TAES Research Monograph

RM 6C
January 1976

Grasses and Legumes in Texas – Development, Production, and Utilization

The Texas Agricultural Experiment Station,
J.E. Miller, Director,
Texas A&M University System
College Station, TX

Chapter 5

PRINCIPLES OF GRAZING MANAGEMENT

Table of Contents

Chapter 5

PRINCIPLES OF GRAZING MANAGEMENT

Marvin E. Riewe*

Grazing is the feeding of cattle on usually actively growing pasture. Grazing management is the art of controlling the feeding of cattle on pasture to maximize forage yield of adequate quality for acceptable animal performance. Obtaining sufficiently high animal performance to insure satisfactory economic returns is paramount.

Prescription guidelines for grazing management frequently emphasize production of animal products per acre. Carrying capacity, or production of livestock products per unit area, has meaning, however, only if individual animal performance exceeds an acceptable minimum.

Economic return on land area involved frequently is only slightly related to the production of livestock products per unit area. Further, maximum economic return on the land area involved is not always paramount; return on invested capital is sometimes more important. Thus, the objective of the grazing enterprise affects management decisions.

Grazing management entails making day-to-day decisions that involve a number of considerations. The purpose of this paper is to report and review applicable principles that have been elucidated through research. In addition, some applications will be suggested that may be helpful in maximizing the economic return from a grazing enterprise.

RECONCILING ANIMAL NUTRIENT REQUIREMENTS WITH KIND AND AMOUNT OF FORAGE

Perhaps the most important consideration in grazing management is to supply the

*Professor in charge, The Texas Agricultural Experiment Station, Angleton.

This publication is a part of Research Monograph 6, "Grasses and Legumes in Texas--Development, Production, and Utilization," The Texas Agricultural Experiment Station.

kind and amount of forage needed by the particular class of grazing animals to perform the productive function intended. Different classes of cattle have different requirements for digestible energy. Cattle have a digestible energy requirement for body maintenance which varies with body size, muscular activity (which includes the work of walking and grazing), growth, and/or milk production. These requirements, shown in Table 5-1 (N.R.C., 1970), are fitted to the capability of several classes of forages to meet these requirements in Figure 5-1, according to the procedure suggested by Lippke (1968).

Animal Nutrient Requirements

High producing dairy cattle have an energy requirement, particularly in early lactation, that cannot be met by any combination of forage and grains. To acquire the additional energy needed for high milk production in early lactation, energy stored as body fat prior to parturition may be used. Continued feeding of feeds high in digestible energy content is necessary for the dairy cow to maintain milk production and to regain body condition in preparation for the next lactation.

Lactating beef cows, even in early lactation, can obtain their entire energy requirement from high quality pasture. A beef cow generally will reach maximum milk production about 75 days after calving and then level off for the next 60 days. At that time, the cow must also be gaining weight to allow her to rebreed. Then, digestible energy requirements are highest. Digestible energy requirements decrease thereafter as milk production decreases and the calf derives more of its needed energy through grazing.

The dry beef cow, on the other hand, has the lowest nutrient requirement of any class of cattle. If she is in adequate body condition, only body maintenance is necessary. If body condition needs to be improved after weaning and prior to calving, her requirements are higher, but only fair quality forage is required.

Beef heifers calving as 2-year olds have an energy requirement for body maintenance, muscular activity, milk production, and growth. To meet the simultaneous energy demand for these physiological functions plus rebreeding, high quality pasture is required. The total demand for digestible energy for these functions is equal to

Table 5-1. Daily digestible energy requirements for grazing cattle.

Description of cattle			Megacalories digestible energy required					
Class of cattle	Wt. lb.	Lb. milk prod. or ADG	Maintenance	Muscular activity	Growth and/or milk prod.	Total	Total lb. TDN req.	% TDN req. in forage
Dairy cow	1,200	50	16.7	0-1.3	37.1	55.1	27.6	76
Beef cow - wean 600 lb. calf	1,000	18	13.3	1.0-4.0	11.9	27.7	13.9	61
Beef cow - wean 500 lb. calf	1,000	14	13.3	1.0-4.0	8.8	24.6	12.3	57
Two-year old, 1st calf heifer	800	14	12.0	1.0-4.0	13.7	28.2	14.1	65
Beef cow, dry, pregnant	1,000	fetal growth	13.3	1.0-4.0	2.7	18.5	9.3	52
Stocker calf	330	1.1	6.2	0.6-2.4	3.4	11.1	5.6	72
Stocker calf	330	1.7	6.2	0.6-2.4	4.2	11.9	6.0	78
Stocker calf	440	1.1	7.4	0.8-2.7	5.5	14.6	7.3	63
Stocker calf	440	1.7	7.4	0.8-2.7	7.0	16.1	8.1	69
Stocker yearling	660	1.1	10.3	1.0-3.0	8.1	20.4	10.2	57
Stocker yearling	660	1.7	10.3	1.0-3.0	10.9	23.2	11.6	63

Percent dry matter digestible (% DMD) and % TDN are almost interchangeable expressions of the digestible energy content of a forage.

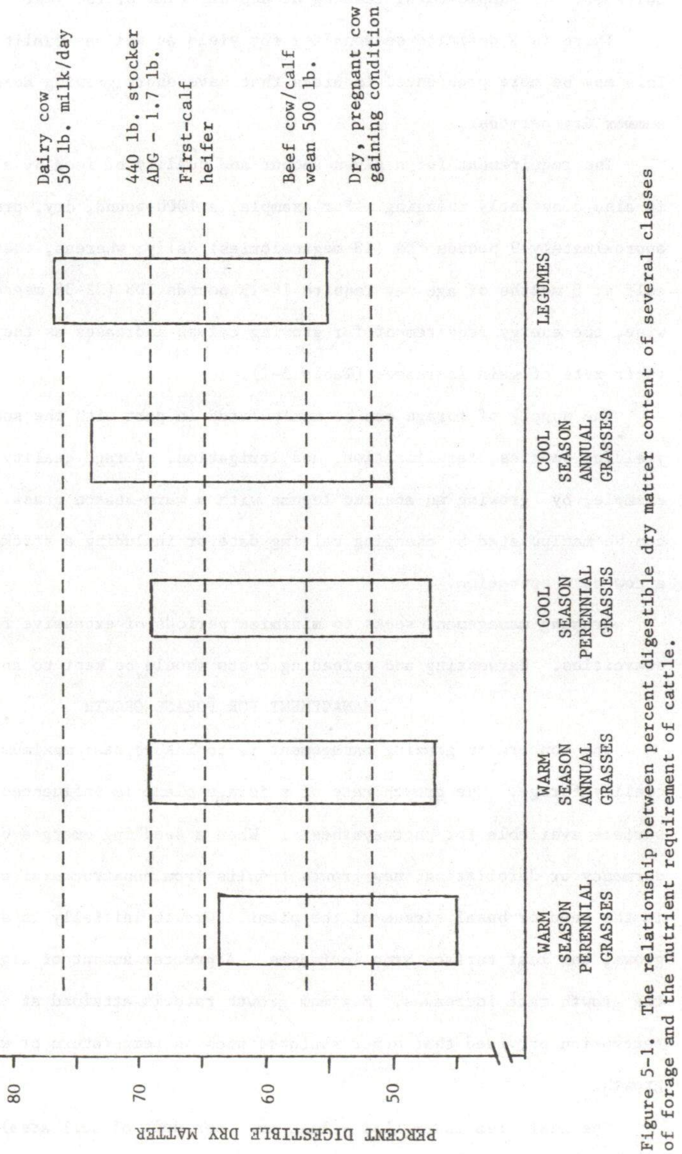

Figure 5-1. The relationship between percent digestible dry matter content of several classes of forage and the nutrient requirement of cattle.

the energy demand of the larger, mature cow, but the capacity of the heifer to consume forage is less. Thus, lactating 2-year old heifers require forages higher in digestible energy than older cows.

Stocker steers or growing heifers require high quality forage for good gains. Because their capacity to consume forage is limited, light, young stocker calves require highly digestible forage for good gains. Larger stocker calves and yearlings can produce higher gains on forages of equal or sometimes lower digestible energy content. Economics frequently dictate, though, that heavier stocker calves gain faster than lighter ones.

Classes of Forage

Extensive digestion trials conducted by The Texas Agricultural Experiment Station at Angleton and College Station have suggested a system of classifying forages according to their expected digestible energy content (Figure 5-1). The upper limits are the expected digestibility when sufficient growth has occurred to allow cattle to graze to fill. Higher digestibilities than the upper limits have been found for every forage class in certain studies. Particularly higher digestibilities have been noted for cool-season perennial grasses adapted to more temperate climates. The indicated ranges in digestibilities suggest the decrease expected with advancing maturity as well as differences in digestibility among species within a class.

The kind of forage being grazed should provide adequate digestible energy for grazing cattle to perform as expected. However, factors other than forage digestibility also influence animal performance. (1) Sufficient forage must be available for the animal to graze to fill. (2) Forage must be acceptable and readily accessible to the animal. For example, cattle may graze less when pastures are muddy than when footing is firm. (3) The animal's prior treatment and condition influences its performance on pasture. (4) The animal's genetic potential to produce or gain profoundly influences its performance.

Legumes commonly grown in Texas, such as alfalfa, white clover, burclover, crimson clover, and vetches, have the highest digestible energy content of any class of forage. Legumes are highest in cell contents, the most digestible fraction of forage

(Van Soest and Moore, 1965). Legume pastures partially meet the needs of high producing dairy cows and are generally adequate for all classes of beef cattle. Sericea lespedeza, an exception to this general rule, attains a high tannin content at an early stage, which reduces the amount of forage consumed by the grazing animal.

