AN ABSTRACT OF THE THESIS OF

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A scorecard method for determining range condition was developed for the tallgrass prairie of east central Kansas. It was designed for use primarily by non-professional range managers. Data was collected by the step-loop method of determining vegetation composition and density. The step-loop data was entered into both a vegetation scorecard and a soil stability scorecard to determine overall condition classification of a range site. To assure that the data obtained by the step-loop method was a reliable index to vegetation composition and density, plots were clipped by the frame-point method and estimates of basal density were made. It was shown that as the number of step-loop hits on decreaser species and increaser species increased, so did the lbs/acre dry-weight production and the basal density. This seemed to indicate that the step-loop method was a reliable index to vegetation composition and density.

Because range condition is closely related to range utilization, stubble height curves for determining the utilization of <u>Andropogon gerardi</u> Vitman., <u>A. scoparius</u> Michx., <u>Sorghastrum nutans</u> (L.) Nash., and <u>Panicum virgatum</u> L. were formulated. Since native grasses have two mature forms, those that produce seedstalks and those that do not produce seedstalks, two stubble height curves were formulated for each

species. One curve was for use during a year in which seedstalks dominate (normal or favorable year) and the other curve was for use during a year in which seedstalks do not dominate (unfavorable year).

Finally, the relative growth rates (RGR) of *A. gerardi*, A. *scoparius*, *S. nutans*, and *P. virgatum* were measured as a possible indication of density dependant growth rates between range condition classes. No significant difference in RGR was found between almost all comparisons of condition classes or between the mean total heights, mean dry weights, or leaf area ratios of the various species at the two major study sites.

TALLGRASS PRAIRIE
RANGE ASSESSMENT TECHNIQUES

A Research Thesis
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the Division of Biological Sciences
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In Partial Fulfillment
of the Requirements for the Degree
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by
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Many thanks are extended to Dr. Jim Mayo for his enthusiasm, support, ideas, instruction, and help in making this thesis a successful bit of research. Thanks also to Drs. Tom Eddy and John Ransom for serving as committee members. The help of Jo Ann (Morgan) Orth and Jay Barber will not be forgotten.

Extra special thanks to my husband, Ken, for his help (often on some very hot days!) and for his support throughout this entire project. Also, extra special thanks to my parents who taught me the values and rewards of a good education.

INTRODUCTION

Range management as a science has existed only since the turn of the century. In the late 1800's, the disaster of long-term overgrazing struck the western and southwestern rangelands of the United States forcing the initiation of research for the intelligent use of rangelands. Since its birth, range management has become a science rooted in the application of ecological principles (Stoddart, et. al, 1975).

Concern for the long-term maintenance of native grassland range was the motivation behind this thesis. The initial objective was to develop a tallgrass prairie range condition scorecard for use by both private and public range managers who may have had little or no training in range management, plant ecology, or plant taxonomy. The aim was to develop a simple, practical, fast, and easy-to-learn method for determining range condition that could be applied in a general way to the Flint Hills of east central Kansas. In addition, stubble height curves for utilization were to be formulated. As the ideas and thoughts about the research progressed, it was decided that a third feature would be added to the research. This involved the measurement of relative growth rates (Blackman and Wilson, 1951; Harper, 1977) of the key grass species at each of the four major study areas. The relative growth rate study was added to the research in hopes that it would be a reflection of differences between condition classes in regard to plant vigor and plant density.

Each of the three aspects of this research will be discussed in detail in the following pages.

The scientific names of the grasses studied follow the nomenclature of Hitchcock's Manual of Grasses of the United States (1971). The generic placement of little bluestem has been subjected to controversy over the last several years. Some believe that it should be placed in a new genus, Schizachyrium (J.W. Wilson, personal communication). Since the debate is not over, little bluestem shall be referred to as Andropogon scoparius Michx.

The research designs utilized herein are a compromise between the designs necessary for the special needs of range studies and the designs necessary to satisfy those of scientific research. The designs are based on the key species and key area concepts of range management. The key species concept involves the selection of a few important forage species from a heterogenous mixture of plants. The vigor, abundance, and use of these plants serve as the indicators for management decisions. The key area concept involves the selection of an area representative of the management unit. Key areas are important because no range can be uniformily grazed due to the arrangement of topographic features, fences, watering locations, etc. (Stoddart, et. al, 1975).

Range Condition

Maximum productivity of native tallgrass prairie rangelands is best achieved by maintaining the climax or near climax vegetation. For a variety of reasons, many native tallgrass prairie rangelands have regressed from these optimum conditions. The ability to recognize the successional stage of a particular range site (i.e. its degree of departure from the climax) is necessary for proper range management and analysis of range trend.

The current composition and productivity of the vegetation of a particular range site compared to its potential composition and productivity (i.e. climax) is referred to as range condition. Early in the history of range management, and in many instances today, range condition was determined by reconnaissance surveys, i.e. a judgment based on what the range examiner saw on a site and what the examiner knew from experience could potentially be on the site. Estimates of forage density and forage species were made and the grazing capacity for the site was determined by the use of numerical figures referred to as forage-acre factor and proper-use factor. These surveys gave accurate enough results, but they were time consuming tasks requiring detailed work by highly trained range technicians. The reconnaissance survey method did not classify and analyze the condition of the range site, but rather had the goal of determining grazing capacity. The result of all these features was the lack of consistency within this survey method (Humphrey, 1947).

Thus, the reconnaissance surveys provided no record of vegetation composition and range condition. Without such a record, it is difficult to make comparisons and monitor trends over a period of several years. Range condition classes have been established for the purpose of categorizing range sites and for keeping accurate yearly records of range condition. A variety of publications over the last several decades have dealt with the concept and field application of range condition classes. Humphrey (1949) reviews the history of the range condition method and credits Dr. L. A. Stoddart as the first range researcher to apply the method in the field.

Humphrey and Lister (1941) set forth six condition classes and the corresponding vegetation for each class. Management revisions necessary in each class were prescribed for the benefit of vegetation and soil. By 1947, Humphrey had reduced the number of range condition classes to the following five based on the per cent of potential forage production: excellent, good, fair, poor, and very poor. These classes correlated with plant succession stages where good and excellent condition classes represented the climax or near climax. In most cases, the very poor would represent the weedy successional stage with the other condition classes representing intermediate successional stages. In addition, the higher the condition class the lower the erosion hazard.

After several years of field application of the range condition method, it was determined that the following four condition classes would be sufficient (Humphrey, 1949):

Excellent	--	produces 75-100 per cent of possible forage
Good	--	produces 50-75 per cent of possible forage
Fair	--	produces 25-50 per cent of possible forage
Poor	--	produces less than 25 per cent of possible forage

The essential features of this revised and more detailed range condition method were: forage production, density, erosion, forage vigor, and litter. Forage production was the primary characteristic to measure in order to classify a site as to condition, but evaluation of the remaining features was necessary to more accurately classify a site.

Density, i.e. ground cover, was noted as an essential feature, especially in perennial grasslands where a sharp reduction in density is a severe blow to condition and composition and yet this is not always reflected in forage production measurements. Erosion potentials of soil were given more attention as a criterion in rating range condition. Condition class ratings for a particular site could be reduced one, two, or even more classes depending on the severity of erosion. Forage vigor was considered an unreliable feature of condition because of the effects of overgrazing and plant density on vigor, but at the same time it was considered a feature that could not be ignored. Litter, on the other hand, was considered a reliable feature for range condition determination. The presence of litter is a safeguard against soil erosion and also an indication that past grazing use was not excessive (Humphrey, 1949).

Thus, Humphrey's work was an early attempt to quantitatively apply the range condition method in terms of potential forage production. Later researchers (Dyksterhuis, 1949; Parker, 1954) questioned Humphrey's method because of its lack of an ecological basis.

Dyksterhuis (1949) proposed a system based on quantitative ecology which took into account both the present and potential climate, soil, and vegetation. In his work, Dyksterhuis began to distinguish factors which related to range trend from factors which related to range condition. For example, vigor was discarded as a measure of condition because it could not be measured quantitatively and because vigor of decreasers on poorer condition ranges was often better than on ranges nearer the vegetative climax.

First, sites were classified on the basis of species composition so that both current and potential range conditions could be recognized in regard to not only vegetation, but also soils. These site classifications recognized that some soils were developmental and some were climax soils as was the corresponding vegetation. Secondly, using the ecological concepts of decreasers, increasers, and invaders as proposed by Weaver and Hansen (1941), condition classes were established based on the percentages of these plant groups. Lastly, stocking rates for the various condition classes within each site were recommended (Dyksterhuis, 1949).

The work of both Humphrey and Dyksterhuis were important steps in establishing the range condition method for field application. However, the methods of both of these researchers were beyond the technical scope of the ordinary range manager. After several years of preliminary work, Kenneth Parker (1951) developed a range condition scorecard for use by the USDA Forest Service. Parker's objective was to formulate a method which was ". . .simple, practical, accurate, technically sound, and which will yield concrete measurements. . ." (Parker, 1951).

Working in the western and southwestern U. S., Parker (1951) developed the three-step method for measuring range condition and trend; the method does not measure forage production. The three-step method is summarized in the following discussion.

Step one is the establishment of permanent line transects on areas representative of the range site. The transects were permanently marked by steel posts and were 100 feet long in most instances. One-hundred observations were made at one foot intervals along a steel tape. Observations were made by using a 3/4" loop attached to a long wire rod. At each one-foot interval, the loop was dropped to the ground. Whatever material that was found within the ring was recorded as an observation, e.g. vegetation (by species), rock, litter, or bareground. If more than one plant species or other material occurred within the loop, the material or species which covered more than one-half the diameter of the loop was recorded as the hit. Perennial plants were recorded as a hit only when the loop encountered the crown of the plant. In Parker's method, the vegetation was categorized as desirables (approximately equivalent to decreasers), undesirables (approximately equivalent to invaders), and intermediates (approximately equivalent to increasers) (Parker, 1951).

Prior to its adoption as a method, the 3/4" loop was compared to other methods (Parker, 1950). The frequency-point method was tested against the 3/4" loop on fair and poor condition classes of *Agropyron spicatum* (Pursh) Scribn. and Smith. The density of *A. spicatum* by the frequency-point method was slightly higher on the poor site than on the fair site, and yet simple observation of the two sites indicated that the fair site had an obviously greater density of *A. spicatum*. The 3/4" loop method showed that the fair site had a greater density of *A. spicatum* than the poor site. The frequency-point method also resulted in greater differences between individual examiners than did the 3/4" loop method. The 3/4" loop method was also tested against a stem-count method. Once again, the alternative method resulted in greater differences between individual examiners.

Parker (1950) used the per cent density obtained by the line intercept method as an index against which to compare the per cent density obtained by the 3/4" loop method, the paced transect method, and the frequency-point method. His conclusion was that all three of these methods are good indices of the area occupied. Of the three methods, the loop method had the best correlation with r=.9719.

Thus, the 3/4" loop method was found to be an accurate compromise between a point and a plot. The loop method was sensitive to differences and changes within and between range condition classes and in over one-half the cases the differences (or error) between examiners were not significant (Parker, 1950). However, as was pointed out by Parker (1950) and others (Hutchings and Holmgren, 1959) the three-step method is not an actual measure of per cent plant area but it is a reliable index of plant area.

As a part of step one, plant vigor was measured by recording the maximum leaf length of ten randomly selected important desirable species.

When the 100 observations had been recorded, the data was summarized as to number of hits on bareground, rock, litter, and vegetation (by species). The number of hits on desirable and intermediate species was termed the forage density index and 100 minus the number of hits on bareground was termed the ground cover index (Parker, 1951).

Step two was the summarization of all the transects on a particular range site and the classification of the site as to condition. The classification was done by means of a scorecard. Forage density index, composition, and vigor of desirable species were each given a numerical point rating based on the transect summaries. The total points were used to categorize the vegetation as to excellent, good, fair, poor, or very poor. The soil condition was rated on a separate scorecard based on the ground cover index and the current erosion. Soil was also classified as to excellent, good, fair, poor, and very poor (Parker, 1951).

Step three was the photographing of the transect. A general view photograph of the transect was taken and a closeup of a 3 X 3 plot was taken. These provided a visual record. The photographs were always taken from the same vantage point (Parker, 1951).

The three-step method as developed by the Forest Service was designed for application in the field as chiefly a one-man job. In some instances, a two-man crew would be more convenient. The three-step method also had the advantage that it could be done almost anytime of the year. The only restriction was that the plants be large enough so that they could be recognized. Clipping, on the other hand, could only be done at the end of the growing season (Parker, 1950, 1951).

Weaver and Hansen (1941) divided prairie grasses and forbs into three natural groups based on their responses to continued grazing, i.e. those that decrease under heavy grazing (decreasers), those that increase under heavy grazing (increasers), and those weedy plants that are not ordinarily found in climax prairie (invaders). Using these three groups of plants as indices, Voight and Weaver (1951) studied the species composition and basal area of four range condition classes in the Lincoln, Nebraska, area.

Excellent, good, fair, and poor range conditions were described in regard to the percentages of decreasers, increasers, and invaders. Decreaser grasses accounted for 66.6 per cent of all the vegetation in excellent pastures and only 1.9 per cent in the poor pastures. Increasers ranged from 30.5 per cent in excellent pastures to 31.7 per cent in poor pastures. Invaders made up 2.1 per cent of excellent pastures and 47.5 per cent of poor pastures (Voight and Weaver, 1951).

Evans and Love (1957) presented a sampling method to determine botanical composition and herbaceous cover. Their step-point method was found to be of valid use in botanical inventories in relation to environmental factors, in agricultural situations, and in range research.

A single pin was used to inventory botanical composition in the step-point method. The pin was placed at the toe of the examiner's boot and lowered to the ground; the foot was held at a 30° angle. The plant species hit by the pin or the plant species nearest the pin was recorded. Only the vegetation was recorded. Bareground, litter, and rock were not recorded. Evans and Love used predetermined sampling designs in establishing transects.

The step-point method was combined with an estimation method for determining ground cover so that the number of step-points could be reduced while still yielding a statistically valid sample. A square-foot frame was used and the ground cover within the frame was estimated to the nearest ten per cent. The locations of the frame-points were incorporated into the sampling design at specified step-points. The frame was placed so that its side was centered on the toe of the examiner's boot. Ten frame-points were used with 100 step-points.

When compared to the point-frame method, the step-points yielded similar data in regard to ground cover and botanical composition. The step-point method took approximately 30 minutes; the point-frame method required 3-4 hours (Evans and Love, 1957).

In this study, a combination and modification of the methods of Parker (1950, 1951) and Evans and Love (1957) were chosen as the method for determining range condition. It was felt that such a combination would provide a simple, practical, fast, and easy-to-learn method for determining range condition. The methods of other researchers were rejected because: (1) reconnaissance surveys provide no record of vegetation composition and range condition and require a high degree of training in order to obtain accurate results; (2) Humphrey's (1949) method relies on the often inaccurate forage production measurements rather than the more accurate ecological measurements; and (3) Dyksterhuis' (1949) method is beyond the technical scope of the ordinary range manager.

Utilization

Range managers have long understood that proper stocking rates are necessary to maintain or improve range condition. The rate of stocking determines the degree of utilization (i.e. forage removal) of key forage species; in turn the pressures placed on key species play a major role in upward or downward trend of range condition. Thus, it is necessary to be able to determine if utilization of key species is at satisfactory or unsatisfactory levels.

A number of methods for determining the degree of utilization of key species have been devised. Heady (1949) summarizes many of these methods into two categories: estimate methods and measured methods. The estimate methods to be reviewed included a reconnaissance of an entire range area, an ocular estimate of small plots, and a utilization estimate based on comparison with standardized photographs for utilization. Measured methods reviewed by Heady (1949) included a comparison of the total weight of a grazed plant with that of an ungrazed plant as well as methods where the height of grazed plants was compared to the height of ungrazed plants to determine utilization. Heady (1949) also reviewed the method of Stoddart (1935) where the number of grazed and ungrazed stems within a plot are counted and a percentage of utilization is calculated. Lastly, Heady (1949) reviewed Lommasson and Jensen's (1938) method that considered both height removal and weight removal.

Heady (1950) recognized that no matter what method for determining utilization is used, it must be one in which a record can be kept for future reference by possibly different range managers. This is necessary for monitoring trends in range condition. After reviewing these methods for determining utilization, Heady (1949) concludes "Since percentage weight removal seems to be one of the best measures of forage use, and no direct measure of the forage eaten by livestock is available, the best possibilities for a research method seems to be in the conversion of stubble height to weight removed."

Lommasson and Jensen (1938) were the first to recognize that neither height nor weight alone could be used as a reliable index of utilization. This they attributed to the characteristic that there is greater biomass in the lowermost portion of a grass plant than in the uppermost portion of a grass plant. It was, therefore, concluded that the relationship between volume and height must be considered when determining the degree of utilization of range grasses. The result of these conclusions was the formulation, by species, of utilization tables and scales.

Working in Arizona and New Mexico, Crafts (1938) prepared height-volume charts for determining utilization of major southwestern range grasses, e.g. Bouteloua gracilis (blue grama). Mature grasses were clipped into 1- or 2-inch sections from the tallest stalk to the ground. The dried sections were weighed and a relationship between the per cent of height and the per cent of weight was determined. When this relationship was expressed graphically, the resulting curve for each of the grasses studied was a parabola, thereby illustrating that the greatest biomass was in the lowermost portion of the grass plant (Crafts, 1938).

Reid and Pickford (1941) also recognized this characteristic distribution of forage in grasses and the necessity of preparing height-weight curves for each species in order to measure utilization. Working with Festuca viridula, Reid and Pickford (1941) also developed height-weight curves. Their curves differed from those of the earlier workers (Crafts, 1938; Lommasson and Jensen, 1938) in that they plotted per cent of weight removed vs. height of stubble in inches, rather than expressing the height as a percentage. This method was referred to as the stubble height method and the shape of the curve was also similar to a parabola.

The characteristic distribution of forage in grasses has been termed a conical form of growth (Lommasson and Jensen, 1943; Heady, 1950; Stoddart et. al., 1975). Adapting the work of Heady (1950), Stoddart et. al. (1975) illustrated that the distribution of forage throughout the height of a grass plant was conical by plotting the per cent of forage vs. the plant height of Agropyron spicatum and Festuca idahoensis. The shorter plants had a more conical form while the taller plants had a more cylindrical form (Heady, 1950). Graphic relationships such as these show that if one-half the height of a plant was removed, it did not necessarily remove one-half of the available forage.

