie and Bill Yowell for their extra efforts during the development of APSAT and to Jimmy and Sharon Holman, Curry and Bonnie Lou Campbell and the staff of the Sonora Research Station.

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Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture, Zerle L. Carpenter, Director, Texas Agricultural Extension Service, The Texas A\&M University System.


[^0]:    ${ }^{1}$ Tall grass prairie $=$ Cross Timbers, Coastal prairie. ${ }^{2}$ Southern mixed prairie $=$ Texas rolling plains, high plains.
    ${ }^{3}$ Shortgrass prairie $=$ Permian Basin, Panhandle.
    ${ }^{4}$ Chihuahuan desert $=$ Texas-Pecos area.
    ${ }^{\text {Pinyon-juniper }}=$ Edwards plateau, portions of Texas-Pccos. ${ }^{6}$ Oak woodland $=$ Edwards plateau.

[^1]:    a Adapted from Gillen et al. (1992), Gillen and McCollum (1992), Heitschmidt