Cool-season (temperate) annual grasses, such as ryegrass and cereals, are usually not so high in digestible energy over the whole range of plant maturities as commonly grown legumes. They generally are adequate for stocker calves and first-calf heifers and more than adequate for older cows nursing calves or dry cows.

Cool-season (temperate) perennial grasses, such as TAM Wintergreen hardinggrass and tall fescue, are adequate for cows nursing calves. Hardinggrass appears to be adequate for heavier stocker calves. Bromegrass or orchardgrass, which may be superior to hardinggrass or fescue, are limited in adaptation to the northwestern part of Texas. The change in digestible energy content over time is not so rapid as with the warm-season annual grasses. A suitable legume frequently can be grown with the cool-season perennial grass to improve animal performance.

Warm-season (tropical) annual grasses, such as sudangrass, sorghum x sudangrass hybrids, and millet, provide good quality forage at times when forage from permanent pastures may be in short supply or of poor quality. The digestible energy content drops rapidly in these forages as they begin to boot and advance in maturity. When immature (pre-boot), they can meet part of the requirement of producing dairy cows. They are satisfactory for heavier stocker calves and beef cows with nursing calves.

Warm-season (tropical) perennial grasses include native grasses such as bluestems and indiangrass and introduced grasses such as bermudagrasses, dallisgrass, kleingrass, and buffelgrass. These grasses provide forage with adequate levels of digestible energy to form the base pasture for beef cow-calf operations. Some may be considered for grazing by yearling stocker cattle. If a legume can be grown successfully with the warm-season perennial grass, forage quality and animal performance are almost always improved. As a class, this group of forages is lower in digestible energy than any other class. To describe these as "high quality" forages is generally misleading.

Amount of Forage Required

A primary consideration in grazing management is to reconcile the cattle's need

for forage with the pasture's ability to produce. If this is not accomplished, excessive surpluses may develop at one time of the year, with a concomitant high requirement for supplemental feeding at another time of the year.

There is a definite seasonality for yield as well as quality of the forage grown. This may be more pronounced in areas that have short growing seasons or recurrent summer dry periods.

The requirement for a given amount and quality of feed by a given class of cattle is also constantly changing. For example, a 1000-pound, dry, pregnant cow requires approximately 9 pounds TDN (18 megacalories) daily; whereas, that same cow and her calf at 8 months of age may require 16-19 pounds TDN (32-38 megacalories) daily. Likewise, the energy requirement for growing calves increases as they grow in size or as their rate of gain increases (Table 5-1).

The supply of forage can be manipulated in part with the substitution of higher yielding species, fertilization, and irrigation. Forage quality may be improved, for example, by growing an adapted legume with a warm-season grass. Peak demand periods can be manipulated by changing calving date or including a stocker growing program with a cow-calf operation.

Grazing management seeks to minimize periods of excessive forage surpluses or scarcities. Harvesting and refeeding costs should be kept to an acceptable minimum.

MANAGEMENT FOR FORAGE GROWTH

One concern in grazing management is to insure near maximum production of adequate quality forage. The growth rate of a forage plant is influenced by the amount of leaf surface available for photosynthesis. When a seedling emerges or growth begins after dormancy or defoliation, new growth results from nonstructural carbohydrates stored in the seed or basal tissue of the plant. Growth initially is slow, but as the plant grows, the leaf surface area increases. A greater amount of light is intercepted, and the growth rate increases. Maximum growth rate is attained at near maximum light interception provided that other factors, such as temperature or water, do not limit growth.

The leaf area index (LAI - leaf area per unit of soil area) concept is useful in studying the amount of leaves required to intercept sufficient light to maximize growth rate. An LAI of 5 indicates that the leaf surface area (one side of leaves only) in the forage canopy is 5 times that of the soil surface underneath.

When sufficient leaves are present to intercept most of the light, lower leaves in the canopy become photosynthetically less active because of shading by upper leaves. If additional growth occurs, the respiration rate in lower leaves may exceed photosynthesis causing leaf loss and reduced forage quality. If the forage canopy almost completely shades the soil surface for extended time periods, new tiller initiation may be reduced. This could result in a more open sward after harvesting or grazing with a subsequent reduction in new growth. Thus, very light grazing pressures or excessively long rest periods in rotational grazing schemes should be avoided.

On the other hand, if grazing pressure is such that little leaf surface area exists at any time, total forage yield is sharply reduced. If overgrazing is severe and prolonged so that new growth is initiated repeatedly at the expense of nonstructural carbohydrates in the base of the plant, the plant may die. This problem is more pronounced on upright growing bunchgrasses than on stoloniferous sodforming grasses.

Nearly complete light interception by leguminous pasture plants with near horizontal leaves occurs at lower LAI's than for grasses with erect or semi-erect leaves (Brown and Blaser, 1968). Thus, the LAI required for near complete light interception varies with species.

At times, less than complete light interception may be desirable to favor tiller initiation or to reduce competition for desirable companion species. For example, near complete light interception for any length of time by a dallisgrass-white clover canopy would favor neither new tiller initiation by dallisgrass nor survival of the highly desirable white clover.

In some instances, grazing management must consider morphological characteristics of a plant as well as light interception for maximum forage growth. For example, alfalfa probably yields best and persists longest when harvested or grazed near the bloom stage to remove all top growth. This practice favors basal-bud development, which plays a role along with leaf area in total forage yield. Thus, yield is

maximized even though leaf area is reduced to near zero at each cutting after having reached a greater level than needed for nearly complete light interception (Brown and Blazer, 1968).

Maintaining acceptable forage quality is difficult with some high yielding warm-season perennial grasses. Often, acceptable forage quality cannot be obtained concurrently with maximum forage yields. To maintain acceptable quality, a leaf surface that is less than that required for near complete light interception may be desirable, although total forage yield will be reduced.

EFFECT OF STOCKING RATE

One of the more important considerations in grazing management is the stocking rate for a given pasture. The stocking rate and resulting grazing pressure directly affects production or gain per animal and per acre. Grazing pressure affects the quantity of forage grown, the amount of forage consumed by each animal, and the proportion of total forage produced that is consumed by grazing animals. This, in turn, affects the amount gained or produced per animal and per acre.

The effect of stocking rate on gain per animal and gain per acre is demonstrated with data from a study conducted at Angleton in 1963. Crossbred steers grazed Dallisgrass-white clover pastures at stocking rates of 1.00, 1.25, 1.50, 2.00, 2.25, and 2.50 steers per acre. If stocking rate is expressed as number of animals per acre, there is a negative effect, essentially linear within the area of primary interest, on liveweight gain per animal (Figure 5-2). As the stocking rate is increased to exert greater grazing pressure, gain per animal decreases. Stocking rate may be sufficiently light so that its further reduction will not result in a further increase in gain per animal. Stocking rate may be so light that the forage becomes rank and mature and gain per animal may be lower than at a somewhat heavier stocking rate.

The effect of stocking rate on gain per animal has been demonstrated in a number of studies (Riewe, 1961; Cowlishaw, 1969). Increased stocking rates decrease gain per animal in a linear manner when stocking rate is expressed as animals per acre.

Liveweight gain per acre is an expression of stocking rate times gain per animal. A "grazing production curve" for 1963 Angleton data showing the effect of stocking

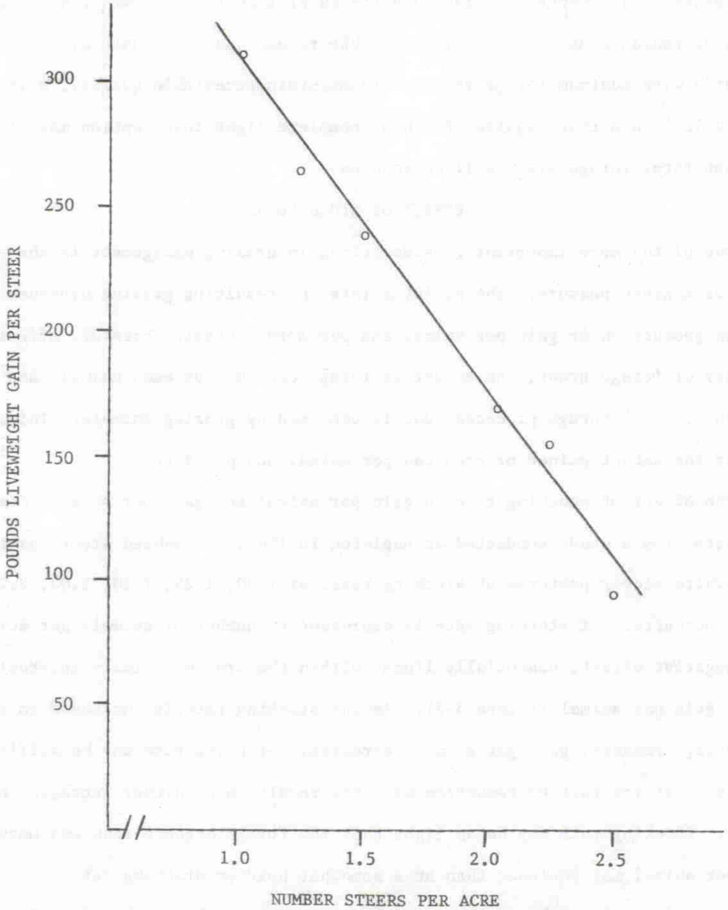

Figure 5-2. The effect of stocking rate on pounds gain per steer (when stocking rate is expressed as steers per acre) on dallisgrass-white clover pastures, 1963, Angleton.

rate on both liveweight gain per animal and per acre is shown in Figure 5-3 (Riewe, 1965). The essentials of this curve are that (a) except for very light stocking rates, a negative linear relationship exists between stocking rate and gain per animal, (b) increasing the stocking rate results in an increase in gain per acre until the point of maximum gain per acre is reached; thereafter, further increases in stocking rate result in decreased gain per acre, and (c) the animal maintenance level (no gain) would be reached with a stocking rate double that producing maximum liveweight gain per acre. The latter is equivalent to a 50 percent reduction in land area per animal if stocking rate is expressed as number of acres per animal.