Lommasson and Jensen (1943) developed similar tables to those of Crafts (1938). These authors worked in the states of Montana, Idaho, and Wyoming and prepared tables for grasses such as Agropyron spicatum (bluebunch wheatgrass).

Plants were dug and the vegetation bound with string. The vegetation was clipped at regular intervals. Each interval was weighed and the percentage of weight by interval was calculated. Each plant was categorized into a height class and the percentage of weight utilized per interval for each height class was tabulated against stubble height. This method recognized that individual plants of the same species varied in height. Lommasson and Jensen (1943) showed that A. spicatum had height classes ranging from 10 inches to 32 inches with varying rates of utilization per interval for each of the height classes. They recognized that most grasses had two forms at maturity -- those plants that produce seedstalks and those plants that did not produce seedstalks.

In this study, stubble height curves were formulated because of the interrelationship of range condition and range utilization. Range condition usually changes because of the intensity of utilization. In keeping with this study's objectives of simple, practical, fast, and easy-to-learn, generalized stubble height curves for the tallgrass prairie for application by non-professional managers were formulated. The stubble height curves were used to determine the average per cent utilization, the per cent of plants grazed, and the per cent of plants grazed 50 % or more for a key species. All three of these factors determine whether or not a key area is being utilized at satisfactory levels.

Relative Growth Rates

Relative growth rates (RGR) have been measured on a variety of species, both plant and animal. Many of these studies have been in highly controlled laboratory situations. In this study of rangelands, the measurement of RGR was applied in an uncontrolled field situation.

RGR is defined by the following equation (Blackman and Wilson, 1951; Harper, 1977):

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \text{ expressed as g/g/day.}$$

In addition, RGR = NAR X LAR where NAR is the net assimilation rate and LAR is the leaf area ratio. NAR and LAR are further defined as:

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1} \text{ expressed as g/cm}^2\text{/day.}$$

$$LAR = \frac{L_2 - L_1}{W_2 - W_1} \times \frac{\log_e W_2 - \log_e W_1}{\log_e L_2 - \log_e L_1} \text{ expressed as cm}^2\text{/g.}$$

In all three equations, W is the plant dry weight, t is the time, and L is the photosynthetic area.

RGR is an expression of how a plant grows in regard to its increase in weight over a period of time. For example, just because plant A is 10 inches tall and plant B is 20 inches tall, it does not necessarily mean that plant B has twice the growth rate of plant A. In fact, both plants may be growing at about the same rate relative to their increase in weight over a certain time period. NAR is a measurement of the difference between photosynthesis and respiration. LAR measures the amount of photosynthetic area exposed by a plant in relation to the weight of the plant.

Blackman and Wilson (1951) used RGR, NAR, and LAR to compare plant species of shady habitats with plant species of sunny habitats. The research was conducted in both field and lab situations. A curvilinear relationship was found to exist between light intensity and relative growth rate.

Clatworthy and Harper (1962) used RGR as a parameter to measure the vigor of a species in pure and mixed cultures of _Lemna_ spp. and

Salvinia natans. The growth rates were always higher for a species when it was grown alone than when it was grown with any of the other species.

Because of the observations of Clatworthy and Harper (1962) it was thought that RGR measurements might prove valuable on rangelands where the focus of study is a heterogenous mixture of range grasses. Pielou (1974) stated that the growth rate of individual organisms and populations is density dependent. Since changes in range condition are often accompanied by changes in plant density as well as plant vigor, it was felt that differences in relative growth rates might occur between condition classes.

DESCRIPTION OF STUDY AREA

Condition class studies and relative growth rate studies were conducted in both Osage and Chase Counties in Kansas. Osage County is found in the Osage Cuestas subdivision of the Osage Plains physiographic region, while Chase County is in the Flint Hills Upland subdivision of the Osage Plains (Schoewe, 1949; Küchler, 1974). The boundaries of these two physiographic regions and the location of the two major study sites within them are shown in Figure 1.

The studies in Osage County were conducted on property owned by the U. S. Army Corps of Engineers, Kansas City District, at Melvern Lake. The first of these study areas (hereafter referred to as Melvern site 1) is Corps of Engineers tract 101, T18S, R15E, S15NW1/4. Figure 2 is a photograph of this site. This tract was purchased by the U. S. government in January 1968. The previous owner had uncontrolled access to the land until November 1968.

From 1969 to 1972, Melvern site 1 was leased to private individuals for grazing. Haying leases were issued on this site from 1973 to 1982. The area was subjected to a controlled spring burn in 1981 and 1982. Prior to that time, regular controlled burns occurred. In 1983, the area was not burned and not hayed. In 1979, the management of 395 acres of native prairie was leased by the Corps of Engineers to the Grassland Heritage Foundation of Shawnee Mission, Kansas. Melvern site 1 is on the extreme western end of this management lease (Hall, 1984).

The second study area at Melvern Lake (hereafter referred to as Melvern site 2) is Corps of Engineers tract 100, T18S, R15E, S9SE1/4. The photograph in Figure 3 is Melvern site 2. This tract was purchased


Flint Hills Uplands
• Mayo Sites

Figure 1. Location of the major study areas within the physiographic regions of Kansas (after Schoewe, 1949).

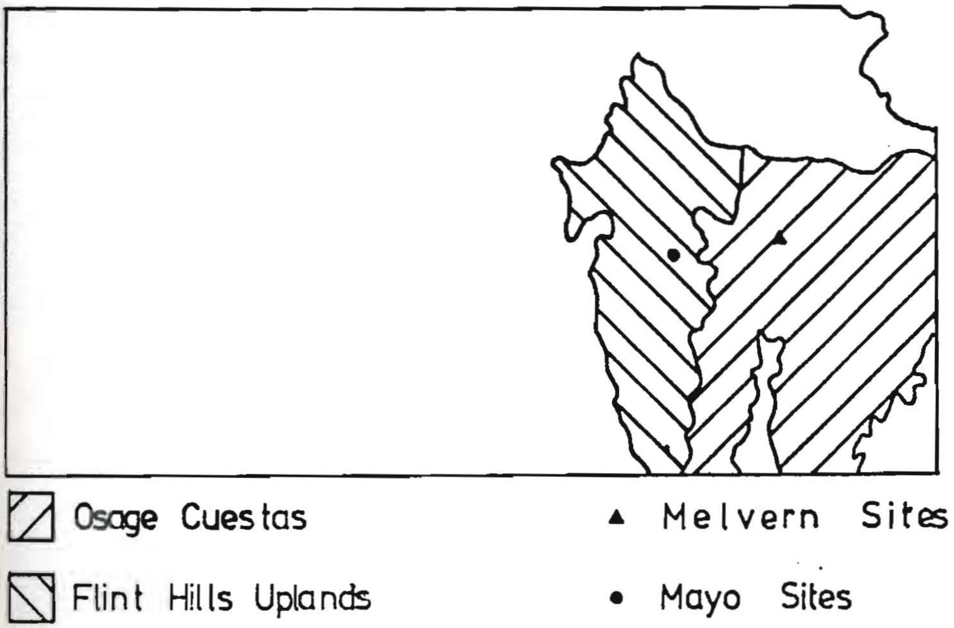

▨ Osage Cuestas
▨ Flint Hills Uplands
▲ Melvern Sites
● Mayo Sites

Figure 2. Melvern site 1 is shown in the foreground. The corner hedge fence post was used as a permanent landmark for the range condition and relative growth rate studies.

Figure 3. Melvern site 2 is shown in the foreground. The large sumac colony is in the center of this site. Melvern site 1 can be seen in the background on the right-hand side of the photograph.

by the U. S. Government in May 1968. The previous owner grazed the site until September 1968. At that time both cattle and fences were removed. Since this study area is at the entrance to a camping and recreation area, it has been neither grazed nor hayed since September 1968. The last controlled burn on the site was April 1981 (Hall, 1984). Currently the site supports native tallgrasses and a host of woody invaders.

Figure 4 is a portion of the soil survey map for Osage County showing the soil types of Melvern sites 1 and 2. Both sites are near the entrance to the Arrow Rock Public Use Area on the south side of Melvern Lake. Melvern site 1 is an Eram-Lula soil type complex and a Loamy Upland range site. Melvern site 2 is a Clareson-Eram soil type complex and a Shallow Falts-Loamy Upland range site (USDA, unpublished).

Table 1 is a summary of the 1983 data for temperature and precipitation at Melvern Lake for the duration of the study. Weather data for the site for the last several years was not readily available.

In Chase County, the studies were conducted on property owned by J. Mayo. The first of these sites (hereafter referred to as Mayo site 1) is T19, R6E, S12NW1/4. This site is located on a ridge top. The second site (hereafter referred to as Mayo site 2) is T19, R6E, S12SW1/4 and is located to the south of Mayo site 1. Figures 5 and 6 are photographs of these two sites.

Both Mayo sites have been used as part of a cow-calf operation for approximately the past 15 years. Prior to that time, these sites were primarily utilized in a steer operation. These sites are regularly subjected to controlled spring burns. In 1983, both sites were burned on April 24, but neither site carried the fire very well.

Figure 4. Soil types of Melvern sites 1 and 2. Cm = Clareson-Eram soil type complex. Eo = Eram-Lula soil type complex. (USDA, unpublished)

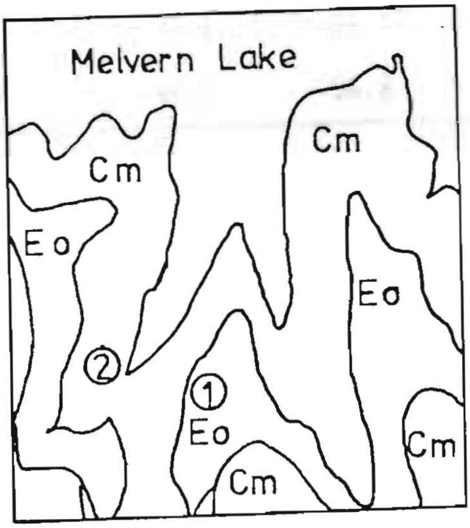

Melvern Lake
Cm
Cm
Eo
Eo
②
①
Eo
Cm
Cm

Table 1. Temperature and precipitation data for May through October, 1983, at Melvern Lake (Shideler, 1984).

MONTH	TEMPERATURE (°F) Average Maximum	Average Minimum	Average	PRECIPITATION (in.) Total	Greatest Day	Date
May	70.7	47.6	59.2	5.85	2.10	28
June	80.8	59.3	70.1	6.61	1.58	19
July	91.2	66.7	79.0	1.71	1.71	4
August	97.3	68.5	82.9	0.32	0.11	30
September	83.7	55.1	69.4	2.32	0.86	20
October	67.0	46.6	56.8	5.11	1.37	19

Figure 5. Mayo site 1 is shown in the foreground.

Figure 6. Mayo site 2 is shown in the foreground. The Kentucky coffee tree in the center served as the permanent landmark at this site.

Figure 7 is a portion of the soil survey map for Chase County showing the soil types of Mayo sites 1 and 2. Both sites are a Clime-Sogn soil type complex and a Limy Upland-Shallow Limy range site (Neill, 1974).

Table 2 is a summary of the precipitation data for May through September, 1983, at Elmdale, Kansas. This was the weather station nearest the study area. No other data was available.

A third study area was located in Lyon County adjacent to the northwest corner of Ross Natural History Reservation on the Jack Lefler property. This area was utilized in the range condition class study only. The site (hereafter referred to as the Lefler site) is utilized in steer operations and is regularly burned. The portion of the Lefler site studied is a Clime-Sogn soil type complex and a Limy Upland-Shallow Limy range site (Neill, 1981).

Figure 7. Soil types of Mayo sites 1 and 2. Cs = Clime-Sogn soil type complex. Dw = Dwight soil type. Tc = Tully soil type. Ls = Ladysmith soil type. (Neill, 1974)

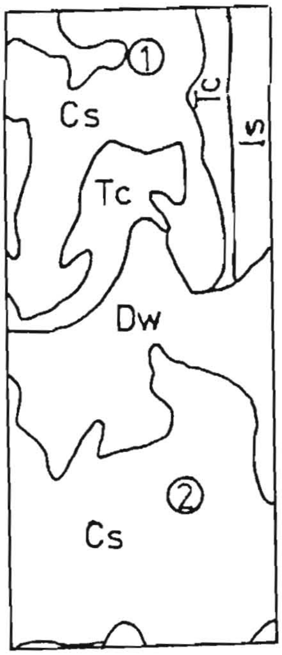

①
Cs
Tc
Tc
Is
Dw
②
Cs

Table 2. Precipitation data for May through September, 1983, at Elmdale, Kansas (Shideler, 1984).

MONTH	PRECIPITATION (in.) Total	Greatest Day	Date
May	4.12	1.85	21
June	4.46	1.85	3
July	1.25	1.05	4
August	1.63	0.80	21
September	3.13	0.90	20

MATERIALS AND METHODS

Range Condition

Studies of range condition were conducted in September, October, and November, 1983, at both Melvern sites, both Mayo sites, and at the Lefler site. These sites were selected because of their accessibility and because of their apparent differences in condition. It was not possible at the beginning of the study to precisely determine what the condition of each site was since the goal of the study was to determine just that. Thus, these sites were selected in hopes that by the conclusion of the study they would prove to represent a variety of condition classes. The objective, therefore, was to classify each site as excellent, good, fair, or poor based on the following criteria: (1) soil stability, (2) species composition, and (3) per cent basal ground cover. Since these are quantitative measurements, assessment of range condition and trend due to environmental conditions and management practices would be possible (Cook, 1962).

The sampling method used was a combination of the step-point method of Evans and Love (1957) and the 3/4" loop method of Parker (1950, 1951). A 3/4" diameter loop attached to a metal rod was the basic sampling tool. In addition, a 1/4 m^2 plot frame was utilized for the ocular estimate and clipping portion of the study. This method was known as the step-loop/frame-point method.

As was prescribed by Evans and Love (1957), each transect consisted of 100 step-loops with ten frame-points. A table of random numbers (Freese, 1962) was used to select the location of the ten frame-points within the 100 step-points. The location of each 100 step-point transect was determined chiefly by the contour of the soil-type as shown on the Soil Conservation Service soil type map (Neill, 1974, 1981; USDA, unpublished). Features such as fence lines and hedge rows were avoided. This is the manner in which a range technician would select key areas.

Data was collected in the following manner. The 100 step-loops consisted of 100 paces. At the completion of each pace the 3/4" loop was placed at the toe of the examiner's boot as the foot was held at a 30° angle from the ground. (This procedure is the same as Evans and Love (1957) who used pins rather than loops.) The loop was lowered to the ground, perpundicular to the examiner's foot. The sample was considered a hit on vegetation if at least one-half the diameter of the loop was covered by the crown of the plant. The species hit was recorded. Hits such as rock, bareground, and litter also occurred (Parker, 1950, 1951).

When a step-loop was sampled that had also been randomly selected for sampling by the frame-point method, the following procedure was followed. After recording the hit of the loop, the 1/4 m^2 frame was placed at the toe of the examiner's boot so that the side of the frame nearest the examiner was centered on the boot. The per cent of basal area within the frame covered by vegetation, litter, rock, and bareground was estimated by sight and recorded. All vegetation within the frame greater than one-inch in height was clipped at ground level and the plants were separated into individual, labelled, brown paper bags. Litter and vegetation from the previous season was not bagged. When working on grazed sites, care was taken to assure that the frame-points included only ungrazed vegetation since the object was to measure total production.

The bagged samples were taken to the laboratory and oven-dried at 100°F for at least 48 hours. The samples were weighed on a Mettler H54AR balance to obtain oven-dry weight in g/1/4 m^2.

The weight of each species for all ten frame-points of each transect was totalled to obtain g/2.5 m^2. These weights were converted to pounds per acre by the steps shown below. Conversion factors used in these calculations were obtained from the Handbook of Chemistry and Physics (Weast, 1968).

Step 1.

$$g/2.5\ m^2 \div 2.5 = g/m^2$$

Step 2.

$$g/m^2 \times 4046.8564\ m^2/acre = g/acre$$

Step 3.

$$g/acre \div 1000\ g/kg = kg/acre$$

Step 4.

$$kg/acre \times 2.2046\ lbs/kg = lbs/acre$$

The production in pounds per acre for each transect was listed by species and the total production for each transect was figured. The per cent of total production for each species was also calculated. Total pounds of production and the per cent of total production for the categories of decreasers, increasers, and invaders was also calculated.

The step-loop hits were summarized by species and by the categories of decreasers, increasers, invaders, rock, litter, and bareground.

Data from two transects were collected at each of the five sites. The mean pounds of production, mean per cent of production, and mean number of step-loop hits by species were calculated for each site from the data of the two transects. Each transect took approximately 4-5 hours to complete.

The data obtained in the range condition studies and publications of previous researchers were utilized to formulate a range condition scorecard similar to that of Parker (1950, 1951). It was necessary to formulate two scorecards, i.e. a vegetation scorecard and a soil stability scorecard. The record sheet for recording data, the taxa list, the vegetation scorecard and the soil stability scorecard are shown in Figures 8 through 11. The taxa list (Figure 9) is a list of some of the most commonly encountered plants in the tallgrass prairie; many other species will also occur.

The vegetation scorecard that Parker (1950, 1951) developed consisted of three portions: forage density index, composition, and vigor of desirable species. Forage density index and composition were used in the tallgrass prairie scorecard but the vigor of desirable species was not. Humphrey (1949) considered vigor an unreliable indication of condition due to the effects of environmental factors and plant density on vigor. Dyksterhuis (1949) discarded vigor as a measure of condition because it could not be measured quantitatively. Parker (1954) recognized these objections but discarded them because the method he devised for measuring vigor (Parker, 1951) could overcome both objections. In his method, leaf lengths were measured as an indication of vigor and a new set of criteria for the vigor of these leaf lengths was formulated each year to account for seasonal environmental influences.

Although Parker's (1951) vigor measurements seem to be valid, they were discarded from the tallgrass prairie scorecard because of the necessity of formulating new vigor criteria each year. The scorecard is designed chiefly for use by non-professional range managers and it is

Figure 8. Form for recording data obtained by the step-loop method and for summarizing the condition class analysis.