Stocking rate also may be expressed as number of acres per animal. If stocking rate is expressed in this form, the relationship between stocking rate and gain per animal can be best expressed by the equation, $Y = a + bX^{-1}$. This equation describes a curve (Figure 5-4) that shows that (1) gain per animal decreases gradually as the amount of land or pasture per animal is decreased to a point producing maximum liveweight gain per acre; i.e., in this study, 0.61 acre per steer, (2) further decreases in pasture per animal causing a marked depression in gain per animal and (3) animal maintenance level would be reached with about 50 percent of the land area per animal required for producing maximum liveweight gain per acre.

With light grazing pressure, much of the forage at any given time may be unused. If the forage advances in maturity, cattle may tend to concentrate their grazing in localized areas. This is commonly referred to as "spot grazing." Spot grazing occurs when cattle have sufficient opportunity for selective grazing to reject more mature forage, less desirable forage around dung or urine spots, and forage of less palatable species. As the stocking rate is increased, the ungrazed areas become smaller and constitute a smaller part of the total pasture area. With a heavy stocking rate, almost all available forage at any given time may be grazed with little evidence of spot grazing.

Figure 5-5 shows the results of mapping grazed and ungrazed areas in 5 x 50 foot plots on several dates in pastures stocked with 1, 1.5, and 2 steers per acre on dallisgrass-white clover pastures at Angleton. With a stocking rate of 1 steer per acre, less

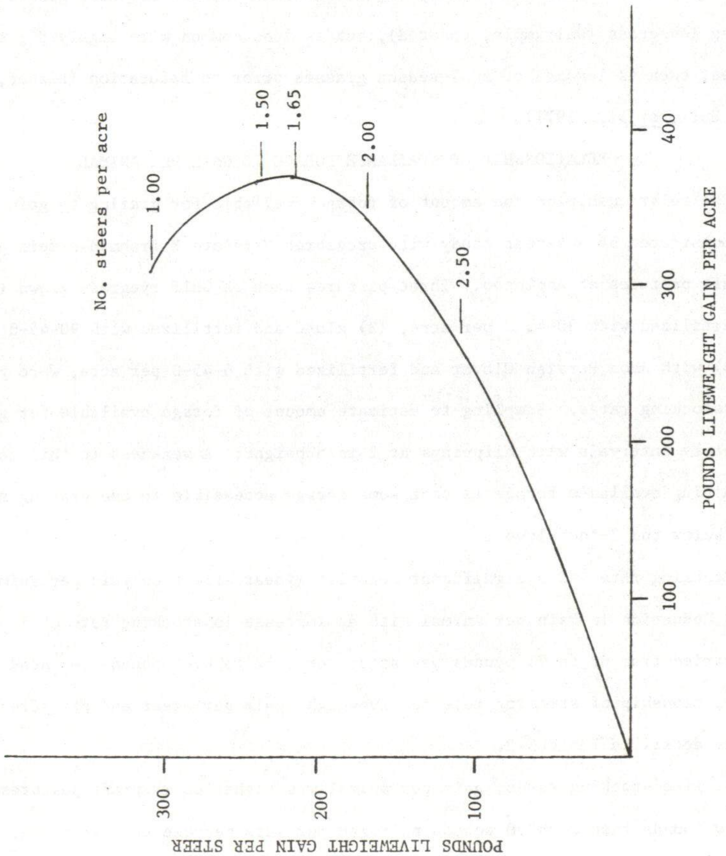

Figure 5-3. Effect of stocking rate on liveweight gain per steer and per acre on dallisgrass-white clover pasture, 1963, Angleton.

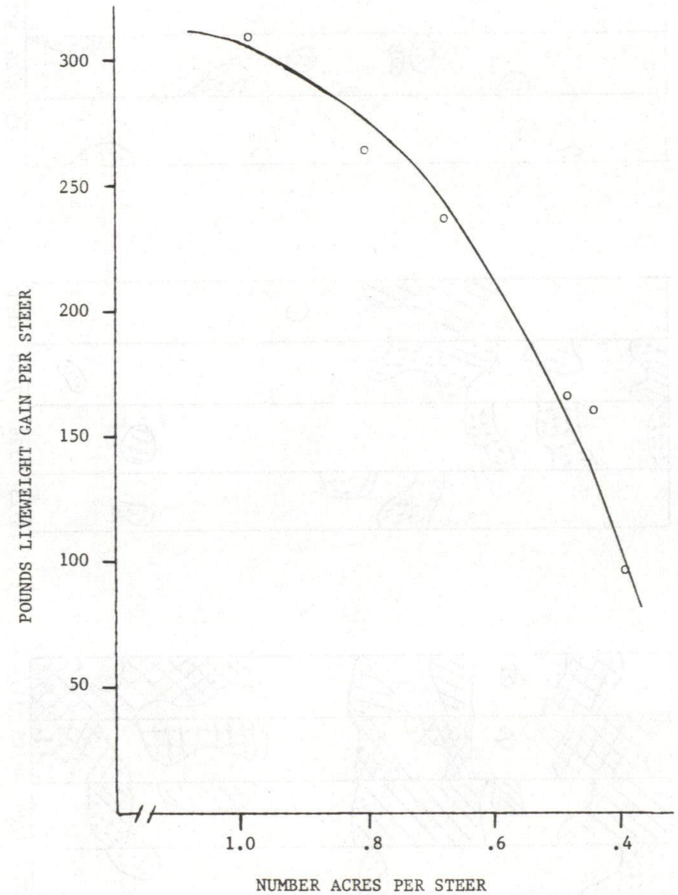

Figure 5-4. The effect of stocking rate on pounds gain per steer (when stocking rate is expressed as acres per steer) on dallisgrass-white clover pasture, 1963, Angleton.

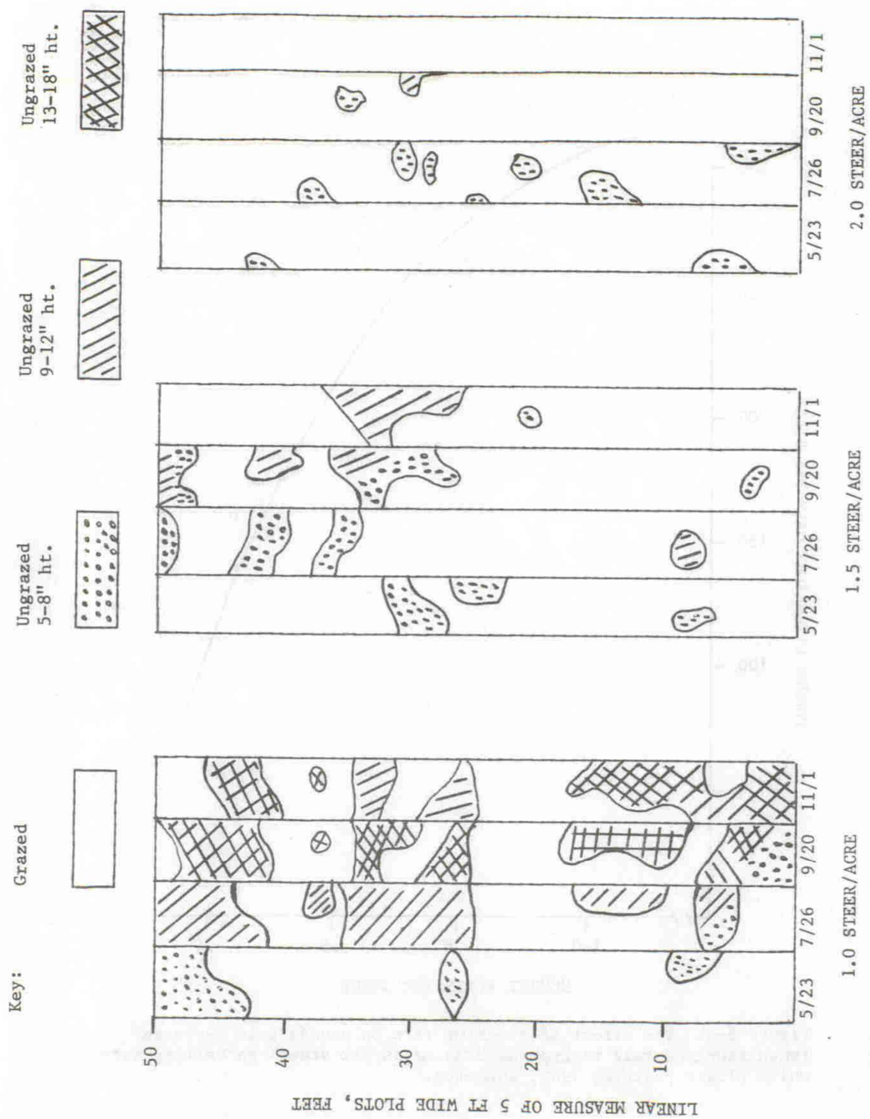

Figure 5-5. Typical patterns showing the effect of stocking rate on degree and nature of spot grazing for steers grazing dallisgrass-white clover pastures, Angleton.

of the total area was grazed on any given date; however, a portion of the apparently ungrazed areas on one date was grazed at a later date. With a stocking rate of 2 steers per acre, more of the area was uniformly and closely grazed. Ungrazed spots were less conspicuous, were smaller in size, and were likely to be grazed again sooner than with a lighter stocking rate.