RECORD OF STEP LOOPS
AND
CONDITION CLASS ANALYSIS

Date ______________________ Examiner ______________________

Transect No. ______________________ Location ______________________

Soil Type ______________________ SCS Range Site ______________________

DECREASERS

INCREASERS

INVADERS

ROCK

LITTER

BAREGROUND

Bareground	____
Rock	____
Litter	____
Plant Density Index	____
Total	100

Forage Density Index ____
(No. of decreasers + increasers)

Ground Cover Index ____
(100 - no. hits on bareground)

CONDITION CLASSIFICATION

VEGETATION:

Forage Density Index	____
Composition	____
Total	____

Condition Class ______________________

SOIL:

Erosion Hazard Index	____
Current Erosion	____
Total	____

Condition Class ______________________

OVERALL RANGE CONDITION: ______________________

NOTES:

Figure 9. Taxa list for tallgrass prairie scorecard.

TAXA LIST

DECREASERS

Symbol	Scientific Name	Common Name
Ange	Andropogon gerardi	Big bluestem
Ansc	Andropogon scoparius	Little bluestem
Pavi	Panicum virgatum	Switch grass
Sonu	Sorghastrum nutans	Indian grass
Spas	Sporobolus asper	Tall dropseed
Trda	Tripsacum dactyloides	Eastern gamagrass
Kocr	Koeleria cristata	June grass
Sppe	Spartina pectinata	Prairie cordgrass
ELY	Elymus spp.	Wild-rye
Amca	Amorpha canescens	Lead plant
Deil	Desmanthus illinoensis	Illinois bundleflower
PET	Petalostemon spp.	Prairie clovers
ROS	Rosa spp.	Rose
Baau	Baptisia australis	Wild indigo

INCREASER

Symbol	Scientific Name	Common Name
Popr	Poa pratensis	Kentucky bluegrass
Bocu	Bouteloua curtipendula	Side-oats grama
Bogr	Bouteloua gracilis	Blue grama
Bohi	Bouteloua hirsuta	Hairy grama
Buda	Buchloe dactyloides	Buffalo grass
Pasc	Panicum scribnerianum	Scribner's panicum
Agsm	Agropyron smithii	Western wheatgrass
Ersp	Eragrostis spectabilis	Purple lovegrass
CAR	Carex spp.	Sedges
Acmi	Achillea millefolium	Yarrow
Arlu	Artemisia ludoviciana	Sage
ERI	Erigeron spp.	Fleabane
Sila	Silphium laciniatum	Compassplant
Veba	Vernonia baldwini	Baldwin's ironweed

INVADERS

Symbol	Scientific Name	Common Name
ARI	Aristida spp.	Three-awn
BRO	Bromus spp.	Brome
Chve	Chloris verticillata	Windmill grass
DIG	Digitaria spp.	Crabgrass
Paca	Panicum capillare	Witchgrass
Spcr	Sporobolus cryptandrus	Sand dropseed
AMB	Ambrosia spp.	Ragweed
Vest	Verbena stricta	Vervain
Xadr	Xanthocephalum dracunculoides	Annual Broomweed
Juvi	Juniperus virginiana	Red cedar
Syor	Symphoricarpos orbiculatus	Buckbrush
Rhgl	Rhus glabra	Smooth sumac
Codr	Cornus drummondii	Rough-leaved dogwood
PRU	Prunus spp.	Plum
Gltr	Gleditisia triacanthos	Honey Locust

Figure 10. Tallgrass Prairie Vegetation Scorecard for Upland Sites.

TALLGRASS PRAIRIE VEGETATION SCORECARD FOR UPLAND SITES

Forage Density Index

This is the total number of hits on decreasers and increasers. Exclude the number of hits on invaders. Rate from 0 to 8.

61 or more hits = 7-8 (Excellent)
41 to 60 hits = 5-6 (Good)
21 to 40 hits = 3-4 (Fair)
20 or less hits = 0-2 (Poor)

Composition

Rate from 0 to 8 based on the following characteristics.

Desirable perennial grasses dominate, especially big bluestem and little bluestem. Desirable prairie forbs e.g. Illinois bundleflower, leadplant, New Jersey tea, and compass plant are found abundantly among the grasses.

7-8 (Excellent)

Desirable perennial grasses still abundant, but are on the decline. Only a moderate number of desirable prairie forbs remain. Invader forbs and weeds e.g. western yarrow, western ragweed, annual broomweed, snow-on-the-mountain, and ironweed occur occassionally.

5-6 (Good)

Desirable perennial grasses largely replaced and occur only in localized bunches. Dropseed, three-awn, and annual brome increase in abundance. Shorter grasses, e.g. blue grama and buffalo grass may also increase. Invader forbs and weeds common. On some sites, woody invaders e.g. red cedar, sumac, buckbrush, honey locust, etc. occur with an understory of desirable perennial grasses. Burning potential on these woody sites is still good.

3-4 (Fair)

Desirable perennial grasses and forbs only relics. Invaders and weeds are much or most of the vegetation. A large variety of annual and weedy grasses (e.g. windmill grass, crabgrass, witchgrass, and foxtails) also dominate. On some sites, woody invaders e.g. red cedar, sumac, buckbrush, honey locust, etc., occur with <u>no</u> understory of desirable perennial grasses. Burning potential on these woody sites is gone.

0-2 (Poor)

Classification of Vegetation Score

Total the points assigned for forage density index and composition to determine the vegetation conditon based on the scale below.

Excellent = 13-16
Good = 10-12
Fair = 6-9
Poor = 0-5

Figure 11. Tallgrass Prairie Soil Stability Scorecard for Upland Sites.

TALLGRASS PRAIRIE
SOIL STABILITY SCORECARD
FOR UPLAND SITES

Erosion Hazard Index

Based on the ground cover index (100 - the number of hits on bareground). Rate from 0-8 points.

Ground Cover Index		Rating
93-100	no erosion hazard	7-8
76- 92	slight erosion hazard	5-6
50- 75	moderate erosion hazard	3-4
49 or less	severe erosion hazard	0-2

Current Erosion (Rate from 0-15)

No evidence of soil movement; plant and litter cover effective in protecting soil; runoff is clear; no piling up of litter behind plants; gullies if present completely stabilized and healed. 13-15

Soil movement slight; but difficult to recognize; may be evidence of past accelerated erosion but now fairly well stabilized; plant and litter cover appears effective in protecting soil; plant pedestals few or sloping sided and stabilized; rills, alluvial deposits and gullies if present are nearly healed; some litter may be dammed against vegetation, forming miniature alluvial fans; trampling displacement slight, no noticeable compaction; rodent activity normal. 10-12

Soil movement moderate; definitely discernible, may be accelerated in spots and stable elsewhere; plant cover and litter effectiveness doubtful in protecting soil; considerable bare soil; many plant pedestals, some steep sided; erosion pavement forming with occasional exposed pebbles; occasional alluvial deposits and rills present; gullies if present, not raw; trampling displacement and compaction noticeable, but not excessive; rodent activity may not be noticeable; runoff murky. 7-9

Soil movement advanced; plant cover and litter definitely not effective in preventing soil movement; considerable bare soil; steep sided plant pedestals numerous; stony soils with well formed erosion pavement; rills, and alluvial deposits common; gullies, if present, with raw sides; trampling displacement and compaction common; rodent activity may be excessive; runoff muddy. 4-6

Figure 11. (Continued)

Soil movement severe; plant cover inadequate, litter lacking; subsoils exposed in many places; pedestals of stronger perennials almost completely eroded away; erosion pavement complete on stony soils; rills and alluvial deposits numerous; gullies, if present, with raw sides; rodent activity generally severe; runoff from summer storms flashy and muddy often causing miniature mud flows. 0-3

Classification of Soil Score

Total the points assigned for erosion hazard index and current erosion to determine the soil stability condition based on the scale below.

Excellent	20-23
Good	15-19
Fair	10-14
Poor	0- 9

Classification of Overall Range Condition

The condition class rating which is lowest is the overall range condition class. For example, if the vegetation condition is excellent and the soil stability condition is good, then the overall range condition class is good.

felt that a valid scorecard can be formulated without the difficult problems presented by vigor measurements.

Forage density index is the number of hits on decreasers plus increasers. It was assumed that Melvern site 1 is in excellent condition due to its management history (see "Description of Study Area") and due to the overall nature of its vegetation composition. Thus, Melvern site 1 was used as the reference point from which to establish the four categories for the forage density index on the vegetation scorecard.

According to Humphrey (1949) and Neill (1974), a range is in excellent condition if it has 76-100 per cent of the climax vegetation; is in good condition if it has 51-75 per cent of the climax vegetation; is in fair condition if it has 26-50 per cent of the climax vegetation; and is in poor condition if it has less than 25 per cent of the climax vegetation.

At Melvern site 1, 81 of the step-loop hits were on decreasers and increasers with the remaining 19 hits occurring on litter. There were no hits on invaders, rock, or bareground. For the purpose of establishing the forage density index, the 81 actual hits will be rounded to 80. Based on the criteria of Humphrey (1949) and Neill (1974), let 80 hits equal 100 per cent of the climax vegetation and 61 hits equal 76 per cent of the climax vegetation (i.e. 76 % of 80). This would represent the excellent category for forage density (i.e. 61 or more hits). Good, fair, and poor conditions for the forage density index were derived in a similar manner.

The composition portion of the vegetation scorecard was also designed after the format of Parker (1950, 1951). The criteria established for each of the composition categories were based on field observations and is supported by Voight and Weaver's (1951) work on these condition classes in the tallgrass prairie of eastern Nebraska.

The final portion of the vegetation scorecard is the overall classification of the vegetation score. To determine the vegetation condition, the points assigned for forage density index are added to the points for composition. The total score is used to determine vegetation condition.

The soil stability scorecard was constructed after the design of Parker (1951). It consists of two major portions, the erosion hazard index and the current erosion.

Erosion hazard index is a scale based on the ground cover index that was determined in the step-loop method. The erosion hazard index used in the tallgrass prairie soil stability scorecard is based on the guidelines proposed by Reid and Love (1951).

Criteria for the current erosion ratings were taken directly from Parker (1951). Although these criteria were established for southwestern ranges, it is felt that they are applicable to a wide variety of ranges, including the tallgrass prairie.

Soil stability is classified as to overall condition by totalling the points for erosion hazard index and current erosion. Overall range condition is the lower rating of vegetation condition and soil stability condition.

Utilization

Stubble height curves were prepared in both fall 1982 and fall 1983 for the four major range grasses of the tallgrass prairie: *Andropogon gerardi* Vitman., *A. scoparius* Michx., *Sorghastrum nutans* (L.) Nash., and *Panicum virgatum* L.

In 1982, samples were collected on September 29 and October 5 and 30 at Melvern site 1. Maturation of all species was essentially complete by September 29, so the different collection dates do not reflect different growth stages.

In 1983, all samples were collected on October 12. Again maturation was complete and growth had essentially ceased by this time. These collections were also made at Melvern site 1.

Since individual genets are difficult to distinguish in perennial grasses (Harper, 1977) it was necessary at the onset of this study to specify distinguishable sampling units. The species involved in this study tend to grow in bunches; each one of these bunches was arbitrarily designated a colony for the purpose of collecting samples, although each bunch in reality probably represents only a small portion of an original zygote.

The colonies to be collected were located randomly by use of an X, Y coordinate system. A landmark served as the permanent 0, 0 point and in this case was a corner hedge fence post. Values for X and Y were selected from a table of random numbers (Freese, 1962). The species to correspond with each X, Y coordinate was randomly selected by drawing. The X, Y coordinate was located by pacing-off the randomly selected values from the permanent 0, 0 point. The colony of the corresponding species that was nearest the X, Y coordinate was collected in this manner in both 1982 and 1983.

The collection method for each colony was similar to that of Lommasson and Jensen (1943). These authors dug the plants, bound the vegetation with string, and clipped the plants at regular intervals. In this study, the colony was weeded of any stray species and/or litter.

The vegetation was partially bound with string by holding the leaves in an upright position against the stems and culms. The entire colony was clipped at ground level and further secured with string. The result was a neat bundle of grass. Clipping rather than digging the plants prevented severe disturbance of the site.

The bundled colonies were taken into the laboratory for sectioning. In 1982 the bundles were cut into 15 cm sections beginning at the bottom of the bundle. The plants were considerably shorter in 1983 so these bundles were cut into 10 cm sections beginning at the bottom of the bundle. Each section was placed in an individual brown paper bag and labelled as to species, colony (bundle) number, and section of height. The bags were placed in a drying oven for at least 24 hours at approximately 100°F.

The dried sections were weighted on a Mettler H54AR balance to obtain oven-dry weights. The per cent of total volume (dry weight) for each section of each colony was calculated. These values for each of the five colonies of each species were averaged together by section height to obtain a mean per cent of volume (dry weight) by section. Variance, standard error of the mean, and 95 per cent confidence intervals were calculated for each section of each species. Mean per cent of dry weight remaining was plotted against actual height remaining in cm for each species for both 1982 and 1983 to achieve the stubble height curves. In addition, per cent of forage by section was plotted against height in cm to show the growth form of each species.

Relative Growth Rates

Relative growth rate (RGR) studies were initiated at Melvern sites 1 and 2 on May 10, 1983, and were conducted at approximately two-week intervals until October 9, 1983. RGR studies at Mayo sites 1 and 2 began on May 19, 1983, and were conducted at approximately two-week intervals until October 1, 1983.

Relative growth rates were measured for the four major tallgrass prairie grass species (*A. gerardi*, *A. scoparius*, *S. nutans*, and *P. virgatum*) at both Melvern sites and at both Mayo sites. Five plants of each species were randomly collected at each site on every collection date throughout the course of the study period.

The plants to be collected were located randomly by use of an X, Y coordinate system. A landmark served as the permanent 0, 0 point. At Melvern site 1 the landmark was a corner hedge fencepost; at Melvern site 2 it was a signpost; at Mayo site 1 it was a rock outcrop; and at Mayo site 2 it was a Kentucky coffee tree. Values for X and Y were selected from a table of random numbers (Freese, 1962). The species to correspond with each X, Y coordinate was randomly selected by drawing.

The X, Y coordinate was located by pacing-off the randomly selected values from the permanent 0, 0 point. The five individual plants of the specified species nearest the X, Y coordinate were collected. If more than five plants were near the X, Y coordinate, the five tallest plants were collected. Plants which had been grazed or predated upon were avoided whenever possible.

The plants were collected and measured one at a time. First, the total height of each plant was measured and recorded. Total height measurements were done by holding a meter stick in a vertical position next to the plant. The leaves of the plant were held in an upright position against the stems or culms and the height of the uppermost leaf or inflorescence was recorded.

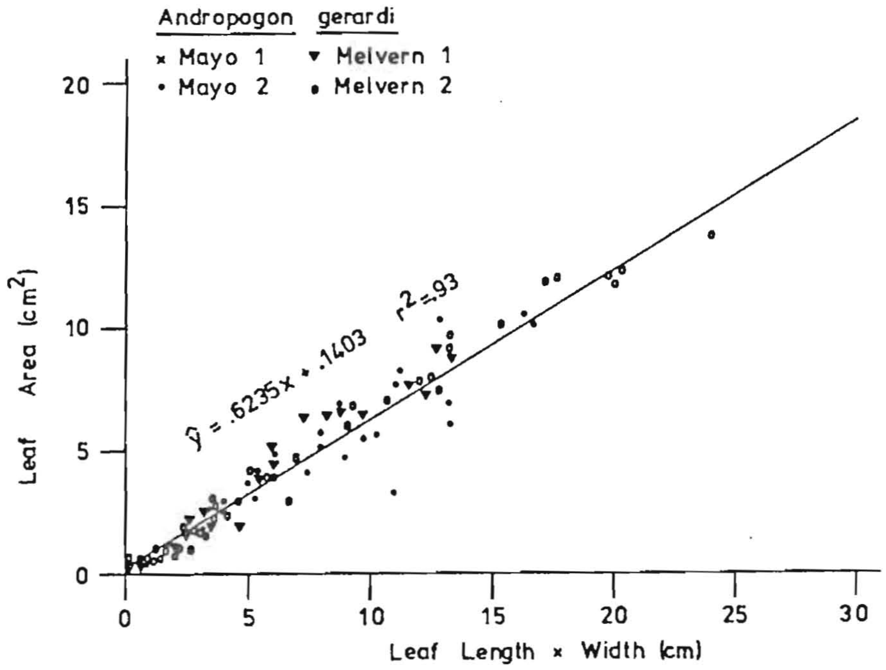
Next the plant was cut one cm above the surface of the soil. The length and width of each leaf in cms was recorded. Lengths were measured from the collar of the leaf sheath to the tip of the blade. The width was measured at the blade's widest point. Leaf areas were measured by tracing each leaf of the plant on one mm^2 graph paper. The traced leaves were cut out of the paper and each tracing weighed on a Mettler H54AR balance. The weight of the paper was divided by the average weight of ten squares of paper of one cm^2 (Table 3) to obtain the leaf area in cm^2. Leaf area was determined in this manner through the collections of June 8. After that time, leaf areas were calculated by a linear regression in which leaf length times leaf width of the previous data was plotted on the X-axis and leaf area was plotted on the Y-axis. The linear regressions for each species are shown in Figures 12-16. Equations for leaf area were determined by combining the

Table 3. Weights of one cm^2 graph paper in g for leaf area determination.

.00700g
.00700
.00631
.00674
.00668
.00674
.00700
.00700
.00644
.00700
.06791g = ΣX
.006791 g = $\overline{X}$

Figure 12. Linear regression for determining leaf area for <u>Andropogon gerardi</u> at Mayo site 2 and Melvern sites 1 and 2.

Figure 13. Linear regression for determining leaf area for <u>Andropogon gerardi</u> at Mayo site 1.