It has been commonly assumed that once forage on an area is left ungrazed, the forage becomes mature and cattle will graze only previously grazed areas. This frequently may be the case with poorly digestible warm-season perennial grasses, such as weeping lovegrass (Dalrymple, undated), but is less common with highly digestible forages, such as legumes or cool-season grasses prior to maturation (Blaser, et al., 1969; Hull, et al., 1971).

RELATIONSHIP OF AVAILABLE FORAGE TO GAIN PER ANIMAL

The relationship of the amount of forage available for grazing to gain per animal is demonstrated by a 4-year study with crossbred Hereford X Brahman steers grazing Gulf ryegrass pastures at Angleton. Three pastures each of Gulf ryegrass grown (1) alone and fertilized with 30-45-0 per acre, (2) alone and fertilized with 90-45-0 per acre, and (3) with Abon Persian Clover and fertilized with 0-45-0 per acre, were grazed at three stocking rates. Sampling to estimate amount of forage available for grazing was at monthly intervals with clippings at 2-inch height. A weakness in this method of determining available forage is that some forage accessible to the grazing animal remains below the 2-inch level.

Stocking rate had a significant negative linear effect on gain per animal (Figure 5-6). Reduction in gain per animal with an increase in stocking rate of 1 steer per acre varied from 62 to 71 pounds per steer, or 0.52 to 0.60 pounds per head per day. The relationship of stocking rate to liveweight gain per steer and per acre is shown in more detail in Table 5-2.

At like stocking rates, gain per animal was higher on ryegrass pastures fertilized with 90 pounds than with 30 pounds nitrogen per acre because the additional 60 pounds nitrogen increased forage production. Gain per animal was related to the amount of forage available (Figure 5-7). This relationship, described by the polynomial equation

Table 5-2. Effect of stocking rate on 4-year average liveweight gain per steer and per acre (pounds) on several Gulf ryegrass pastures, Angleton.

No. steers per acre	Ryegrass alone 30 lb. N/acre			Ryegrass alone 90 lb. N/acre			Ryegrass-clover		
	Pounds gain			Pounds gain			Pounds gain		
	Obs. per steer[1]	Est. per steer[2]	Est. per acre[3]	Obs. per steer[1]	Est. per steer[2]	Est. per acre[3]	Obs. per steer[1]	Est. per steer[2]	Est. per acre[3]
1.00		189	189					234	234
1.08	183						228		
1.50		158	236		211	316		199	299
1.53				209					
1.64	151						189		
2.00		127	254		177	354		164	328
2.12				168					
2.14	117						154		
2.50		96	239		143	358		129	323
2.69				131					
2.75					126	347			

[1] Actual observed 4-year average liveweight gain.

[2] Estimated from observed gain with equation Y = a - bX.

[3] Estimated gain per steer times number steers per acre.

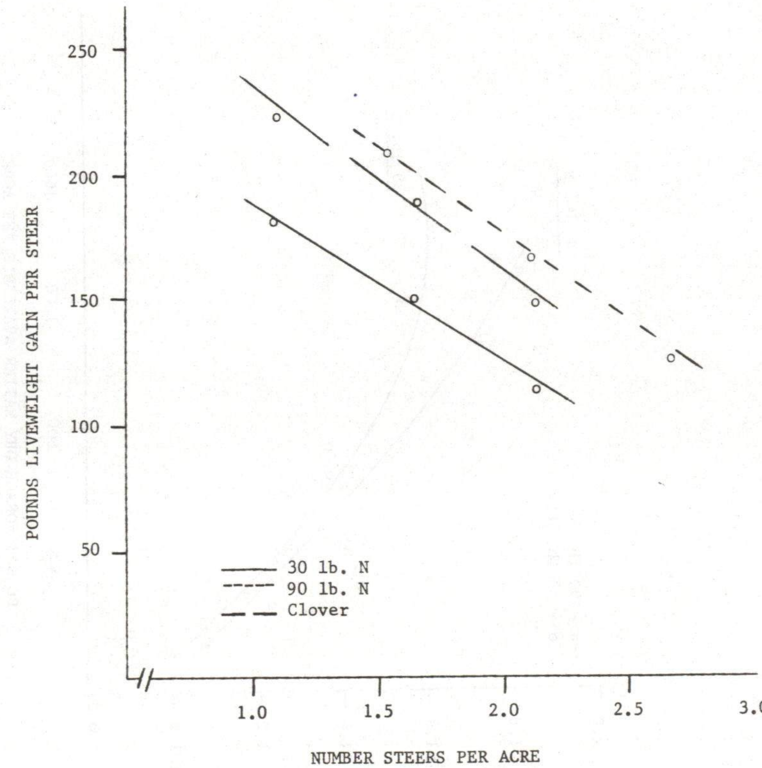

Figure 5-6. The effect of stocking rate on pounds liveweight per steer on several Gulf ryegrass pastures, Angleton, 1962-65.

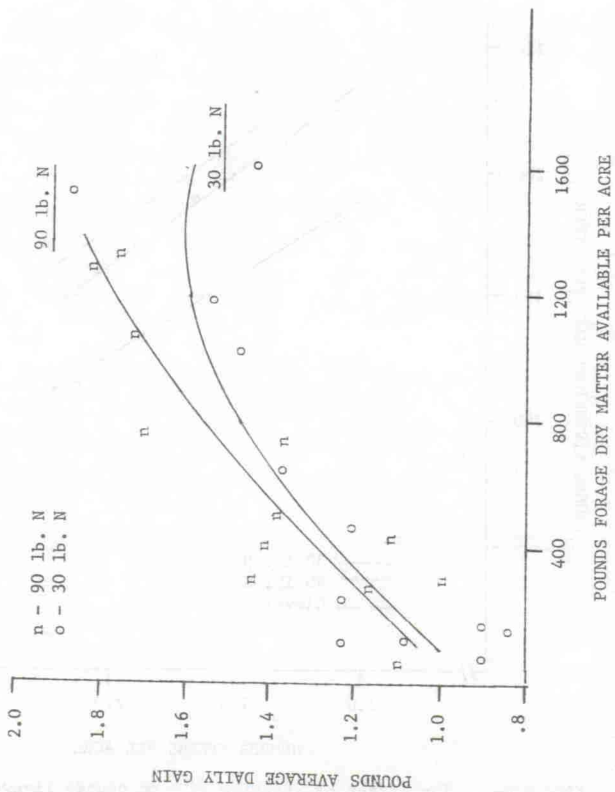

Figure 5-7. The relationship of average pounds forage dry matter available per acre to 4-year average daily gain for steers grazing Gulf ryegrass fertilized with 30 or 90 pounds nitrogen per acre, Angleton.

$Y = a + bX + cX^2$, indicates that the higher gain per animal at like stocking rates on ryegrass pastures fertilized with 90 pounds nitrogen per acre is a response to greater forage availability. There is little indication that the additional 60 pounds nitrogen produced a better quality forage.

More available forage was required to produce a given rate of gain when ryegrass was grown alone than when grown with clover (Figure 5-8). This suggests that clover improves the quality of forage consumed by the grazing animal.

The relationship between forage availability and animal gain also was examined at The Texas A&M University Agricultural Research and Extension Center at Overton (Duble, et al., 1971). Gain per animal was related to forage availability within forage digestibility groupings. When the digestible dry matter content of the available forage was low, acceptable gains were attained only with substantial amounts of forage available for grazing. Acceptable gains were produced with lesser amounts of available forage with high digestibility.

These studies bear out the importance of ample forage being available to permit selective grazing if the animals are to produce good gains. With a stocking rate exerting light grazing pressure, the grazing animal can selectively graze the leafier, more digestible forage. Dry matter consumption per animal is relatively high, but much of the available forage is not immediately utilized. As the stocking rate is increased to exert greater grazing pressure, more of the total available forage is immediately consumed, but the amount consumed per animal decreases (Campbell, 1966; Pieper, et al., 1959; Hull, et al., 1965; and Hodgson, et al., 1971). Frequently, the forage consumed is less digestible. A greater portion of the digestible energy consumed by the grazing animal is used for body maintenance and less is available for gain or milk production. Thus, although more of the forage produced is consumed by the grazing animal (one view of efficiency) as the stocking rate is increased, the forage consumed by the grazing animal is converted to meat or milk less efficiently.

EFFECT OF GRAZING PRESSURE ON ECONOMIC RETURN

Return Per Unit Land Area

Liveweight gain per animal has a direct bearing on economic return independent of

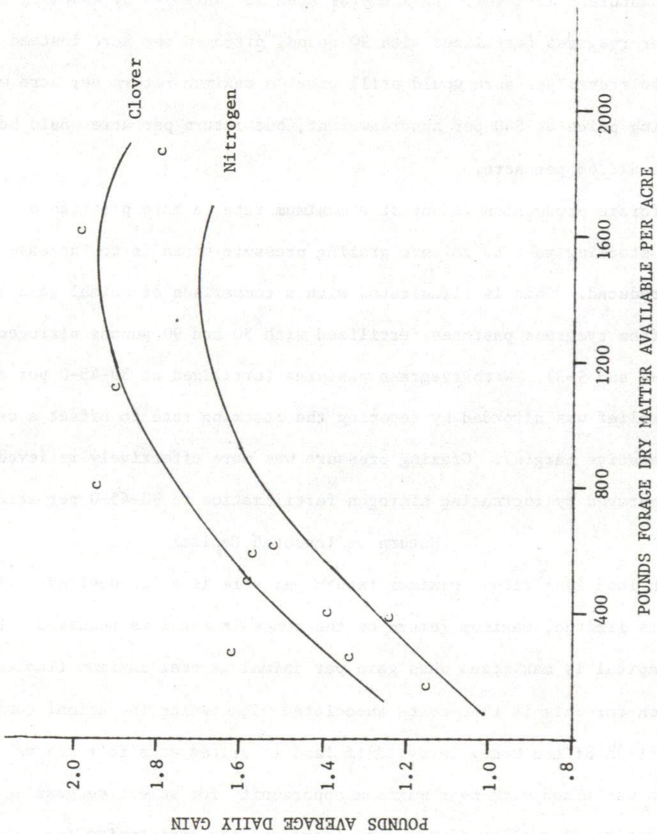

Figure 5-8. The relative relationships of average pounds forage dry matter available per acre to 4-year average daily gain for steers grazing Gulf ryegrass fertilized with nitrogen or grown with Abon Persian clover, Angleton.

the total liveweight gain per unit of pasture area. Costs directly associated with the animal must be paid by gain or production per animal. These costs include a negative price margin between buying and selling, death losses, labor, medications, interest on the money invested directly in the cattle, and supplemental feed. Gain per animal must be sufficiently high to pay these costs before money from animal production is available to pay pasture costs regardless of total liveweight gain per acre. Since stocking rate, and thus grazing pressure, has a direct effect on gain or production per animal, economic return is directly affected by stocking rate.

Several general relationships (Hildreth and Riewe, 1963) can be illustrated with steer gains on Gulf ryegrass pastures fertilized with either 30 or 90 pounds nitrogen per acre (Table 5-3). These data show estimated returns with 400-pound steer calves when purchased at either \$32 or \$40 per hundredweight and later sold at several prices. Specified animal costs when purchase price is \$40 per hundredweight total \$179.46 per head and include: purchase price of 400-pound calves at \$40 per hundredweight-\$160; interest, 10 percent for 200 days-\$8.77; 1 percent death loss-\$1.69; labor for handling calves and medication-\$5.00; and feed cost other than pasture-\$4.00. Specified animal costs when purchase price is \$32 per hundredweight total \$145.36. Pasture costs per acre when ryegrass was fertilized with 30-45-0 are estimated as follows: land lease-\$10.00 per acre; seedbed preparation-\$12.50 per acre; seed and seeding-\$3.00 per acre; fertilizer and fertilizer application-\$18.75; and interest at 10 percent for 270 days-\$3.28, for a total of \$47.53 per acre. When ryegrass was fertilized with 90-45-0 per acre, pasture costs per acre are increased to an estimated \$63.64.

The first general relationship is that the cost of caring for and owning (interest on money invested in cattle) the animal is sufficient to prevent the stocking rate that maximizes gain per acre from also being the stocking rate that maximizes profit per acre. Note in Table 5-3, for example, that stocking rates lighter than those producing maximum gain per acre gave a higher return per acre when buying and selling price per hundredweight were equal (zero margin).

A second general relationship is that when costs associated with owning the cattle increase, such as increased cost for supplemental feeding in the case of cow-calf

Table 5-3. Dollar return per acre at several buying and selling prices for several stocking rates on Gulf ryegrass pastures fertilized with 30 and 90 pounds nitrogen per acre.

Net price, dol./cwt		Number steers/acre						
Purchase	Sale	1.0	1.25	1.50	1.75	2.00	2.25	2.50
		Dollar return with 30 lb. N/acre						
40	44	32.17	43.84	51.56	56.52	57.31	55.56	
	42	20.39	29.49	34.82	37.52	36.23	32.52	
	40	8.61	15.14	18.08	18.51	15.15	9.48	
	38	-3.17	0.79	1.34	0.49	-5.93	-13.56	
	36	-14.95	-13.56	-15.40	-19.50	-27.01	-36.60	
32	36	19.15	29.07	35.75	40.18	41.19	40.13	
	34	7.37	14.72	19.01	21.18	20.11	17.09	
	32	-4.41	0.37	2.27	2.17	-0.97	-5.95	
	30	-16.19	-13.98	-14.47	-16.83	-22.05	-28.99	
	28	-27.97	-28.33	-31.21	-35.84	-43.13	-52.03	
		Dollar return with 90 lb. N/acre						
40	44			70.43	79.68	85.20	86.97	85.01
	42			52.10	58.89	62.12	61.77	57.86
	40			33.77	38.10	39.04	36.57	30.71
	38			15.44	17.31	15.96	11.37	3.56
	36			-2.89	-3.48	-7.12	-13.83	-23.59
32	36			48.26	56.20	61.08	62.90	61.66
	34			29.93	35.41	38.00	37.70	34.51
	32			11.60	14.62	14.92	12.50	7.36
	30			-6.73	-6.17	-8.16	-12.70	-19.79
	28			-25.06	-26.96	-31.24	-37.90	-46.94

program or a negative margin between buying and selling price in case of stocker cattle, the additional costs must be offset by increasing gain or production per animal. Thus, unless additional forage is produced or the quality of forage improved, either of which will increase production per animal, stocking rate must be reduced to maximize return per acre.

A third consideration is that on any given pasture for a given cost-return situation there is a range in stocking rates that permits near maximum return per acre. For example, near maximum returns per acre were obtained over a range of one-half steer or more per acre. However, risks associated with owning more cattle and reduction in available forage supply are increased with the heavier stocking rates.

The fourth general relationship is that stocking rate producing maximum return per acre on a given pasture is not affected by any cost associated with the land or the pasture production. These include cost of land lease, seedbed preparation, fertilizer, seeding, or any cost associated with the land pasture production. Pasture costs will affect return per acre, but the stocking rate producing maximum return per acre at one land or pasture cost level will also produce the highest return per acre at another pasture cost level. This may be seen in Table 5-3 by assuming a pasture cost of $80 for ryegrass fertilized with 90 pounds nitrogen per acre instead of $63.64 per acre. Two steers per acre would still provide maximum return per acre with both buying and selling price at $40 per hundredweight, but return per acre would be reduced from $39.04 to $22.68 per acre.

If forage production is not at a maximum rate, a more profitable alternative to reducing stocking rate to relieve grazing pressure often is to increase the amount of forage produced. This is illustrated with a comparison of animal gain and economic returns from ryegrass pastures fertilized with 30 and 90 pounds nitrogen per acre (Table 5-2 and 5-3). With ryegrass pastures fertilized at 30-45-0 per acre, only limited relief was afforded by reducing the stocking rate to offset a decrease in sale price (negative margin). Grazing pressure was more effectively relieved and economic return improved by increasing nitrogen fertilization to 90-45-0 per acre.

Return on Invested Capital

When land is limited, maximum return per acre is often desired. If available capital is limited, maximum return on the money invested is required. Return on invested capital is maximized when gain per animal is near maximum (Tables 5-2 and 5-4). The reason for this is that costs associated with owning the animal constitute the major portion of the money invested if land is priced at a fair use value. Gain per animal is maximized with near maximum opportunity for selective grazing. Increasing the production of quality forage also increases the opportunity for selective grazing. Stocking rates less than those required for maximum gain per animal are, of course, less profitable.

Other Limiting Factors

Land or capital may not always be the first limiting factor in a grazing enter-

Table 5-4. Percent return on invested capital at several buying and selling prices for several stocking rates on Gulf ryegrass pastures fertilized with 30 and 90 pounds nitrogen per acre.

Net price, dol./cwt		Number steers/acre						
Purchase	Sale	1.0	1.25	1.50	1.75	2.00	2.25	2.50
		Percent return with 30 lb. N/acre						
40	44	14.2	16.1	16.3	15.6	14.1	12.3	
	42	9.0	10.9	11.0	10.4	8.9	7.2	
	40	3.8	5.6	5.7	5.1	3.7	2.1	
	38	-1.4	0.3	0.4	0.1	-1.5	-3.0	
	36	-6.6	-5.0	-4.9	-5.4	-6.7	-8.1	
32	36	9.9	12.7	13.5	13.3	12.2	10.7	
	34	3.8	6.4	7.2	7.0	6.0	4.6	
	32	-2.3	0.2	0.9	0.7	-0.3	-1.6	
	30	-8.4	-6.1	-5.5	-5.6	-6.5	-7.7	
	28	-14.5	-12.4	-11.8	-11.9	-12.8	-13.9	
		Percent return with 90 lb. N/acre						
40	44			21.2	21.1	20.2	18.6	16.6
	42			15.7	15.6	14.7	13.2	11.3
	40			10.2	10.1	9.2	7.8	6.0
	38			4.6	4.6	3.8	2.4	0.7
	36			-0.9	-0.9	-1.7	-3.0	-4.6
32	36			17.1	17.7	17.2	16.1	14.4
	34			10.6	11.1	10.7	9.7	8.1
	32			4.1	4.6	4.2	3.2	1.7
	30			-2.4	-1.9	-2.3	-3.3	-4.6
	28			-8.9	-8.5	-8.8	-9.7	-11.0

prise. At times, the number of available cattle or the availability of labor or irrigation may be limiting. In some areas of the world, available fertilizer may be limited. If fertilizer had been the first limiting factor in the Gulf ryegrass study, more liveweight gain could have been produced per unit of nitrogen fertilizer by using 30 rather than 90 pounds per acre.