Andropogon gerardi
× Mayo 1
• Mayo 2
▼ Melvern 1
● Melvern 2
$\hat{y}$ = .6235x + .1403
r^2 = .93
Leaf Area (cm^2)
Leaf Length × Width (cm)
0
5
10
15
20
25
30

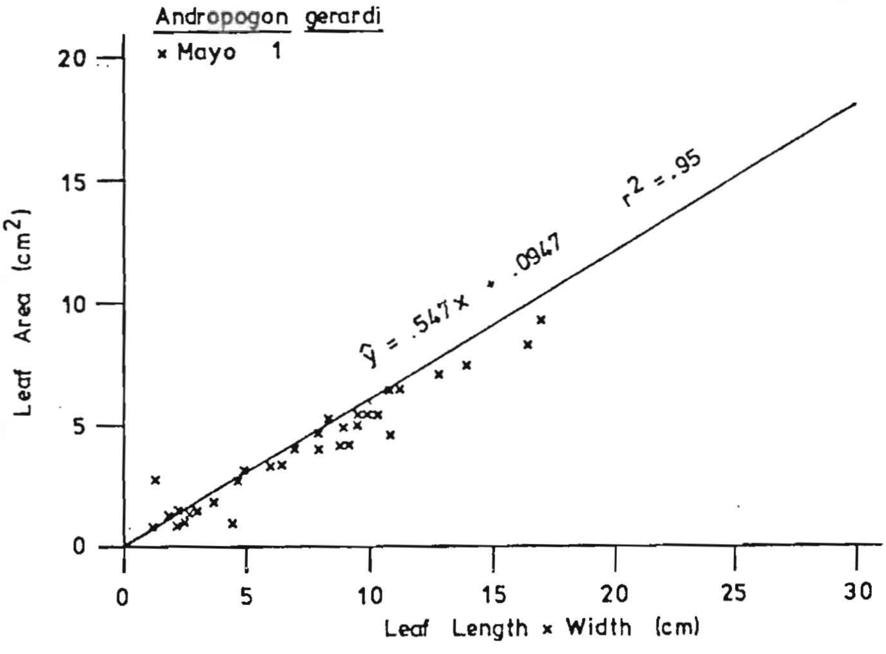

Andropogon gerardi
× Mayo 1
$\hat{y}$ = .547x + .0947
r^2 = .95
Leaf Area (cm^2)
Leaf Length × Width (cm)
0
5
10
15
20
25
30

Figure 14. Linear regression for determining leaf area for <u>Andropogon scoparius</u> at Mayo sites 1 and 2 and Melvern sites 1 and 2.

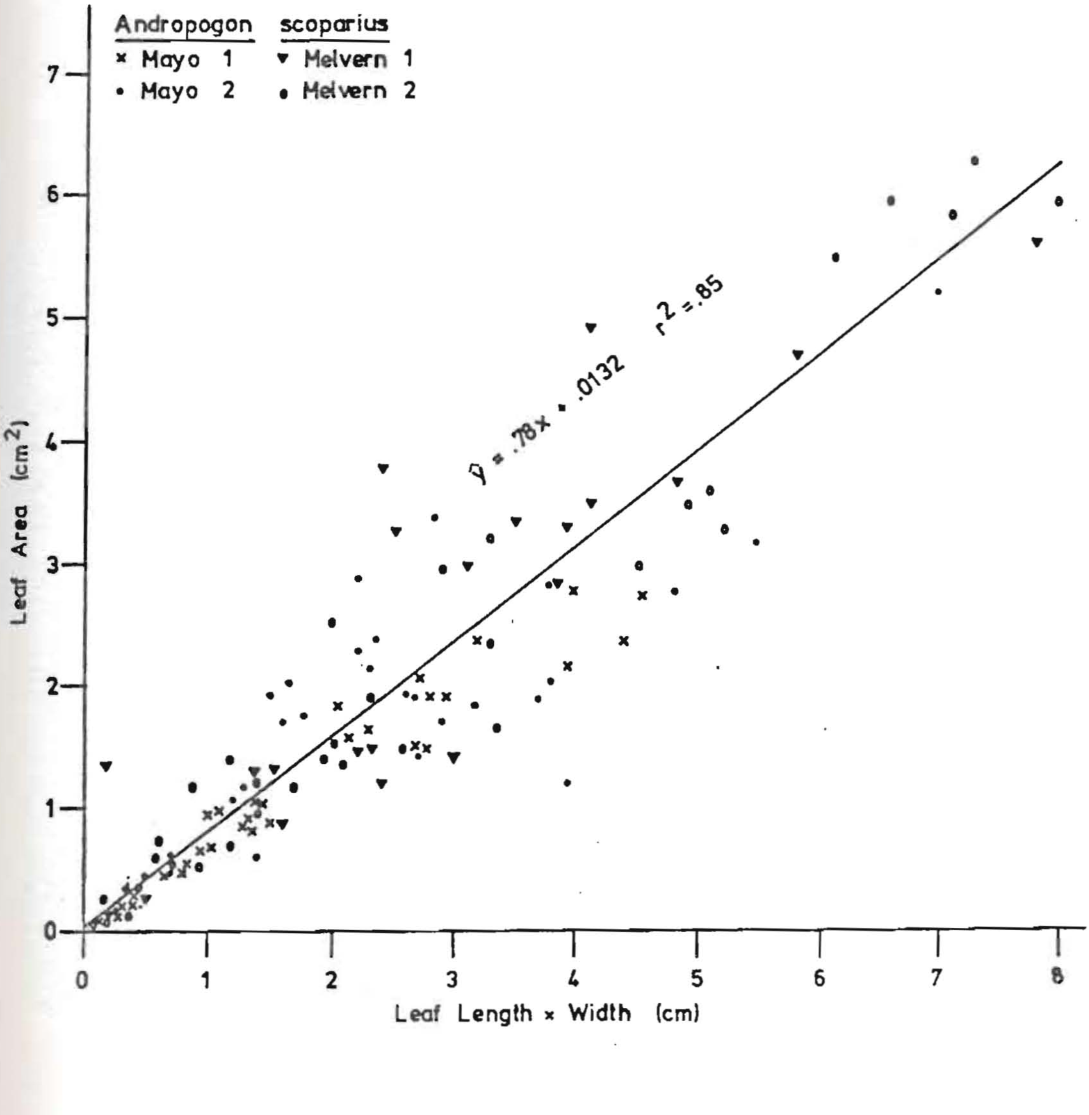
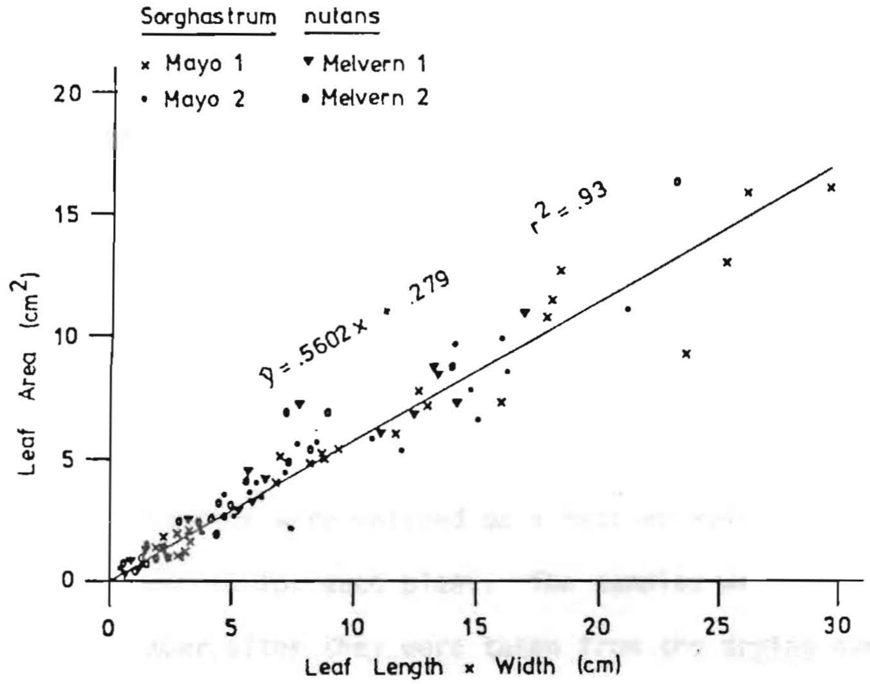
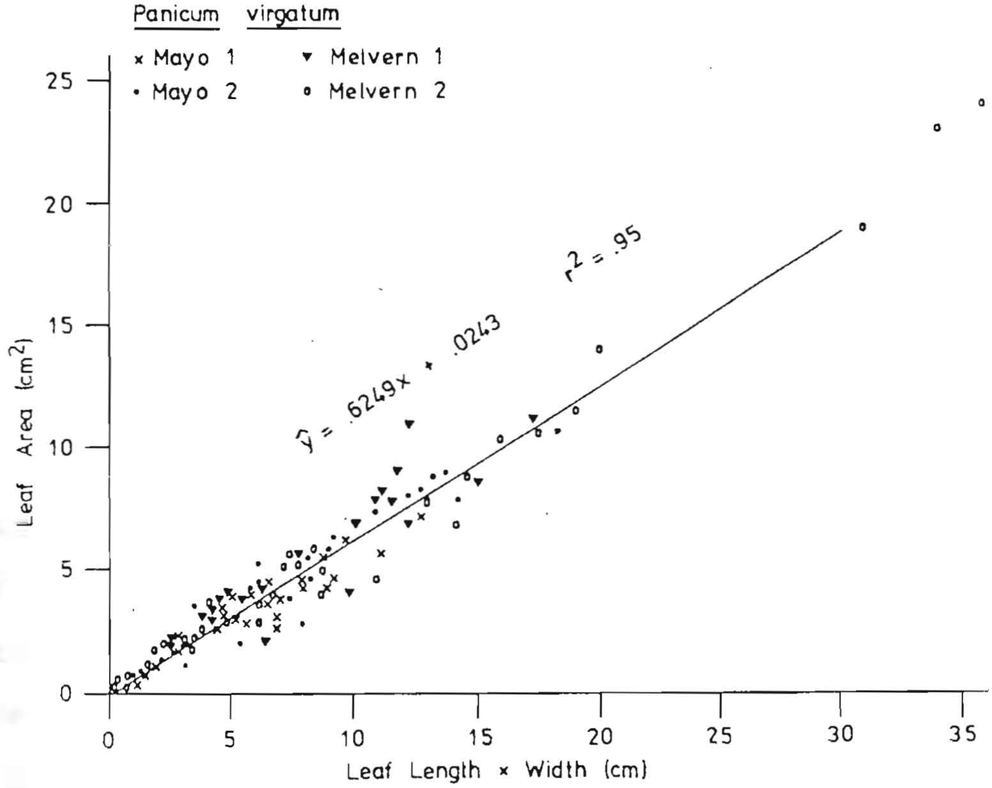

Andropogon scoparius
× Mayo 1
• Mayo 2
▼ Melvern 1
● Melvern 2
ŷ = .78x + .0132
r² = .85
Leaf Area (cm²)
Leaf Length × Width (cm)
0
1
2
3
4
5
6
7
8

Figure 15. Linear regression for determining leaf area for *Sorghastrum nutans* at Mayo sites 1 and 2 and Melvern sites 1 and 2.

Figure 16. Linear regression for determining leaf area for *Panicum virgatum* at Melvern sites 1 and 2 and Mayo sites 1 and 2.


Sorghastrum nutans
× Mayo 1
• Mayo 2
▼ Melvern 1
● Melvern 2
ŷ = .5602x + .279
r² = .93
Leaf Area (cm²)
Leaf Length × Width (cm)
0
5
10
15
20
25
30


Panicum virgatum
× Mayo 1
• Mayo 2
▼ Melvern 1
o Melvern 2
ŷ = .6249x + .0243
r² = .95
Leaf Area (cm²)
Leaf Length × Width (cm)
0
5
10
15
20
25
30
35

data from all sites for each species except for A. gerardi from Mayo site 1. These plants seemed to have shorter and wider leaves than the plants of this species from the other three sites. After all field measurements (i.e. total height, leaf width, and leaf length) were recorded, each plant was placed in an individual brown paper bag and labelled as to species, site, plant number, and date. This entire process was repeated for each of the five plants of all four species at each site. The samples were taken into the laboratory and placed in a drying oven for at least 24 hours at 100°F.

The dried samples were weighed on a Mettler H54AR balance to obtain oven-dry weights for each plant. The samples were kept in a dessication chamber after they were taken from the drying oven and before they were weighed on the balance.

Generally, all the field measurements were done immediately at the collection site one plant at a time. Occassionally, however, due to extreme heat or rain all five plants of a species were collected and placed in a high humidity chamber. The plants were then taken to the shade or the shelter of a vehicle to make the measurements.

Table 4 summarizes the total number of plants and the total number of leaves measured by species for the various sites at the conclusion of the RGR studies.

Relative growth rates, net assimilation rates (NAR), and leaf area ratios (LAR) were calculated as prescribed by the equations of Blackman and Wilson (1951) and Harper (1977). Variance, standard deviations, standard error of the mean, and confidence intervals were calculated for the relative growth rate data (Wyckoff, 1983). The equations for these calculations are shown in the appendix.

Table 4. Total number of plants (Plts) and leaves (Lvs) measured during the 1983 relative growth rate studies at Melvern site 1 (ME 1), Melvern site 2 (ME 2), Mayo site 1 (MY 1) and Mayo site 2 (MY 2).

SPECIES	ME 1 Plts	 Lvs	ME 2 Plts	 Lvs	MY 1 Plts	 Lvs	MY 2 Plts	 Lvs
Andropogon gerardi	55	230	55	258	50	255	50	225
Andropogon scoparius	55	237	55	232	50	194	50	214
Sorghastrum nutans	55	211	55	188	50	185	50	167
Panicum virgatum	55	231	55	245	50	216	50	220

RGR, NAR, and LAR were plotted against time. Mean total heights were also plotted against time. The data was analyzed using the student t test at the p = .05 level of signifigance.

RESULTS AND DISCUSSION

Range Condition

The range condition scorecard that was developed in this study was presented on pages 38 through 44. A completed "Record of Step-Loops and Condition Class Analysis" is shown in Appendix B as an example of the application and use of the scorecard. This example is actual data collected during this study.

Tables 1 through 10 of Appendix C summarize the data collected in the step-loop/frame-point method. The mean step-loop data was used to determine the condition classification for each site as shown in Table 5 below. In addition, the step-loop data for Melvern site 1 (excellent condition) was used to formulate portions of the vegetation scorecard on page 40.

Table 5. Vegetation and soil stability condition classification based on the scorecard method of range condition analysis for Melvern site 1 (ME 1), Melvern site 2 (ME 2), Mayo site 1 (MY 1), Mayo site 2 (MY 2), and the Lefler site (LEF).

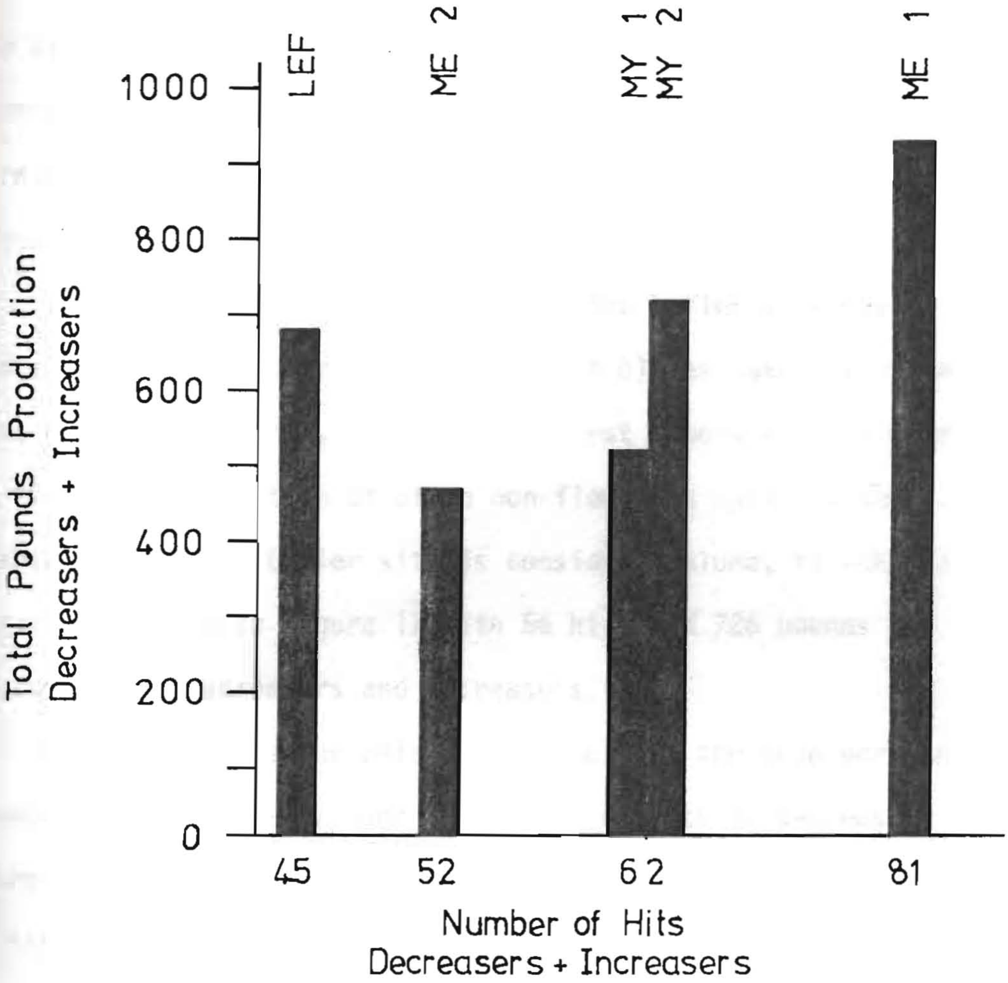
	ME 1	ME 2	MY 1	MY 2	LEF
VEGETATION:					
Forage Density Index	8	5	7	7	5
Composition	7	4	7	5	5
Total	15	9	14	12	10
Condition Class	Exc.	Fair+	Exc.	Good+	Good-
SOIL STABILITY:					
Erosion Hazard Index	8	8	5	5	5
Current Erosion	15	13	11	12	10
Total	23	21	16	17	15
Condition Class	Exc.	Exc.	Good	Good	Good-

These specific sites were selected at the onset of this study because it was hoped that they would represent a variety of condition classes ranging from poor to excellent. Reconnaissance surveys or ocular estimates were the basis for these choices. Initially, it was thought that Melvern site 1 would be in excellent condition, Melvern site 2 would be in poor condition because of woody invasion, Mayo site 1 would be in good to excellent condition, Mayo site 2 would be in poor to fair condition, and the Lefler site would be in fair condition. When measurements were made by the scorecard method, it became apparent that ocular estimates are not a good method for judging range condition. In addition, the ocular estimates do not provide a record of vegetation composition and range condition; the scorecard method does.

Thus, it must be emphasized that in order to accurately judge range condition, actual measurements of the vegetation and soil conditions must be taken. Many range managers rely on clipping plots at the end of the season. Although clipping is a good measure of range condition, it is a very time-consuming task requiring as much as 3-4 hours per transect. Because of this, the number of plots clipped in any year by some range managers is not sufficient to give an accurate indication of vegetation composition and range condition. The step-loop method, however, was found to be an accurate yet quick and easy method for determining range condition in the tallgrass prairie. The step-loop method requires about 30 minutes per transect. Parker (1950, 1951) had previously confirmed this to be true on western and southwestern ranges.

To confirm that the scorecard method would reflect the same trends in range condition as the clipping method, the frame-point method (which involved clipping) was incorporated into the design of the step-loop method. In Figure 17, the total pounds of production of decreasers and increasers (frame-point method) are plotted against the number of hits on decreasers and increasers (step-loop method). With the exception of

Figure 17. Mean total pounds of production of decreasers and increasers vs. the number of step-loop hits on decreasers and increasers. The data used in formulating this graph was the mean data for the two transects taken at each site. LEF = Lefler site; ME 2 = Melvern site 2; MY 1 = Mayo site 1; MY 2 = Mayo site 2; ME 1 = Melvern site 1.


LEF
ME 2
MY 1
MY 2
ME 1
1000
800
600
400
200
0
Total Pounds Production
Decreasers + Increasers
45
52
62
81
Number of Hits
Decreasers + Increasers

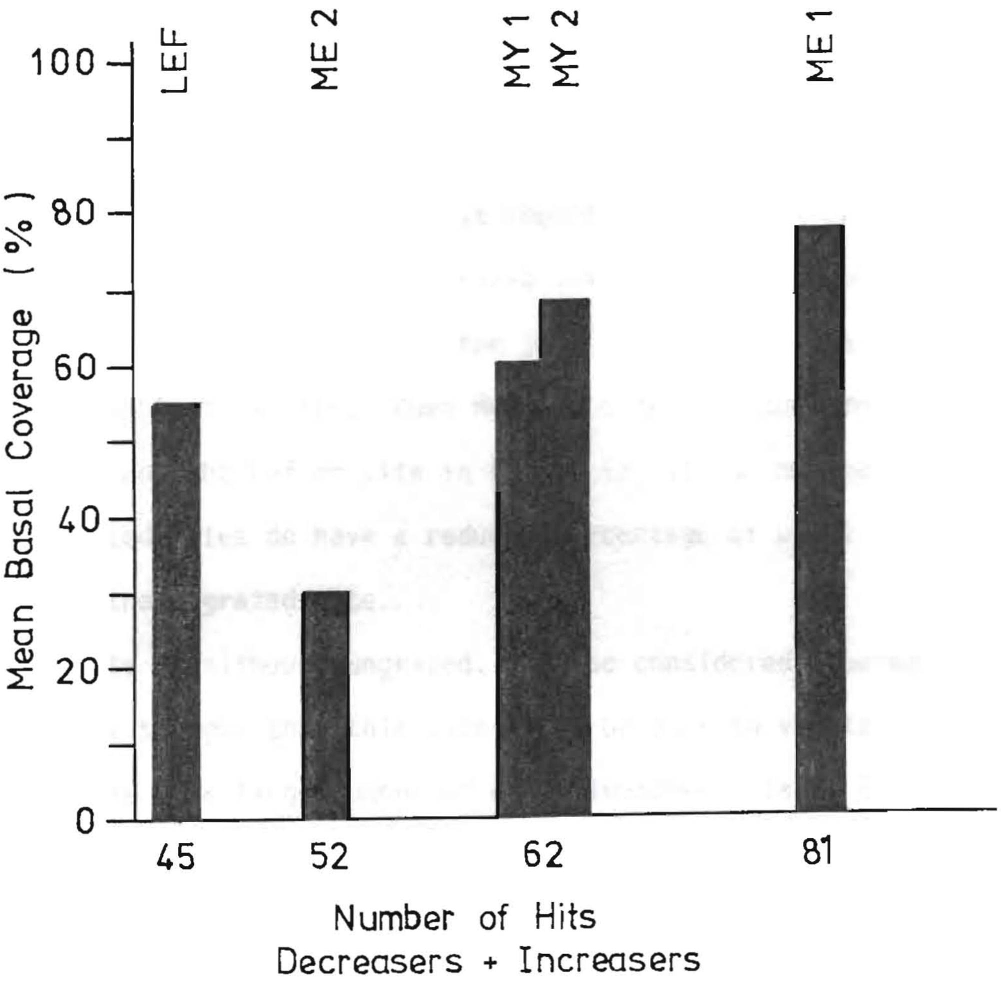
one site (Lefler), as the number of hits increased so did the pounds of production. This would seem to indicate that the clipping method and the step-loop method are both sensitive to differences in vegetation composition. Because of this, it is felt that the step-loop method is a reliable index to vegetation composition and production for the tallgrass prairie.

It is possible that the data from the Lefler site may be erroneous since one of the two transects (transect B) was taken by students. For most of these students, it was their first exposure to this method and to field identification of often non-flowering native grasses. If transect A for the Lefler site is considered alone, it takes a more logical position in Figure 17 with 56 hits and 726 pounds per acre of production of decreasers and increasers.

Figure 18 shows the relationship between the mean per cent basal coverage (basal density) and the number of hits on decreasers and increasers. Again, the same general trends are evident, as the number of hits increases, so does the per cent basal coverage. The Lefler site still is an exception to the trend. However, if Lefler transect A is considered alone, once again it takes on a more logical position in Figure 18 with 56 hits and 55 per cent basal coverage. Because of these relationships, it is felt that the step-loop method is a reliable index to vegetation density as well as vegetation composition.

Condition classes for soil stability were as expected for all five sites. All sites have adequate cover (i.e. litter, rock, plant cover) for preventing erosion. The importance of litter in stabilizing soils and the impact of grazing animals on soil cannot be ignored. Melvern site 1 and 2 have not been grazed for a number of years. Mayo sites

Figure 18. Mean per cent basal coverage vs. the number of step-loop hits on decreasers and increasers. The data used in formulating this graph was the mean data for the two transects taken at each site. LEF = Lefler site; ME 2 = Melvern site 2; MY 1 = Mayo site 1; MY 2 = Mayo site 2; ME 1 = Melvern site 1.


LEF
ME 2
MY 1
MY 2
ME 1
Mean Basal Coverage (%)
100
80
60
40
20
0
45
52
62
81
Number of Hits
Decreasers + Increasers

1 and 2 and the Lefler site have all been subjected to regular grazing. In Figure 19, the difference between the grazed sites and the ungrazed sites can be seen in regard to the amount of bareground and litter; the grazed sites have more bareground and less litter than the ungrazed sites.

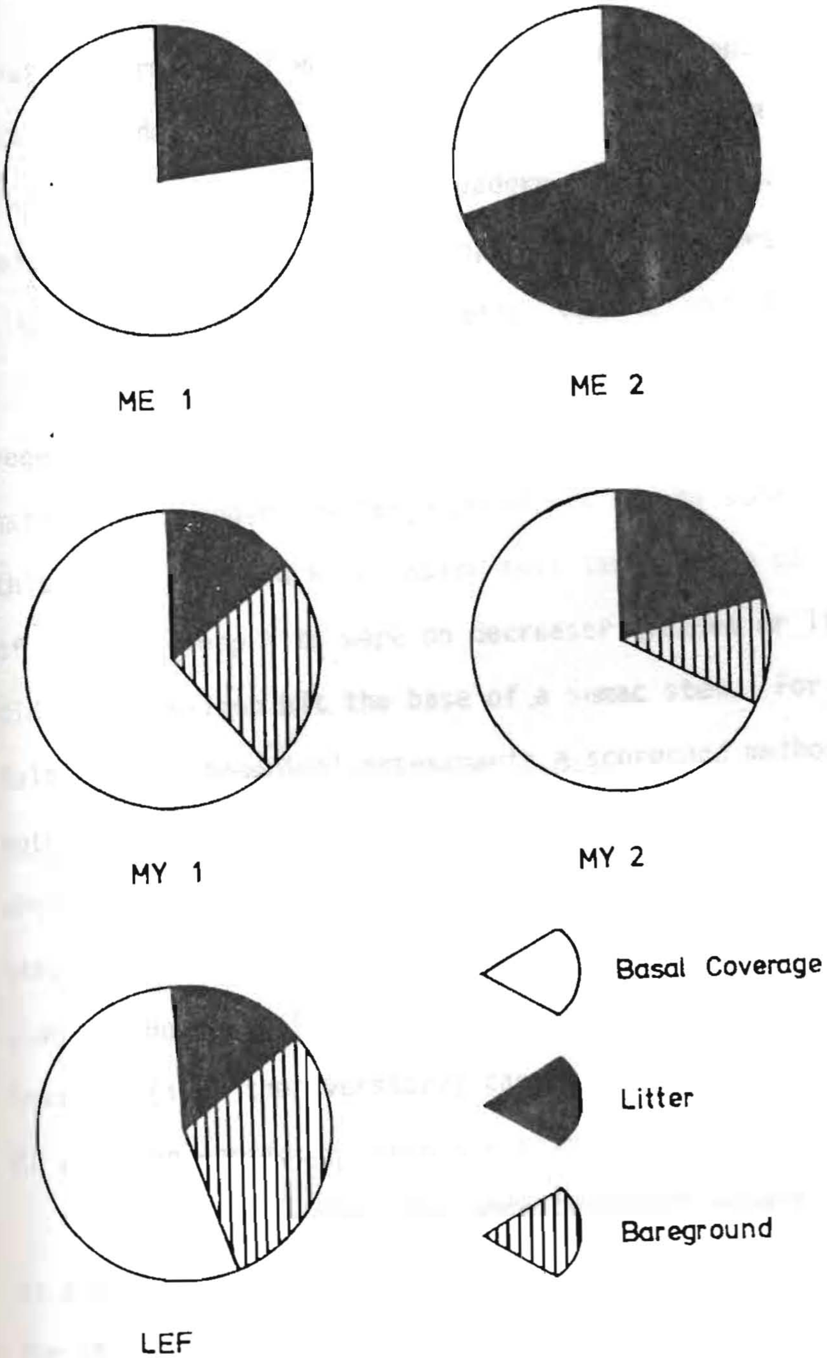
Plant density is probably the most important factor in preventing soil erosion. Melvern site 1, an ungrazed site, has a high percentage of plant density. Humphrey (1949) noted that grazing, especially overgrazing, reduces plant density. When Melvern site 1 is compared with both Mayo sites and the Lefler site in Figure 19, it can be seen that these three grazed sites do have a reduced percentage of plant density as compared to the ungrazed site.

Melvern site 2, although ungrazed, must be considered separately. It was initially thought that this site would be poor in vegetation condition because of a large number of woody invaders. Table 6 is a list of the woody invaders found on this site during June, 1983. The list does include some plants normally thought of as decreasers, e.g. lead plant, but they are included here because they were found in much greater abundance than in climax prairie.

Table 6. Woody invaders found on Melvern site 2 on June 27, 1983.

Common Name	Scientific Name
Lead plant	*Amorpha canescens* Pursh
Rough-leaved dogwood	*Cornus drummondii* Meyer
St. John's Wort	*Hypericum perforatum* L.
Smooth sumac	*Rhus glabra* L.
Rose	*Rosa* spp.
Buckbrush	*Symphoricarpos orbiculatus* Moench
Hawthorne	*Crataegus* spp.
Siberian elm	*Ulmus pumila* L.
Honey locust	*Gleditasia triacanthos* L.
Osage orange	*Maclura pomifera* (Raf.) Schneid.

Figure 19. Ocular estimates within the 1/4 m^2 plot frame of the per cent of basal plant coverage, litter, and bareground. The data shown is the mean of 20 samples, except for the Lefler site where only 10 samples were taken. ME 1 = Melvern site 1; ME 2 = Melvern site 2; MY 1 = Mayo site 1; MY 2 = Mayo site 2 and LEF = the Lefler site.


ME 1
ME 2
MY 1
MY 2
LEF
Basal Coverage
Litter
Bareground

When the data from the scorecard was tabulated, it was determined that Melvern site 2 was in a high fair condition. By looking at the step-loop data in Table 3 of Appendix C and the relative amounts of increasers, decreasers, and invaders in Figure 20, it can be seen that Melvern site 2 had a larger proportion of invaders than any of the other sites (if transect B for the Lefler site is once again not considered).

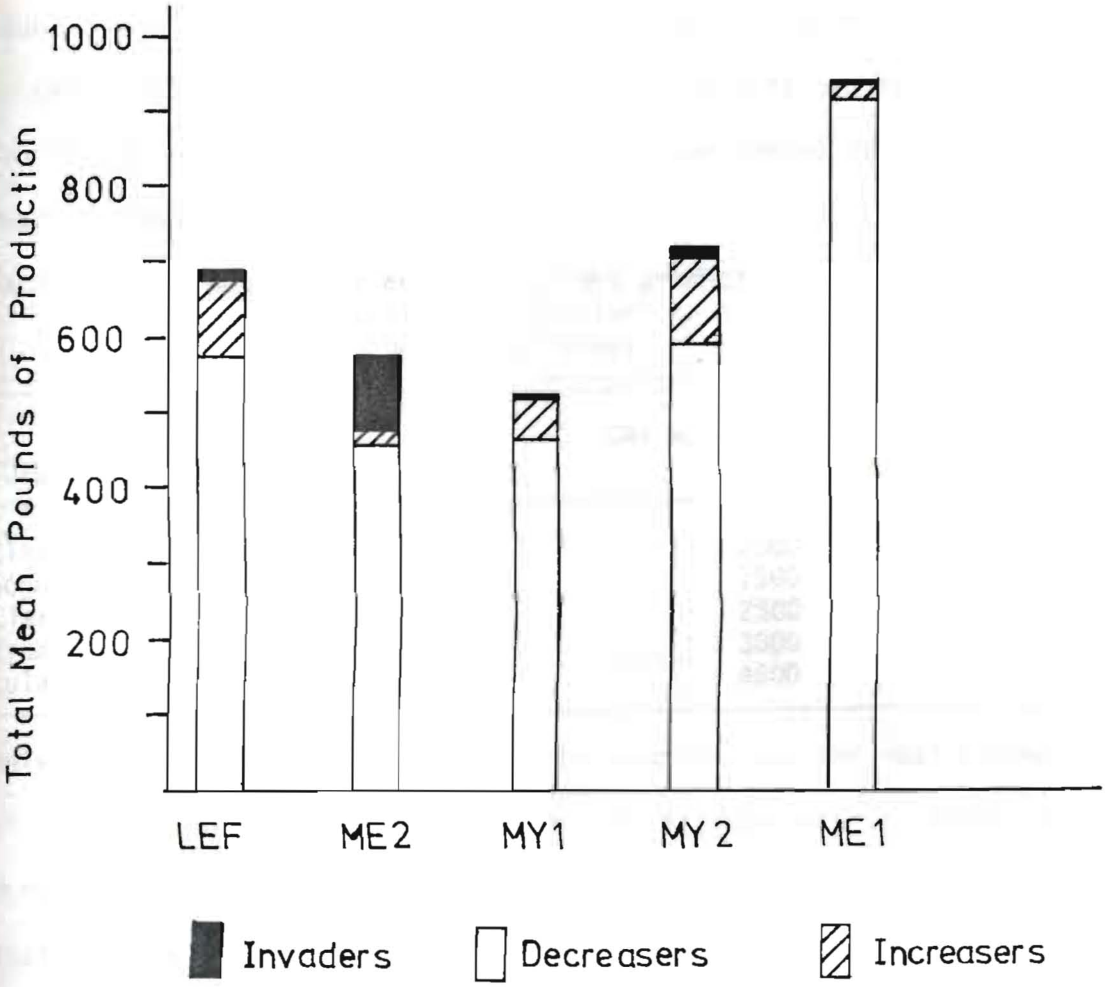
It is felt that the scorecard accurately reflected the understory vegetation at Melvern site 2. There was a surprisingly large amount of native grass under the large colony of smooth sumac (Rhus glabra) on this site. When working inside this large sumac colony, the majority of the step-loop hits were on decreaser grasses or litter; only rarely did the step-loop hit the base of a sumac stem. For this reason, it is felt that in technical assessments a scorecard method where one records both understory and overstory plants for each hit be utilized on sites where there is a large degree of woody invasion. Parker's (1951) three-step method made allowances for recording both understory and overstory plants. However, in a simplified scorecard, notes concerning the woody invasion (i.e. the overstory) can be made on the record sheet (Appendix B) and then considered when classifying the condition.

It should be noted that when decreaser grasses are still present on a site undergoing woody invasion, e.g. Melvern site 2, the potential for the site to return to a higher condition class is still present.

Thus, it is felt that when dealing with condition classes in the tallgrass prairie there are really two types of poor and fair condition classes--those that result from woody invasion and those that result from the impact of overgrazing on herbaceous vegetation.

Finally, the production data obtained in this study was compared

Figure 20. The proportions of invaders, decreasers, and increasers within the mean total production at the Lefler site (LEF), Melvern site 2 (ME 2), Mayo site 1 (MY 1), Mayo site 2 (MY 2), and Melvern site 1 (ME 1).


Total Mean Pounds of Production
1000
800
600
400
200
LEF
ME2
MY1
MY2
ME1
Invaders
Decreasers
Increasers

with the production data presented in the Soil Conservation Service County Surveys (Neill, 1981; USDA, unpublished). Table 7 lists the dry weight production for various soil types in an unfavorable year according to the SCS. Nineteen eighty-three was considered an unfavorable year in regard to growing conditions.

Table 7. The pounds per acre dry weight production in an unfavorable year for the soil types involved in this study (adapted from Neill, 1981; USDA, unpublished).

SOIL TYPE	DRY WEIGHT PRODUCTION lbs/Acre
Clime	2500
Sogn	1500
Clareson	2500
Eram	3000
Lula	4500

Melvern site 1, an Eram-Lula soil type complex, was the most productive of the five sites producing approximately 931 lbs/acre dry weight production. This figure is much less than the SCS estimates. It is felt that the SCS production figures are possibly an overestimate of actual production in an unfavorable year.