Inherent in an evaluation of economic gain on the basis of return per acre is the assumption that the availability of land limits the grazing enterprise. To justify such an assumption is frequently difficult.

GRAZING SYSTEMS

The idea of a system of grazing management involving the rotating of cattle among

two or more pasture divisions dates back for almost 400 years. The long history of the development of the rotational grazing concept has been reviewed by Smith (1956). Archibald Napier advocated in Scotland in 1598 a system of rotational grazing along with the use of common salt as manure. His reason for recommending the use of common salt is unclear, but the rate recommended was small. Benefits, if any, may have arisen from the potash in the salt. Napier was able to obtain a patent for this concept from James VI of Scotland and wrote, "That no man presumed to take upon hand this kind of husbandry without license from the said Archibald or his deputies under the pain of ten shillings to be paid to him for every acre of land they labour therewith, as well grass as corn, conform to his gift granted thereupon by His majesty."

In his essays published in 1775, James Anderson advised farmers to divide their pasture land into 15 to 20 divisions and to allow the animals to graze one division at a time. He recommended that each division be grazed closely to reduce forage waste caused by cattle indiscriminately roaming and soiling the forage. Each division would be rested following grazing to allow the grass to recover sufficiently so that the animal can graze to fill when the division is again made available for grazing. Anderson suggested that plots be grazed closely in order to maintain forage quality and palatability; should the forage become mature, "pastures would become less sweet and nourishing" and "there would likewise be a smaller quantity of grass produced."

In 1788, Marshall suggested that farmers should divide their pastures into three parts with fattening cattle or dairy cows given the first bite of each division followed by replacement or dry stock. Then, each division, in turn, would be given a rest from grazing. George Robison wrote in 1795, "If an enclosure of 24 acres were to maintain 24 beasts; subdivide it into three of equal size, and let the cattle be shifted weedly, from one to another regularly; it may perhaps maintain 27 as well."

In his report in 1800, John Thomson recommended rotational grazing because it would increase grass yield. Thomson contended that too heavy grazing pressures caused reduced forage yields and caused animals to consume too little forage.

Thus, by 1800, most ideas current in modern thought concerning rotational grazing had been advanced. These included: (1) the rapid rotation with many divisions of the pasture, (2) manuring or fertilizing in conjunction with rotational grazing to increase forage yields, and (3) allowing more productive cattle to graze a division first to be followed by replacement or dry stock grazing the coarse, less nutritious remaining forage. Advantages claimed included increased forage production, increased carrying capacity of the pasture, and better animal performance. One must surmise from these early writings that in nearly all cases continuous grazing was associated with heavy grazing pressure.

During the first World War, Dr. Warmbold, Director of the Hohenheim Institute in Germany, proposed a system of intensive pasture management that included: (1) dividing available pasture area into smaller plots or enclosures, (2) dividing the grazing herd according to the production level of the individual animals, (3) frequent rotation of each group of cattle with high producing cows having first access to a pasture division, remaining 2 or 3 days, to be followed by lower producing or dry stock, and (4) the application of commercial fertilizers, particularly nitrogen. This was proposed in lieu of the then common practice (Peter, 1929) of allowing cows, horses, and sheep to graze together on a pasture as long as they could find some food. After the grass became too short, barn feeding began.

Rotational grazing systems generally were not objectively evaluated until the 1930's. In the meantime, worldwide impetus was given to the idea of rotational grazing from a long series of pasture clipping experiments conducted by Woodman and associates (1926-1938). They showed that clipping a creeping bentgrass sward to a height of 0.5 to 1 inch followed by a recovery period of as many as 5 weeks increased annual forage yields when compared with more frequent clipping. Under conditions prevailing at Cambridge, England, Woodman found that the creeping bentgrass, a cool-season perennial, retained much of its nutritive value when cut at 5-week intervals. The assumption was made that close, frequent clipping simulated continuous grazing and less frequent clipping simulated rotational grazing. Thus, the conclusion was drawn that a system of rotational grazing permits higher forage yields and greater carrying capacity than a continuous grazing system. Because a high nutritive value was apparently maintained at least through the fourth week of regrowth, the conclusion also was drawn that individual

animal performance would be maintained and milk production per acre sharply improved. The changes in apparent nutritive value with time were less dramatic than found later by other researchers working with warm-season grasses.

These assumptions were to be challenged, however. Cattle grazing pastures on a continuous basis rarely defoliate an individual plant completely to an inch or two, as close mowing does, nor do they necessarily defoliate a plant frequently. For example, Morris (1969) varied grazing pressure when orchardgrass was continuously grazed with lambs to maintain a sward cover with leaf area indices of 5.3, 4.1, and 3.0. He found that a given 8 x 8 cm area was grazed, on the average, once every 36 days with a leaf area index of 5.3, once every 24 days with a leaf area index of 4.1, and once every 19 days with a leaf area index of 3.0. Similarly, Hodgson (1966) found that with continuously grazed ryegrass, individual tillers were defoliated every 11 to 14 days on a medium stocked pasture and every 7 to 8 days on a heavily stocked pasture. Thus, both the frequency of defoliation and closeness of grazing are a reflection of grazing pressure or stocking rate rather than the system of grazing.

Grazing Pressure and Grazing System

Studies using varying stocking rates in comparing continuous grazing with a system of rotational grazing, invariably show a stocking rate (grazing pressure) times grazing system interaction. This interaction is illustrated with data from a 3-year grazing trial at Angleton with yearling steers grazing dallisgrass-white clover pastures from March through October each year (Figure 5-9). Rotationally grazed paddocks were grazed for 5 days and rested for 25 days. The regression coefficients for stocking rate on gain per animal for the two systems of grazing were significantly different. Although the regression lines did not actually cross within the range of the stocking rates used, there is little doubt that they would have crossed at a heavier stocking rate. In this instance, differences in favor of continuous grazing for gain per animal and gain per acre were greater with a light stocking rate than a heavy stocking rate.

Similar observations were made by McIlvain and Savage (1951) when yearling steers were grazed on vegetation consisting primarily of sand sagebrush with an understory of bluegrass and sand dropseed. Hull, et al. (1967) observed higher gain per animal and per acre with continuous grazing with a light stocking rate with yearling steers graz-

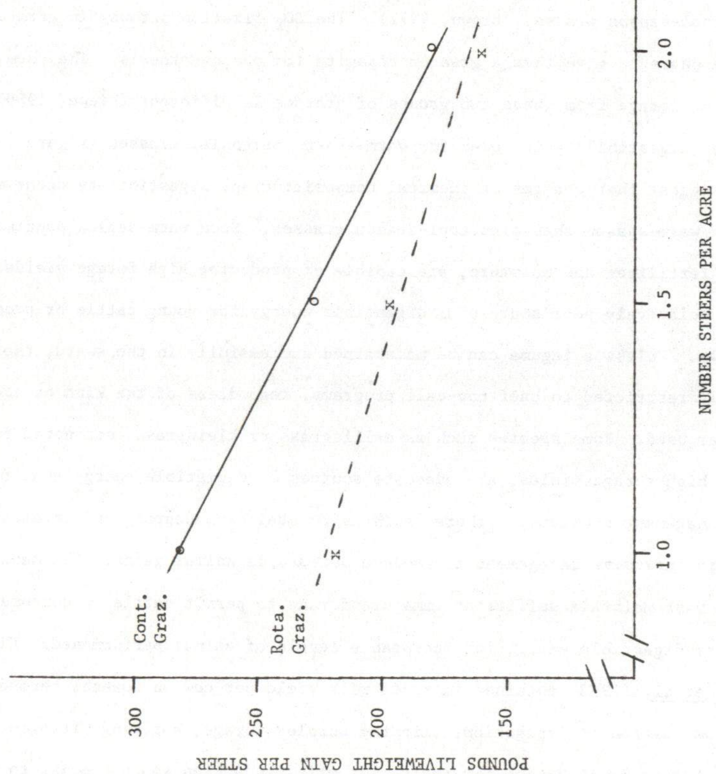

Figure 5-9. Effect of stocking rate on 3-year average pounds liveweight gain of yearling steers on dallisgrass-white clover pastures with continuous and rotational (5 days on-25 days off) grazing, Angleton.

ing pastures primarily of orchardgrass, perennial ryegrass, tall fescue, strawberry clover, and ladino clover. Rotational grazing produced higher gain per animal and per acre with a heavy stocking rate. Blaser, et al. (1969), in a study with steers grazing orchardgrass, found that continuous grazing produced higher liveweight gains per steer and per acre with a stocking rate producing near maximum gain per acre. Rotational grazing was superior to continuous grazing with a stocking rate sufficiently heavy to reduce gain per animal and per acre.

McMeekan and Walshe (1963) found that rotational grazing produced more milk per cow and per acre than continuous grazing. The differences were less with light stocking than with heavy stocking on pastures consisting primarily of perennial ryegrass, orchardgrass, dallisgrass, and white clover. Heavy stocking produced less milk per cow and also less milk per acre than light stocking under continuous grazing, indicating that the stocking rate producing maximum milk per acre had been exceeded. Heavy stocked rotational grazed pastures produced less milk per cow but more milk per acre. This suggests that with continuous grazing at stocking rates lighter than those used in the study, milk production per cow and per acre would have been equal or superior to rotational grazing.