The scorecard method presented in this study should be considered a first attempt at developing this method for the tallgrass prairie of east central Kansas. Further and more extensive use of this scorecard will undoubtedly bring forth a number of revisions and improvements. For example, it is felt that guidelines for the percentages of decreaser grasses and forbs in the various condition classes could be determined. Such guidelines would be particularly helpful for a plant such as lead plant (Amorpha canescens) which in most cases is a desirable decreaser forb, but which in great abundance can be considered a woody invader. In addition, carrying capacity estimates could be formulated for each of the four range condition classes. This would require further study of both condition and utilization.

Utilization

Figures 21 through 24 show the stubble height curves for each of the four species studied for both 1982 and 1983. The curves are formulated after the work of Reid and Pickford (1941). Tables 8 and 9 show the stubble height data for each year.

All colonies of each species collected in 1982 had produced seedstalks. The 1982 growing season was favorable in both temperature and precipitation for the growth of native grasses. The result was plants of vigorous stature with numerous seedstalks.

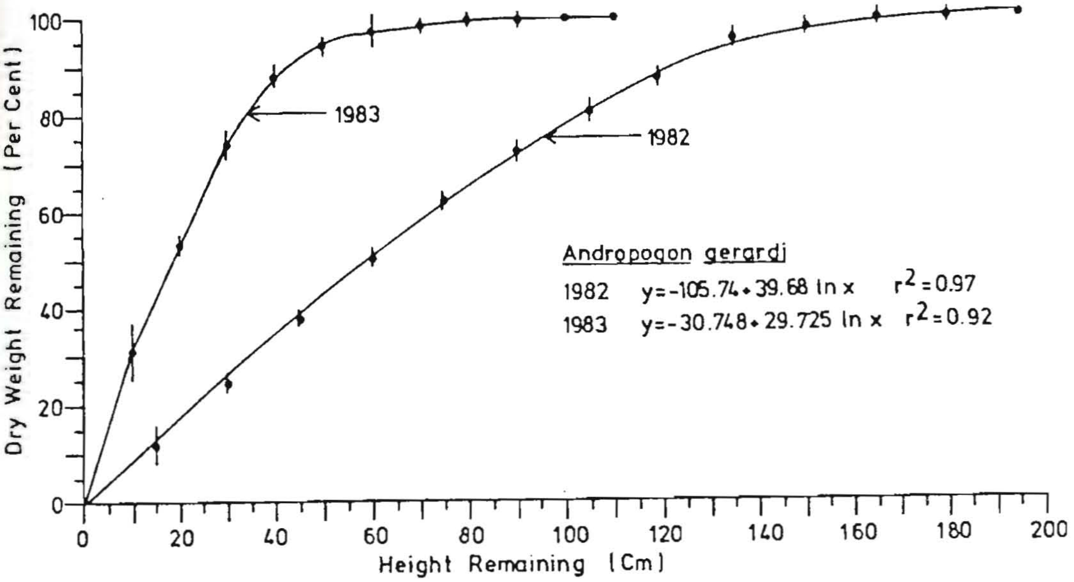
Nineteen eighty-three, however, presented a very dry growing season. The result was the lack of production of seedstalks in three of the four species studied, as well as an overall reduction of maximum height. Of the 1983 samples collected, *P. virgatum* was the only species which had produced fully mature well-developed seedstalks. *S. nutans* produced a few flowering stalks, but none were well-developed. *A. gerardi* showed an occasional, very poorly developed seedstalk and *A. scoparius* produced virtually no seedstalks.

The 1982 and 1983 stubble height curves for *P. virgatum* were rather similar, while those of *S. nutans*, *A. gerardi*, and *A. scoparius* were somewhat different for the two years due to the difference in total height. These same similarities and differences are expressed in another manner in Figures 25 through 28. Here the data is presented so as to show the growth form of the species as was done by Stoddart et. al. (1975) for *Agropyron spicatum* and *Festuca idahoensis*.

Figures 25 through 28 all illustrate that the greatest biomass of

Figure 21. 1982 and 1983 stubble height curves for *Andropogon gerardi*. 95 % confidence intervals are shown on both curves.

Figure 22. 1982 and 1983 stubble height curves for *Andropogon scoparius*. 95 % confidence intervals are shown on both curves.


Dry Weight Remaining (Per Cent)
100
80
60
40
20
0
Height Remaining (Cm)
0
20
40
60
80
100
120
140
160
180
200
1983
1982
Andropogon gerardi
1982 y=-105.74+39.68 ln x r2=0.97
1983 y=-30.748+29.725 ln x r2=0.92

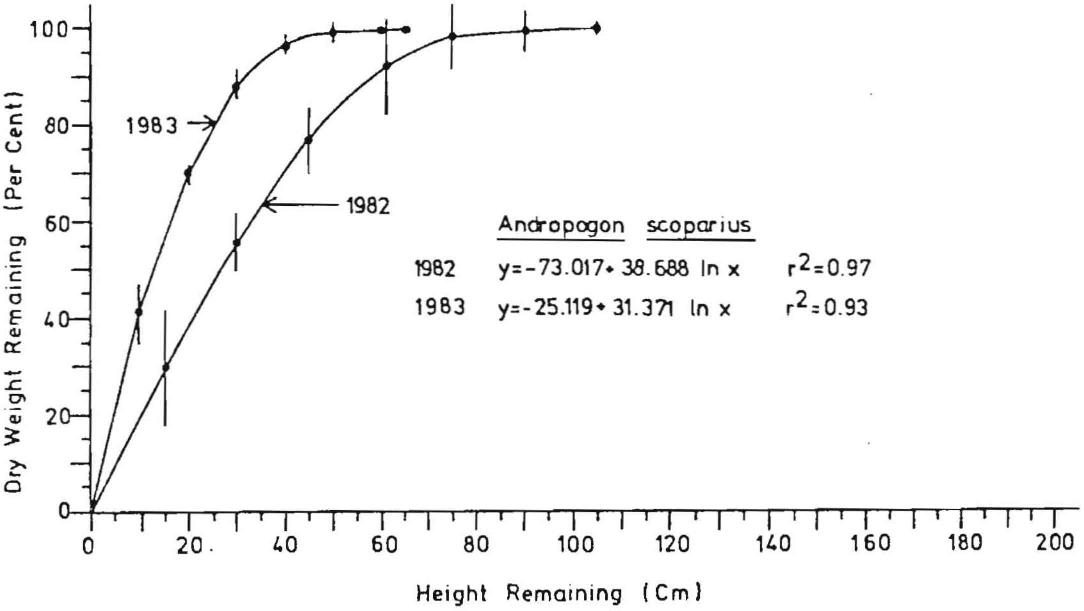
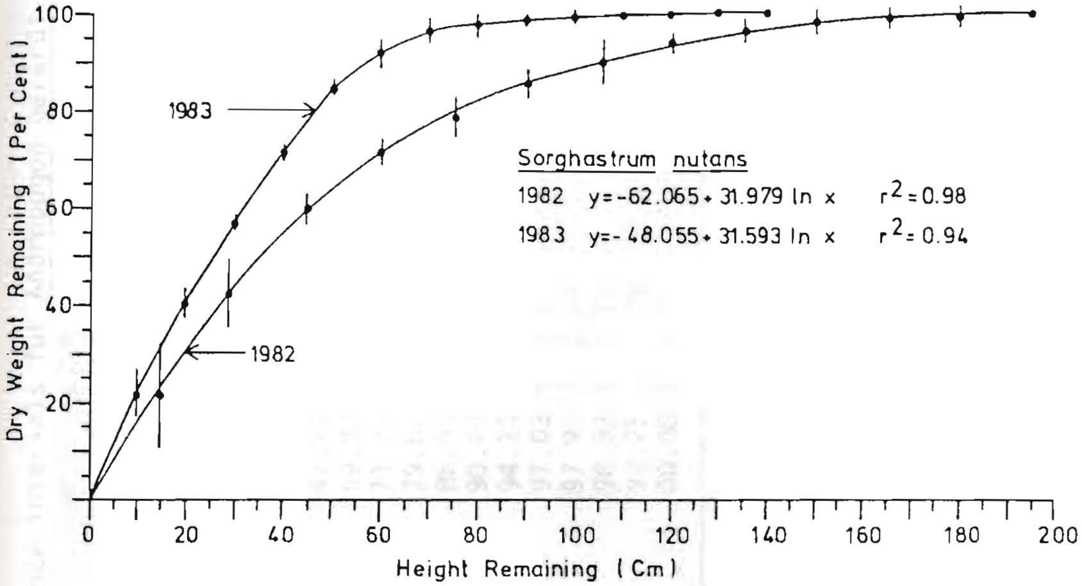

Dry Weight Remaining (Per Cent)
100
80
60
40
20
0
Height Remaining (Cm)
0
20
40
60
80
100
120
140
160
180
200
1983
1982
Andropogon scoparius
1982 y=-73.017+38.688 ln x r2=0.97
1983 y=-25.119+31.371 ln x r2=0.93

Figure 23. 1982 and 1983 stubble height curves for Sorghastrum nutans. 95 % confidence intervals are shown on both curves.

Figure 24. 1982 and 1983 stubble height curves for Panicum virgatum. 95 % confidence intervals are shown on both curves.


Dry Weight Remaining (Per Cent)
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
200
Height Remaining (Cm)
1983
1982
Sorghastrum nutans
1982 y=-62.065+31.979 ln x r2=0.98
1983 y=-48.055+31.593 ln x r2=0.94

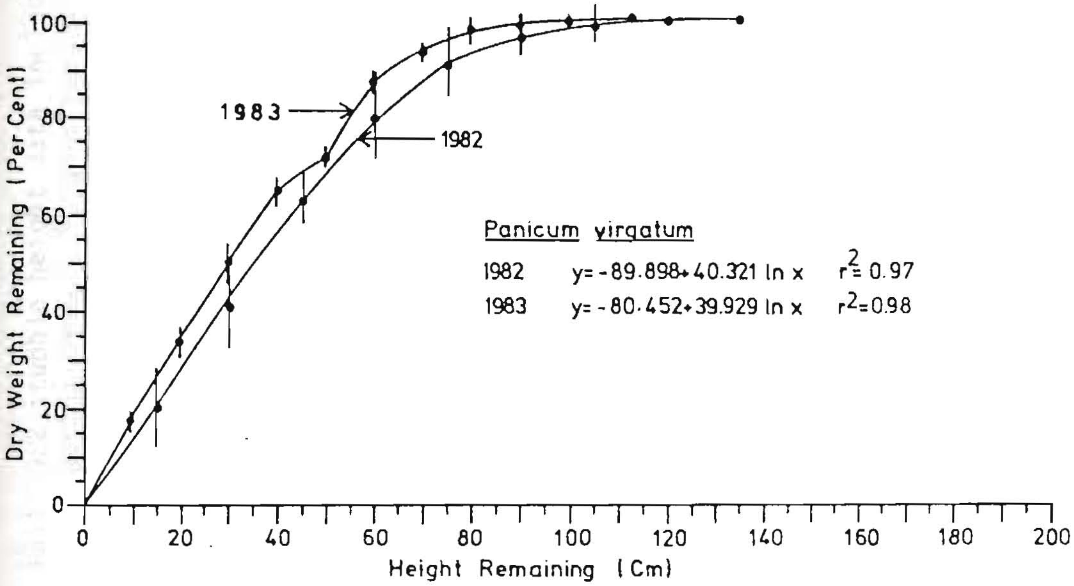

Dry Weight Remaining (Per Cent)
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
Height Remaining (Cm)
1983
1982
Panicum virgatum
1982 y=-89.898+40.321 ln x r2=0.97
1983 y=-80.452+39.929 ln x r2=0.98

Table 8. Fall 1982 stubble height data including 95 % confidence intervals for *Andropogon gerardi* (Ange), *A. scoparius* (Ansc), *Sorghastrum nutans* (Sonu), and *Panicum virgatum* (Pavi).

Stubble Height cm	Per Cent of Dry Weight Remaining Ange	 Ansc	 Sonu	 Pavi
0	0	0	0	0
15	11.60 ± 3.94	30.02 ± 11.73	21.74 ± 11.24	19.66 ± 8.44
30	24.66 ± 1.57	55.74 ± 5.89	42.73 ± 6.89	40.72 ± 8.75
45	37.60 ± 1.28	77.00 ± 7.40	59.92 ± 3.20	62.82 ± 5.40
60	50.20 ± 0.79	91.47 ± 9.72	71.71 ± 2.80	79.90 ± 9.00
75	62.01 ± 0.81	98.18 ± 7.43	79.62 ± 3.54	91.01 ± 7.13
90	72.20 ± 1.04	99.68 ± 3.62	86.50 ± 3.45	96.49 ± 4.04
105	80.49 ± 1.82	100.00 ± 0.89	90.48 ± 5.15	99.27 ± 3.87
120	87.48 ± 1.33		94.24 ± 2.06	99.94 ± 1.35
135	93.66 ± 0.86		97.03 ± 2.24	100.00 ± 0.16
150	97.63 ± 1.30		97.90 ± 2.59	
165	99.50 ± 0.87		98.53 ± 1.75	
180	99.93 ± 0.68		99.75 ± 3.39	
195	100.00 ± 0.20		100.00 ± 0.70	

Table 9. Fall 1983 stubble height data including 95 % confidence intervals for Andropogon gerardi (Ange), A. scoparius (Ansc), Sorghastrum nutans (Sonu), and Panicum virgatum (Pavi).

Stubble Height	Per Cent of Dry Weight Remaining			
cm	Ange	Ansc	Sonu	Pavi
0	0	0	0	0
10	31.24 ± 5.93	40.88 ± 5.63	22.03 ± 5.01	17.76 ± 1.42
20	53.18 ± 2.23	70.46 ± 2.38	40.53 ± 3.25	34.02 ± 2.85
30	73.94 ± 2.53	88.81 ± 3.16	57.06 ± 1.33	49.96 ± 3.92
40	87.63 ± 1.76	97.35 ± 1.89	72.26 ± 1.24	64.63 ± 3.34
50	94.42 ± 2.23	99.83 ± 1.84	84.63 ± 1.28	71.71 ± 1.64
60	97.12 ± 2.76	99.91 ± 0.07	92.24 ± 2.83	87.95 ± 1.78
70	98.44 ± 1.43	100.00 ± 0.01	96.57 ± 2.67	94.48 ± 1.53
80	99.19 ± 1.07		98.38 ± 1.77	97.84 ± 3.20
90	99.76 ± 1.16		99.19 ± 1.17	99.50 ± 2.10
100	99.98 ± 0.61		99.79 ± 0.99	100.15 ± 0.87
110	100.00 ± 0.03		99.81 ± 0.27	100.23 ± 0.12
120			99.86 ± 0.15	100.37 ± 0.37
130			99.87 ± 0.01	
140			100.00 ± 0.00	

Figure 25. The growth form of _Andropogon_ _gerardi_ expressed as the per cent of forage throughout the height of the plant.

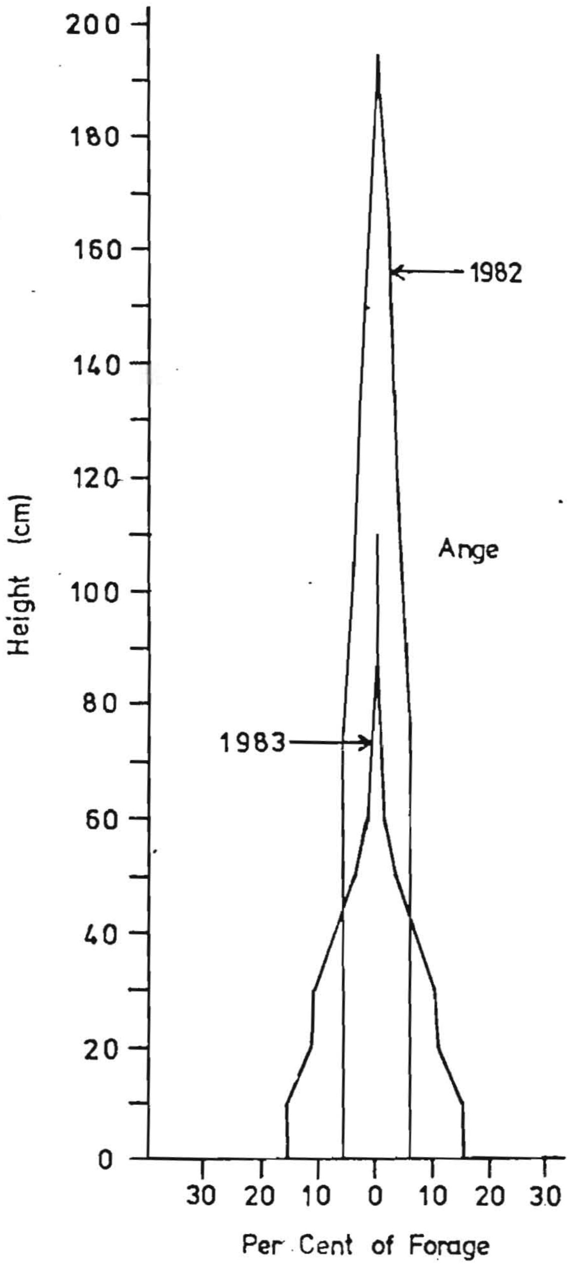
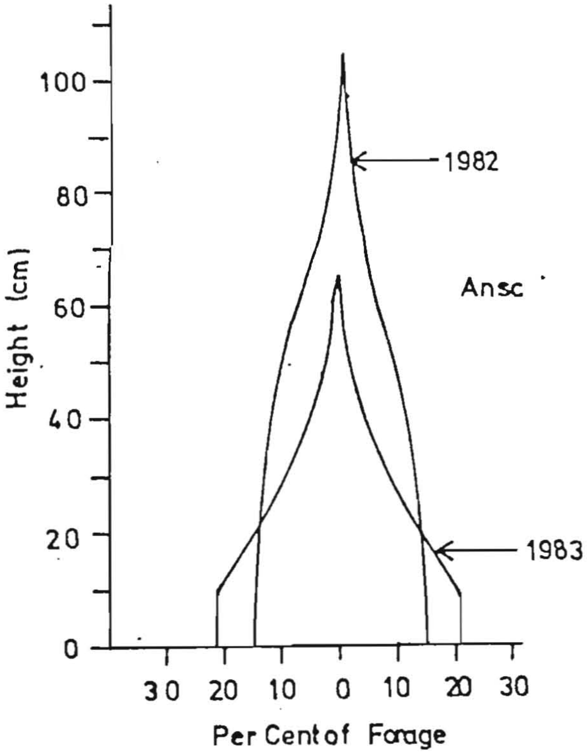

Height (cm)
200
180
160
140
120
100
80
60
40
20
0
1982
1983
Ange
30
20
10
0
10
20
30
Per Cent of Forage

Figure 26. The growth form of _Andropogon scoparius_ expressed as the per cent of forage throughout the height of the plant.

Figure 27. The growth form of _Panicum virgatum_ expressed as the per cent of forage throughout the height of the plant.


100
80
60
40
20
0
Height (cm)
1982
Ansc
1983
30 20 10 0 10 20 30
Per Cent of Forage

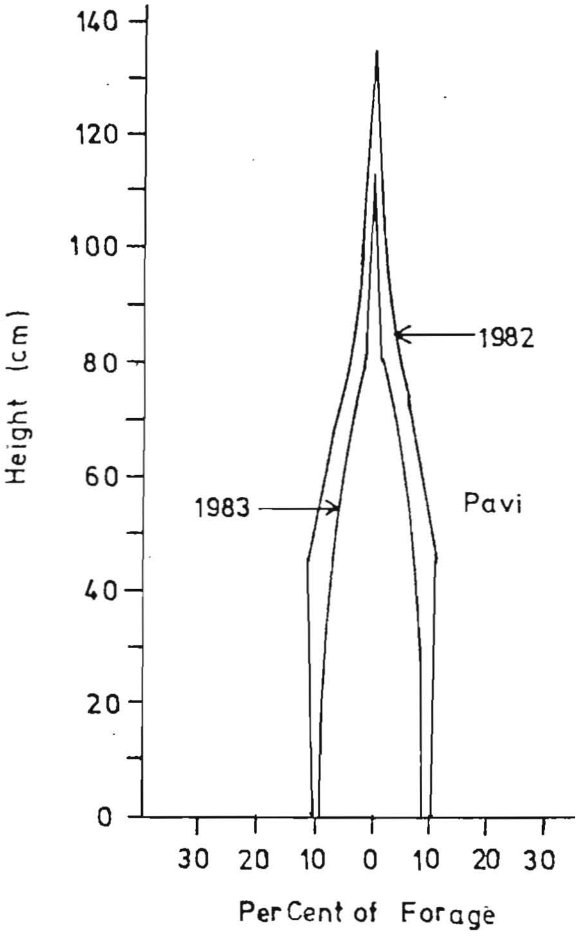
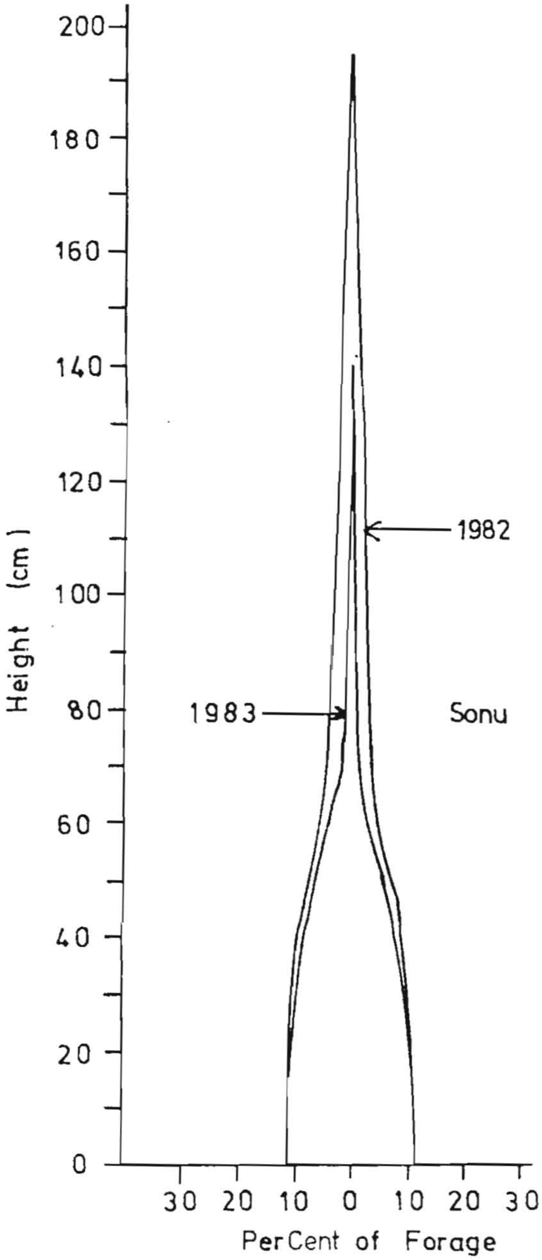

140
120
100
80
60
40
20
0
Height (cm)
1982
1983
Pavi
30 20 10 0 10 20 30
Per Cent of Forage

Figure 28. The growth form of _Sorghastrum nutans_ expressed as the per cent of forage throughout the height of the plant.


200
180
160
140
120
100
80
60
40
20
0
Height (cm)
1982
1983
Sonu
30 20 10 0 10 20 30
PerCent of Forage

each species is in the lowermost portion of the plant. The shorter plants exhibit a conical growth form while the taller plants have a more cylindrical growth form. Because the differences in height are chiefly due to the presence or absence of seedstalks, it can also be said that in general the plants producing seedstalks have a more cylindrical growth form while those plants lacking seedstalks have a more conical growth form. This is especially prominent in Figures 25 and 26 where the 1982 plants of _A. scoparius_ and _A. gerardi_ produced seedstalks and the 1983 plants did not.

Lommasson and Jensen (1943) recognized that individual mature heights varied within a species and this was often due to the presence or absence of seedstalks. The 1982 and 1983 studies vividly illustrate that there are two forms of mature grasses in the tallgrass prairie -- those that produce seedstalks and those that do not produce seedstalks. Within any given year, one mature form or the other will probably be found to dominate a range site. Only one of the four species, _P. virgatum_, did not illustrate this and it is thought that this is not unusual since _P. virgatum_ tends to mature more quickly, even under less favorable conditions, than any of the other three grasses studied.

In a technical assessment of utilization, it is best to determine stubble height curves each year so as to account for seasonal variation much like the ones which occurred in this study. On the other hand, individual farmers and ranchers may not have the resources available (e.g. weighing instruments) which are necessary to determine a yearly stubble height curve. Since one goal of this research was to develop methods that could be used by the average farmer and rancher, the stubble height curves presented here can be standards for the east central Kansas native prairie. The 1982 curve would be used for utilization determination in a year in which seedstalks are produced (normal or favorable year) and the 1983 curve would be used in a year in which seedstalks are not produced (unfavorable year).

In order to determine utilization by the stubble height method, the steps below are followed:

(1) Select key areas within a range management unit that are indicative of the unit in general.

(2) Choose one (or more) of the four key species to measure stubble heights of.

(3) Walk a transect of 50 or 100 paces, stopping at each pace to record the total height of a plant of the specified species which is nearest the toe of the examiner. Record the data on a sheet, e.g. Figure 29. If a plant is ungrazed, record its total height and 0 per cent use. Heights are measured by placing a meter stick beside the plant and holding the stems in an upright position against the meter stick. The end of the meter stick should be resting as nearly as possible on the soil surface.

(4) When 50 or 100 heights have been recorded on the data sheet, convert the stubble heights to per cent <u>utilized</u> by using the appropriate curve. Remember that some plants may have 0 per cent utilization. Determine the average per cent utilization, the per cent of plants grazed, and the per cent of plants grazed 50 per cent or more.

Figure 29. Form for recording stubble height data.

DATA SHEET FOR RANGE UTILIZATION
BY THE
STUBBLE HEIGHT METHOD

Date________________ Key Species________________

Location________________ Examiner________________

Transect No.____________

Stubble Height	Per Cent Use	Stubble Height	Per Cent Use	Stubble Height	Per Cent Use

Average Per Cent Utilization________________

Per Cent of Plants Grazed________________

Per Cent of Plants Grazed 50 % of More________________

Notes________________________________

____

(5) Retain the data sheets so that utilization trends can be monitored. Appendix D shows a completed data sheet for range utilization by the stubble height method.

Once utilization data is accumulated, it must be interpreted to be of any practical value. Range managers have long used the rule-of-thumb of take half and leave half as a guide for acceptable levels of utilization. This adage may seem easy to follow, yet it poses several questions. Does this refer to one-half the total population of available forage or one-half of an individual plant? Some individual plants will be very closely grazed while others will be completely ungrazed. Livestock (and wildlife) do not necessarily graze a range unit uniformily; some of the unit may be essentially untouched while other areas may be obviously overgrazed. The data obtained in the stubble height method provides the answers to these questions. From this data the average utilization of a species can be determined as well as the per cent of plants grazed and the per cent of plants grazed 50 % or more. Total utilization of a range is dependent upon all three of these features.

Therefore, above 50 per cent utilization is considered satisfactory and below 50 per cent is considered unsatisfactory when evaluated in terms of average per cent utilization of all plants measured and in terms of the per cent of the measured plants grazed 50 per cent or more.

The key area-key species concept is applied in the stubble height method. By measuring utilization of key species on key areas, one can get a fairly good idea of the utilization of the total range unit. Further, by walking a transect of 100 paces through the key area, an examiner may pass through several areas of varied grazing use thereby obtaining a good estimate of overall utilization. By using the stubble height method, the examiner is forced to look more closely at the range site than would be done by using any of the reconnaissance or estimate methods for utilization surveys.

Relative Growth Rates

The measurement of relative growth rates (RGR) was included in this study in hopes that the plants of the various range conditon classes would exhibit different RGR's. Clatworthy and Harper (1962) had found that growth rates of *Lemna* spp. and *Salvinia natans* were density dependent. Because of their observations, it was thought that range grasses might also exhibit density dependent growth rates and that these growth rates might be different in the various range condition classes. It has been shown in this study that basal density decreases as the range condition declines.

Figures 30 through 45 are the graphic illustrations of RGR, net assimilation rate (NAR), and leaf area ratio (LAR) for each species at each study site. In addition, the mean total heights for each species for each site are shown in Figures 46 through 61. The mean total heights of the plants increased rapidly during the early part of the summer until they more-or-less reached a peak height in the middle to late summer. It should be noted that the total heights are included here *not* as a measurement of growth, but instead as a reflection of overall stature of the various species.

One of the properties of RGR is that NAR X LAR = RGR. This property was found to be true. The net assimilation rates presented in this study are not direct measurements of photosynthetic and

Figure 30. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for Andropogon gerardi at Melvern site 1. 95 % confidence intervals are shown on the RGR.

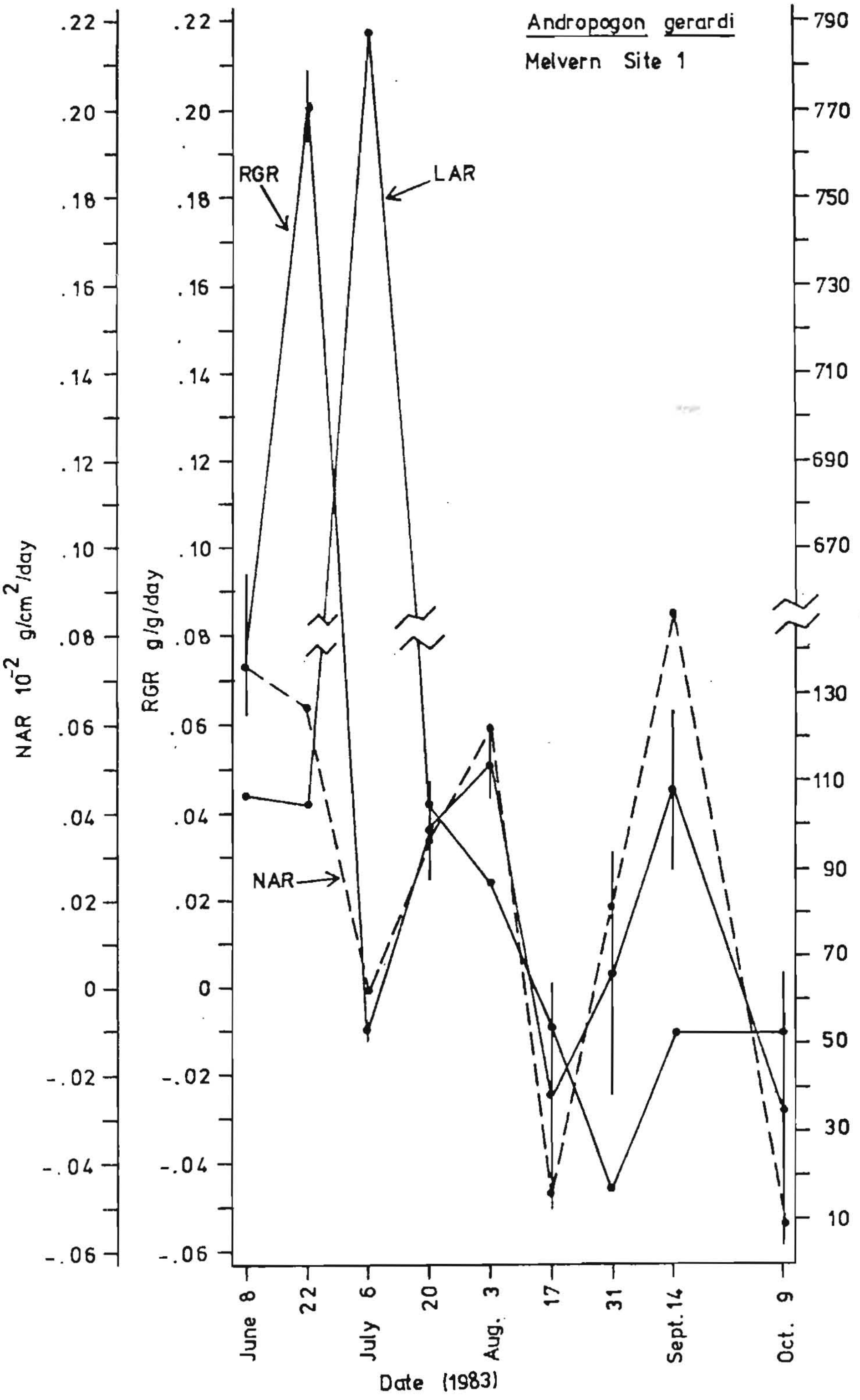

Andropogon gerardi
Melvern Site 1
RGR
LAR
NAR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
790
770
750
730
710
690
670
130
110
90
70
50
30
10
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 31. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for *Andropogon gerardi* at Melvern site 2. 95 % confidence intervals are shown on the RGR.

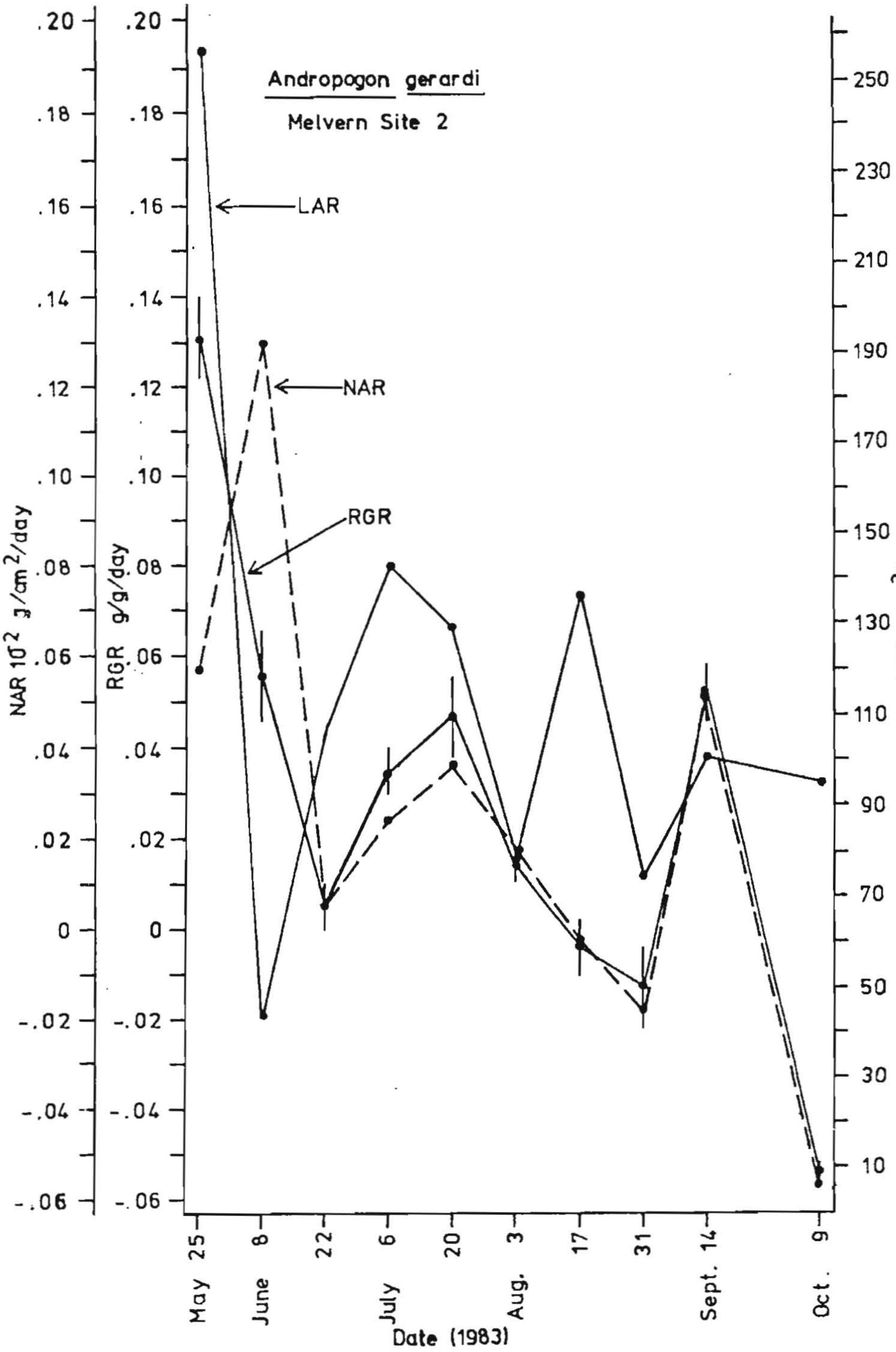

Andropogon gerardi
Melvern Site 2
LAR
NAR
RGR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
250
230
210
190
170
150
130
110
90
70
50
30
10
May 25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 32. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for <u>Andropogon gerardi</u> at Mayo site 1. 95 % confidence intervals are shown on the RGR.