While higher production or gain per animal and per acre at heavy to very heavy stocking rates may be obtained with rotational grazing, production, or gain per animal, is nevertheless reduced because of the effect of heavy grazing pressure. Economically, the increased production per acre must be weighed against the decreased production per animal. Production, or gain per animal, must be adequate to pay for costs associated directly with the animal, regradless of production per acre. When gain, or production per animal, is lowered too much, even though production per acre is increased, the practice may not be economically sound.

Alfalfa vs. White Clover and Grazing System

The kind of legume in the pasture mixture affected results in comparisons of continuous grazing and a system of rotational grazing. Where alfalfa was a major component of the pasture mixture, rotational grazing was equal or superior to continuous grazing in studies by Fuelleman (1948), Brundage and Petersen (1952), Davis and Pratt (1956), Blaser, et al. (1969), and Heinemann (1970) in terms of gain or production per animal, production per acre, and better survival of alfalfa. Harrison (1948) studying an alfalfa-ladino-smooth brome-timothy mixture failed to obtain an increase with rotational over continuous grazing in milk production per cow or per acre. This may have been because of the ladino clover in the pasture mixture.

Continuous grazing was equal or superior to a system of rotational grazing in production per animal and per acre where white or ladino clover was a major component of the pasture mixture in grazing studies by Holdaway and Pratt (1933), Ahlgren (1944), Mayton, et al. (1947), Davis and Bell (1957), Hunt, et al. (1958), Riewe, et al. (1959), Riewe (1965), Blaser, et al. (1969), and Hull, et al. (1971). Ladino or white clover apparently survived better with continuous grazing than with rotational grazing.

In the California work by Hull, et al. (1971), high forage yields apparently were obtained, particularly during the last 2 years of a 4-year study. With steers one year and heifers the second year, continuous grazing produced an average daily gain of 1.61 pounds, while with a 5-field rotation daily gain was 1.43 pounds per head. Continuous grazing produced an average of more than 960 pounds per acre annually, which was greater than with rotational grazing.

The difference in response of alfalfa and white clover to grazing management may be explained by differences in physiological response to defoliation of the two species. Alfalfa is erect growing, palatable, and easily defoliated by grazing. New growth after defoliation is at the expense of nonstructural carbohydrates in the roots. Frequent defoliation may exhaust carbohydrates in the roots so that no further new growth can occur and the alfalfa plant dies. If new growth is allowed to continue, however, carbohydrate stores are replenished. Further, the alfalfa plant, by nature of its growth habit, can compete well for light with grasses that might normally be grown in association with it.

White clover, on the other hand, is a low-growing, stoloniferous species not easily defoliated completely by grazing. Thus, new growth usually is not toally dependent upon carbohydrate reserves in the stolons and roots. During its growing season, photosynthetically active leaves continue to supply carbohydrates for new growth. Because of its prostrate growth habit, white clover often does not compete well with taller growing grasses for light. Rotational grazing or too light grazing pressures frequently allow a grass canopy to develop that shades white clover.

Warm-Season Perennial Grasses and Grazing Systems

Warm-season grasses, as a group, produce higher dry matter yields than cool-season grasses. Optimum temperatures for growth are higher (85° F or higher) than for cool-season grasses (60-78° F). Photosynthesis increases in warm-season grasses up to near full sunlight (10,000 to 12,000 foot candles); whereas, photosynthesis in cool-season grasses is maximum at about 3,000 to 4,000 foot candles. Photosynthesis involves a different biochemical pathway of carbon dioxide (CO_2) uptake in warm-season than in cool-season grasses (Brown, 1972). The CO_2 fixation pathway in warm-season grasses appears to give them a greater capacity for photosynthesis. The chemical composition of forage from these two groups of grasses is different (Riewe, 1968). The dry matter digestibility is lower for warm-season perennial grasses (Figure 5-1). Many studies suggest that changes in chemical composition and digestibility occur more rapidly with warm-season than with cool-season grasses. Some warm-season species, with adequate fertilizer and moisture, are capable of producing high forage yields. Yet, they are relatively poor sources of digestible energy for young cattle or producing dairy cows. Unless a legume can be maintained successfully in the sward, their use is largely restricted to beef cow-calf programs, regardless of the kind or amount of fertilizer used. Some species such as dallisgrass or kleingrass, not noted for exceptionally high forage yields, are adequate sources of digestible energy and present no unique management problems. Others, such as Coastal bermudagrass and lovegrass, appear to require intensive management to produce acceptable animal gains. The management practice must maintain sufficient immature forage to permit cattle to consume adequate amounts of digestible energy for acceptable levels of animal performance. Thus, Rollins, et al. (1963) obtained improved milk yield per cow on Coastal bermudagrass with a combination of irrigation, clipping surplus forage, applying nitrogen, and rotational grazing at 3-week intervals, but milk production was not equal to that of cows grazing Gahi-1 millet. Whether or not the milk yield per cow was high enough to be acceptable is not clear.

Oliver (1972), grazing yearlings and weaned calves on Coastal bermudagrass in Louisiana, obtained higher gain per animal and per acre after July 1 in 2 years out of 3 with a rapid rotational grazing system of 3 days grazing followed by 10 days regrowth. Lancaster (1970) reported that forage on Coastal bermudagrass pastures had a low digestible energy content at this time of the year in Northeast Texas. With either system of grazing in the Louisiana study, weaned calves made low gains, particularly after July 1. Yearling cattle, following a wintering period of no gain, made much better gains, obviously capitalizing on compensatory growth.

McCormick (1971) reported higher gain per animal with grazing and hay rotation than with continuous grazing with 2 yearling steers per acre. The same number of steers were grazed in the grazing and hay rotation as in continuous grazing, but twice the area was alloted. The system was designed so that the animals grazed initial young regrowth and hay was harvested following additional growth on that pasture. The animals were moved to another pasture with young growth, and the system continued. The large steers made an acceptable gain of 1.65 pounds per head per day on the fresh, young leafy forage, but quality of the hay was reduced.

These studies suggest that gain is not necessarily related to the total amount of forage available but to the amount acceptable to the grazing animal. Coarse, poorly digested forage may often be rejected.

In a study with nursing calves and cows grazing Coastal bermudagrass at Overton, Texas (Rouquette and Duble, 1972), calves, without compensatory growth, made much higher daily gains than did the stocker cattle in the Louisiana and Georgia studies. Thus, the primary question in managing forages such as Coastal bermudagrass concerns the adequacy of the forage for its intended use. If forage quality at best is inadequate for the intended use, no method of grazing can overcome the deficiency.

Continuous vs. Rotation Grazing

Continuous grazing, with proper stocking rate, favors the growth of plants that are semi-prostrate morphologically or those that become semi-prostrate under grazing, such as white or ladino clover, bluegrass, orchardgrass, ryegrass, dallisgrass, common bermudagrass, and forages with similar growth haibt (Mayton, et al., 1947; Riewe, et al., 1959; Blaser, et al., 1969; and Hull, et al., 1971. Good animal performance generally is expected. Animal performance appears to be favored by continuous grazing when white or ladino clover is included in the pasture mixture. With proper stocking, continuous

grazing insures a reasonably uniform daily intake of forage and provides the animal a greater opportunity for selective grazing. A favorable leaf area index can be more easily maintained on properly stocked continuously grazed pastures. Trampling losses, particularly on wet boggy soils, are less than when a canopy of forage is allowed to accumulate or cattle are concentrated. Surplus forage may be less easily recognized as surplus under continuous grazing. On the other hand, surplus forage may be carried forward to act as a buffer against a shortage resulting from adverse growing conditions.

Rotational grazing favors the growth and survival of erect growing, easily defoliated plants. Where alfalfa is included in the pasture mixture, usually rotational grazing will favor forage production and animal performance.

Fluctuations in daily consumption of forage are greater with rotational grazing, unless daily-rotation grazing is practiced, than with continuous grazing. When entering a rotationally grazed paddock, cattle selectively graze the leafy, more digestible forage in relatively large amounts. Milk production of dairy cows increases. As grazing continues, the amount of grazable forage decreases. As the opportunity for selective grazing decreases, less forage of poorer digestibility is consumed, and milk production or gain per day drops (Blaser, et al., 1969).

This forage consumption pattern apparently was recognized by Marshall in 1788 (Smith, 1956) and again in the Hohenheim system (Peter, 1929). In both instances, it was suggested that more productive cattle be allowed to graze a paddock first, followed by less productive or dry stock. Definitive supportive data have been obtained in Virginia studies with dairy cows (Bryan, et al., 1961) and steers (Blaser, et al., 1969). With forage species, such as alfalfa, amenable to rotational grazing, the adaptation of this concept into a practical farm situation could be economically feasible.

Fluctuations in daily consumption of forage with rotational grazing can be minimized with a method known as daily-rotational grazing. With daily-rotational grazing, known also as daily strip grazing or close-folding, cattle are moved to a new strip each day. The objective is to maintain high consumption of quality forage with near complete utilization of the grazable forage. Usually daily-rotational grazing is practiced with dairy cows by use of electric fences. Its use is largely restricted to fairly digestible forages, such as certain cool-season perennial grasses, annual grasses, and legumes. On warm-season perennial grass pastures, production per animal will likely be too low to justify the costs involved.

With very heavy grazing pressures, higher forage yields and better animal performance are expected with rotational than with continuous grazing. Performance per animal is nevertheless depressed by the heavy grazing pressure compared with lighter grazing so that the economic feasibility of such a grazing practice may be questioned.

With perennial warm-season grasses that are noted for their low digestible energy content, rapid rotational grazing with a short rest period between grazings, apparently is a means of maintaining a more leafy sward. Digestible energy consumption by grazing cattle may be improved sufficiently to provide for some improvement in performance. The overriding consideration is, however, that such pastures be grazed with the class of cattle that can best utilize forages with low concentration of digestible energy.

When quality forage is in short supply, as at the time of growth initiation in the spring or during periods of slow growth, such as in January on winter pastures, any system of rotational grazing is likely to depress animal gains. Grazing pressure is reduced by allowing cattle to graze the entire available pasture. Rotational grazing often places unreasonable grazing pressure on the sward of paddocks being grazed. On wet soils particularly, trampling losses may increase with rotational grazing.

MANAGING SURPLUS FORAGE

The rate of forage growth varies throughout the growing season. The greatest need for forage should be reconciled with the times that forage is most abundant, provided prohibitive costs are not incurred for another period of the year. Even so, periods of excess forage or shortages may occur. Some surplus may be carried forward "in place" for grazing later. With cool-season grasses, it is often desirable to let fall growth accumulate to provide grazing during the winter months when forage growth is slow.

The quality of warm-season grass forage deteriorates more rapidly with time than cool-season grasses, but some accumulation "in place" of surplus forage for grazing later will reduce the cost of harvesting, storing, and feeding later.

A simple and flexible method of managing and harvesting truly excess forage is to

fence off (often an electric fence is adequate) the part not needed for grazing, harvest at the appropriate time, and then allow grazing as needed. This permits more exact control of the area set aside for harvesting as hay or silage. No additional watering facilities or expensive fencing are needed. The roughest terrain can be used exclusively for grazing, with the harvesting of surplus forage for hay or silage restricted to areas with smoother terrain.

Such a management scheme allows for the maintenance of a more favorable leaf surface area and better control of forage growth. Too severe defoliation or excessive canopy accumulation is avoided. This concept is by no means new. Permutations of this concept have long been used by producers. Harvesting the first growth of warm-season annual grasses for hay with subsequent growth available for grazing is an example. Using crop residues by grazing cattle to relieve pressure on permanent pasture is another. Growing perennial forages primarily for hay but available for grazing at times when the need arises is also an example

LITERATURE CITATIONS

Ahlgren, H. L., I. W. Rupel, G. Bohstedt, and E. J. Graul. 1944. Eight years' results on the effectiveness of fertilization and management in increasing the production of permanent pastures. J. Amer. Soc. Agron. 36:301-315.

Blaser, R. E., H. T. Bryant, R. C. Hammes, Jr., R. L. Boman, J. P. Fotenot, and C. E. Polan. 1969. Managing forages for animal production. Virginia Poly. Inst. Res. Div. Bul. 45.

Brown, R. H., and R. E. Blazer. 1968. Leaf area index in pasture growth. Herb. Abstr. 38:1-9.

Brown, R. H. 1972. The differences in physiology and anatomy of temperate and tropical grasses. Southern Pasture and Forage Crop Improvement Conference Proc. 29th: 15-24.

Brundage, A. L., and W. E. Petersen. 1952. A comparison between daily rotation grazing and continuous grazing. J. Dairy Sci. 35:623-630.

Bryant, H. T., R. E. Blaser, R. C. Hammes, Jr., and W. A. Hardison. 1961. Method for increased milk production with rotational grazing. J. Dairy Sci. 44:1733-1741.

Campbell, A. G. 1966. Grazed pasture parameters. J. Agri. Sci. 67:199-221.

Cowlishaw, S. J. 1969. The carrying capacity of pastures. J. Br. Grassld. Soc. 24:207-214.

Dalrymple, R. L. (Undated). Weeping lovegrass management. The Noble Foundation. Ardmore, Oklahoma.

Davis, R. R., and A. D. Pratt. 1956. Rotational versus continuous grazing with dairy cows. Ohio Agri. Exp. Sta. Bul. 778.

Davis, R. R., and D. S. Bell. 1957. A comparison of bird's-foot trefoil-bluegrass and ladino clover-bluegrass for pasture: I. Response of Lambs. Agron. J. 49: 436-440.

Fuelleman, R. F., W. L. Burlison, and W. G. Kammlade. 1948. Methods of management of a bromegrass-alfalfa mixture. J. Anim. Sci. 7:100-109.

Harrison, C. M., Glen Williams, and Wm. N. Fischer. 1948. Continuous and rotation grazing of a legume-grass mixture with dairy cows. J. Amer. Soc. Agron. 40:357-363.

Heinemann, W. W. 1970. Continuous and rotation grazing by steers on irrigated pastures. Washington Agri. Exp. Sta. Bul. 724.

Hildreth, R. J., and M. E. Riewe. 1963. Grazing production curves. II. Determining the economic optimum stocking rate. Agron. J. 55:370-372.

Hodgson, J., J. C. Taylor, and C. R. Lonsdale. 1971. The relationship between intensity of grazing and the herbage consumption and growth of calves. J. Br. Grassld. Soc. 26:231-237.

Hodgson, J. 1966. Frequency of defoliation of individual tillers in a set-stocked sward. J. Br. Grassld. Soc. 21:258-263.

Holdaway, C. W., and A. D. Pratt. 1933. Progress report of pasture fertilization at the Virginia Agricultural Experiment Station. J. Dairy Sci. 16:95-99.

Hull, J. L., J. H. Meyer, Sergio E. Bonilla, and W. Weitkamp. 1965. Further studies on the influence of stocking rate on animal and forage production on irrigated pasture. J. Anim. Sci. 24:697-704.

Hull, J. L., J. H. Meyer, and C. A. Raguse. 1967. Rotation and continuous grazing on irrigated pastures using beef steers. J. Anim. Sci. 26:1160-1164.

Hull, J. L., C. A. Raguse, and W. D. Henderson. 1971. Further studies on continuous and rotational grazing of irrigated pasture by yearling beef steers and heifers. J. Anim. Sci. 32:984-988.

Hunt, R. E., C. M. Kincaid, and G. W. Litton. 1958. Rotational versus continuous grazing of cattle, sheep and horses. Virginia Agri. Exp. Sta. Bul. 495.

Lancaster, J. A. 1970. Production and management of Coastal Bermudagrass pastures. Pasture and Forage Crop Shortcourse Proc. 5th, Texas A&M University, 59-64.

Lippke, Hagen. 1968. Energy requirements of grazing animals and forage limitations. Pasture and Forage Crops Shortcourse Proc. 3rd, Texas A&M University, 7-10.

Mayton, E. L., J. C. Grimes, and H. T. Rogers. 1947. Effect of grazing management on beef gains from white clovergrass pastures in Central Alabama. J. Amer. Soc. Agron. 39:584-595.

McCormick, W. C. 1971. The management and utilization of coastal and other bermudagrasses in beef cattle programs. Pasture and Forage Crops Shortcourse Proc. 6th, Texas A&M University, 32-44.

McIlvain, E. H., and D. A. Savage. 1951. Eight year comparisons of continuous and rotational grazing on Southern Plains Experimental Range. J. Range Manage. 4:42-47.

McMeekan, C. P., and M. J. Walske. 1964. The interrelationships of grazing method and stocking rate in the efficiency of pasture utilization by dairy cattle. J. Agri. Sci. 61:147-163.

Morris, R. M. 1969. Pattern of grazing continuously grazed swards. J. Br. Grassld. Soc. 24:65-70.

N.R.C. 1970. Nutrient Requirements of Domestic Animals: Number 3, Nutrient Requirements of Dairy Cattle; Number 4, Nutrient Requirements of Beef Cattle. (4th revised ed.). National Research Council, Washington, D. C.

Oliver, W. M. 1972. Coastal bermudagrass pastures for grazing calves and yearlings in Louisiana. Louisiana Agri. Exp. Sta. Bul. 667.

Peter, K. 1929. The Hohenheim System. J. Amer. Soc. Agron. 21:628-633.

Pieper, R., C. Wayne Cook, and L. E. Harris. 1959. Effect of intensity of grazing upon nutritive content of the diet. J. Anim. Sci. 18:1031-1037.

Riewe, M. E., J. C. Smith, E. C. Holt, and J. H. Jones. 1959. Systems of grazing dallisgrass-white clover pastures. Texas Agri. Exp. Sta. PR-2115.

Riewe, M. E. 1961. Use of the relationship of stocking rate to gain of cattle in an experimental design for grazing trials. Agron. J. 53:309-313.

Riewe, M. E. 1965. An experimental design for grazing trials using the relationship of stocking rate to animal gain. Int. Grassland Cong. Proc. IX, 1507-1510.

Riewe, M. E., and Hagen Lippke. 1968. Considerations in determining the digestibility of harvested forages. Forage Quality Evaluation and Utilization, Proc. National Conference, F:1-17.

Rollins, G. H., C. S. Hoveland, and K. M. Autrey. 1963. Coastal bermuda pastures compared with other forages for dairy cows. Alabama Agri. Exp. Sta. Bul. 347.

Rouquette, Jr., F. M., and R. L. Duble. 1972. Stocking-rate effect on forage utilization and performance of cows and calves grazing Coastal bermudagrass pastures. Assn. So. Agri. Workers Proc. 69th, 62-63.

Smith, J. H. 1956. Some early advocates of rotational grazing. J. Br. Grassld. Soc. 11:199-202.

Van Soest, P. J., and L. A. Moore. 1965. New chemical methods for analysis of forages for the purpose of predicting nutritive value. Int. Grassld. Cong. Proc. IX, 783-789.

Woodman, H. E., and others. 1926-38. Nutritive value of pasture. Parts 1-12. J. Agri. Sci. 16-28.