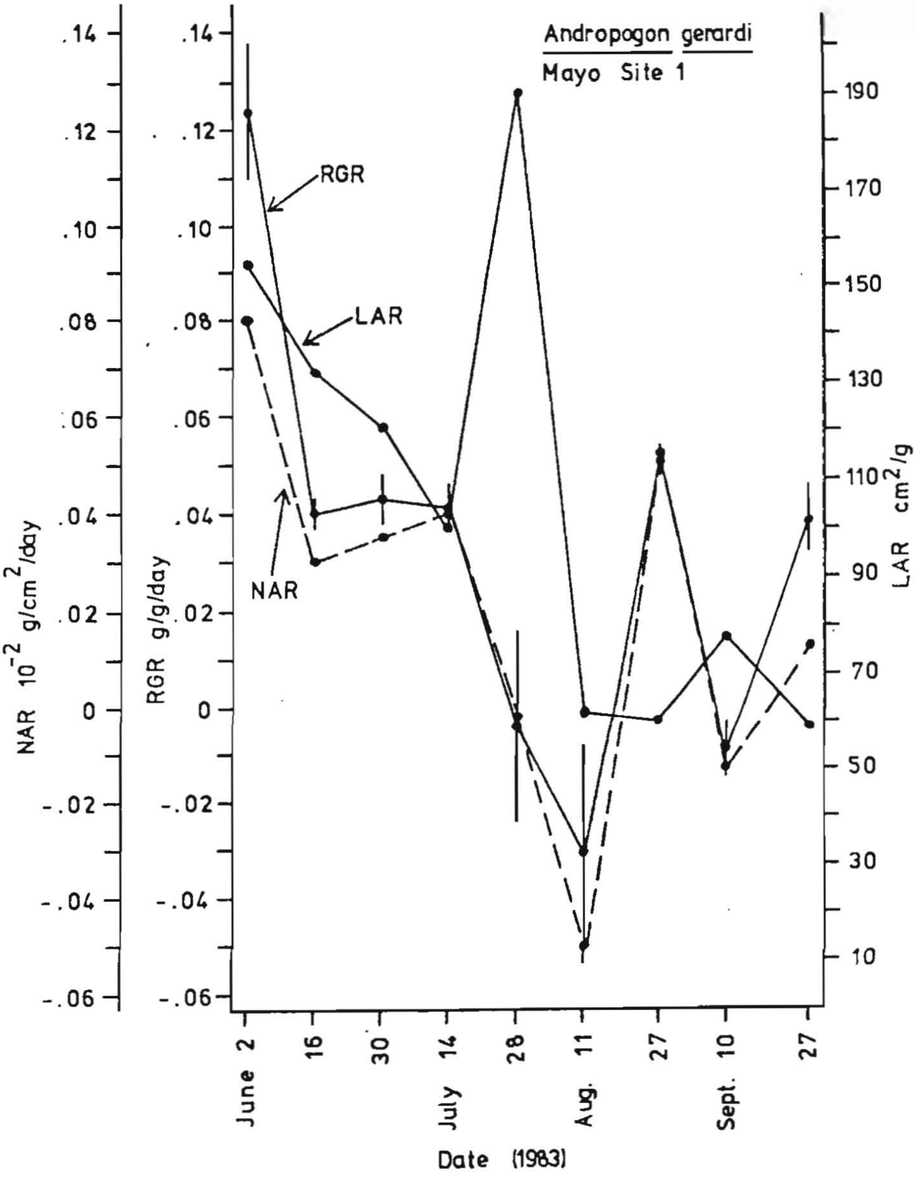

Andropogon gerardi
Mayo Site 1
RGR
LAR
NAR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
190
170
150
130
110
90
70
50
30
10
June 2
16
30
July 14
28
Aug. 11
27
Sept. 10
27
Date (1983)

Figure 33. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for Andropogon gerardi at Mayo site 2. 95 % confidence intervals are shown on the RGR.

Andropogon gerardi

Mayo Site 2

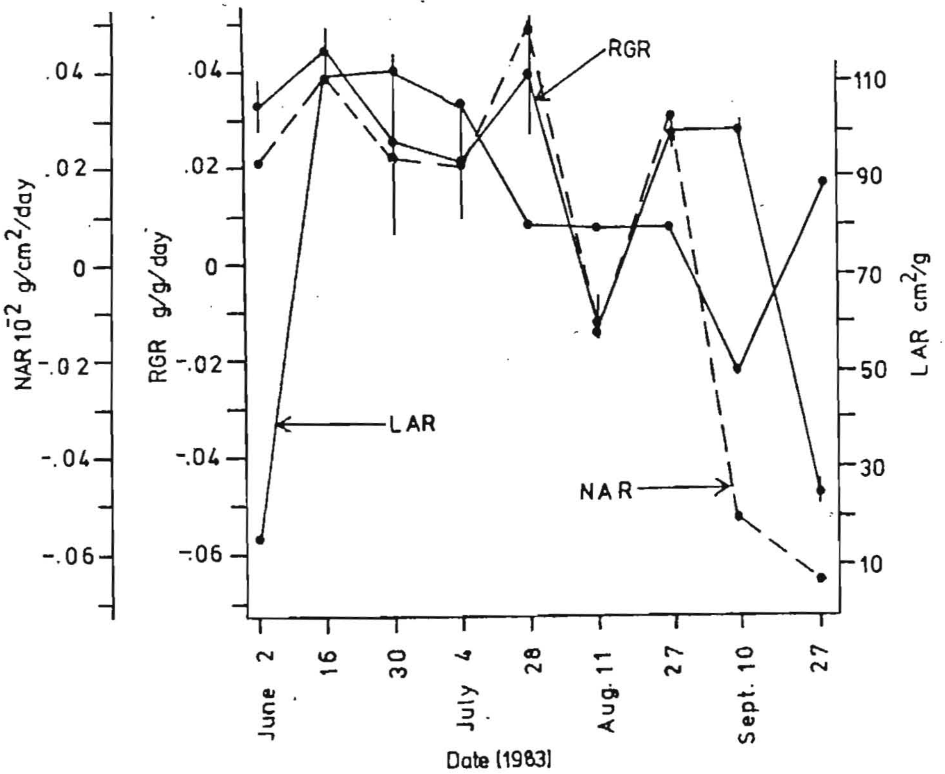


Figure 34. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for <u>Andropogon scoparius</u> at Melvern site 1. 95 % confidence intervals are shown on the RGR.

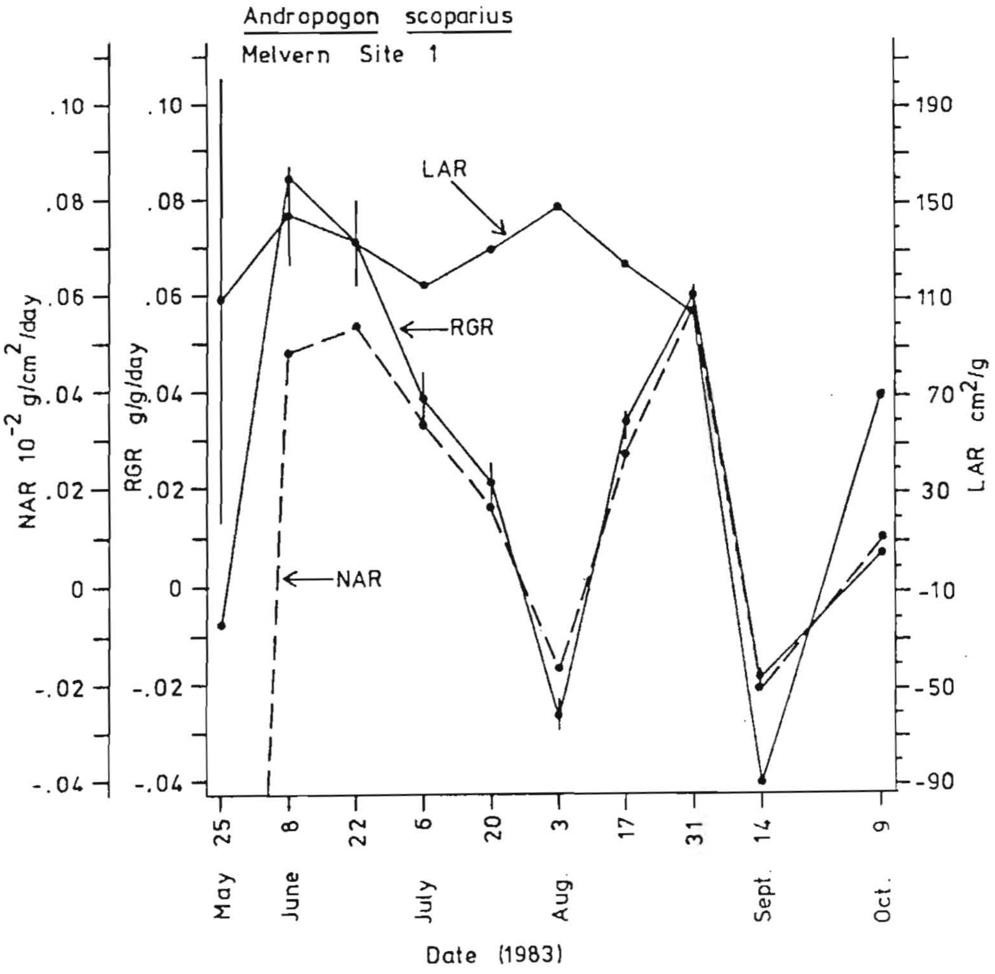

Andropogon scoparius
Melvern Site 1
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.10
.08
.06
.04
.02
0
-.02
-.04
190
150
110
70
30
-10
-50
-90
LAR
RGR
NAR
25 May
8 June
22
6 July
20
3 Aug.
17
31
14 Sept.
9 Oct.
Date (1983)

Figure 35. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for <u>Andropogon scoparius</u> at Melvern site 2. 95 % confidence intervals are shown on RGR.

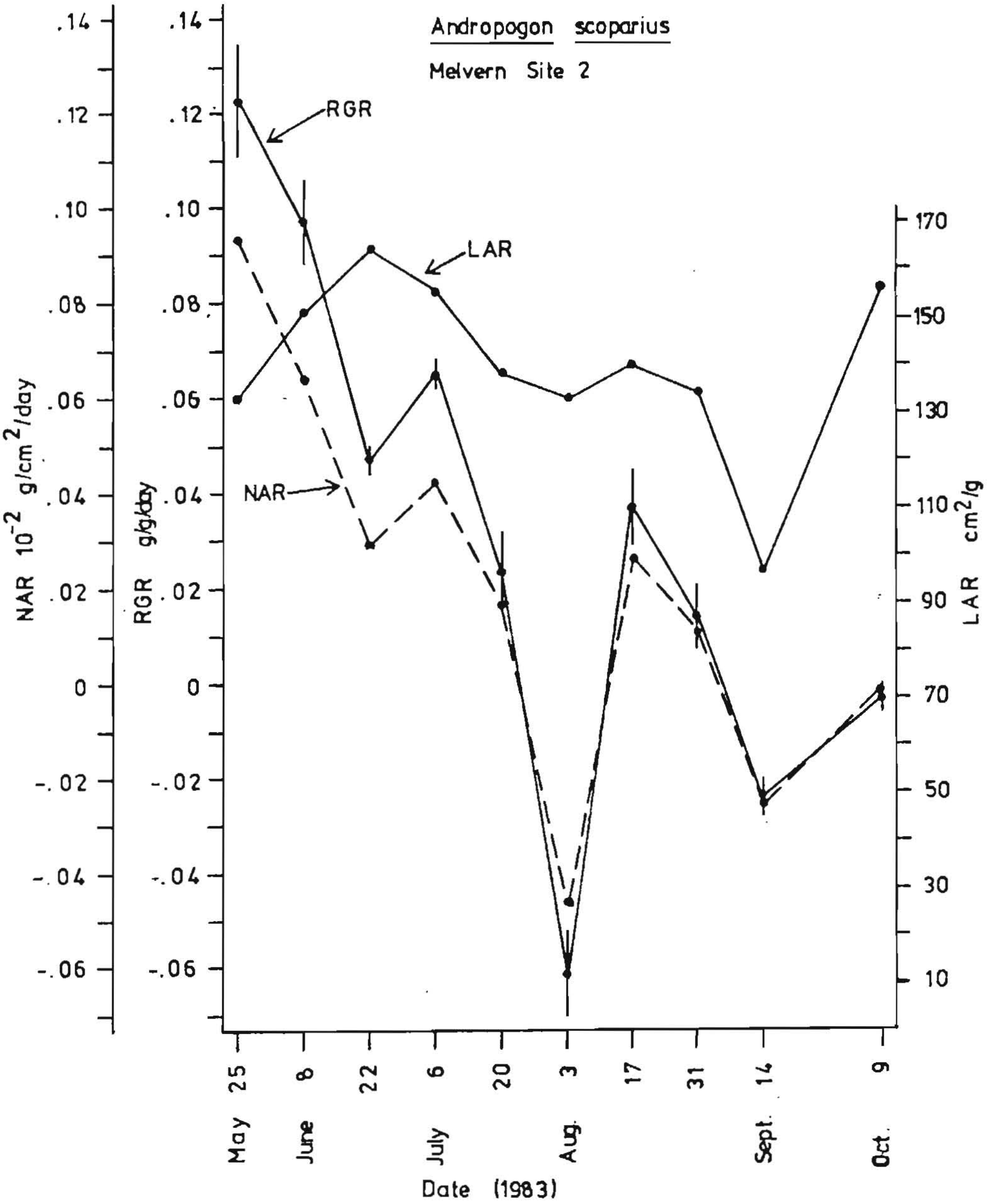

Andropogon scoparius
Melvern Site 2
RGR
LAR
NAR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
170
150
130
110
90
70
50
30
10
May 25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 36. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for *Andropogon scoparius* at Mayo site 1. 95 % confidence intervals are shown on the RGR.

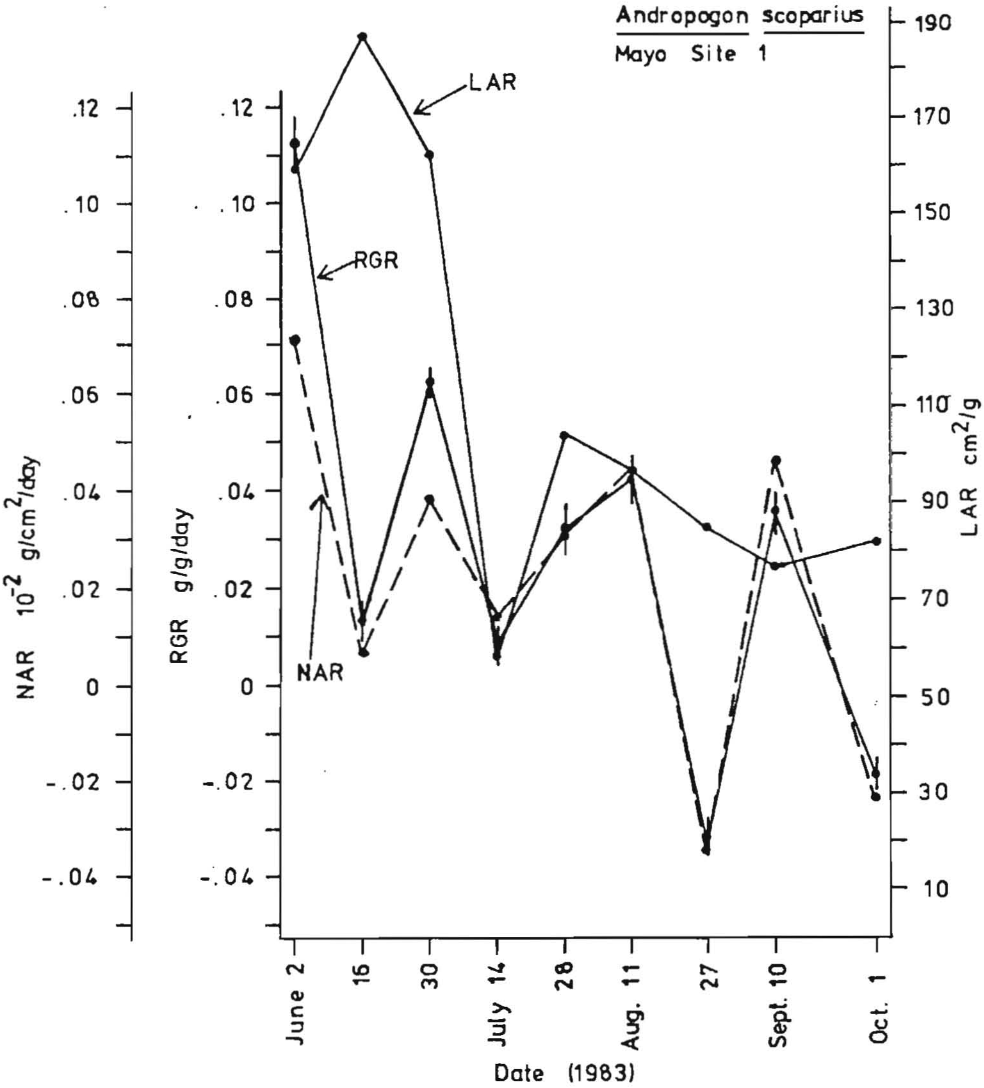

Andropogon scoparius
Mayo Site 1
LAR
RGR
NAR
NAR 10-2 g/cm2/day
RGR g/g/day
LAR cm2/g
.12
.10
.08
.06
.04
.02
0
-.02
-.04
190
170
150
130
110
90
70
50
30
10
June 2
16
30
July 14
28
Aug. 11
27
Sept. 10
Oct. 1
Date (1983)

Figure 37. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for _Andropogon_ _scoparius_ at Mayo site 2. 95 % confidence intervals are shown on the RGR.

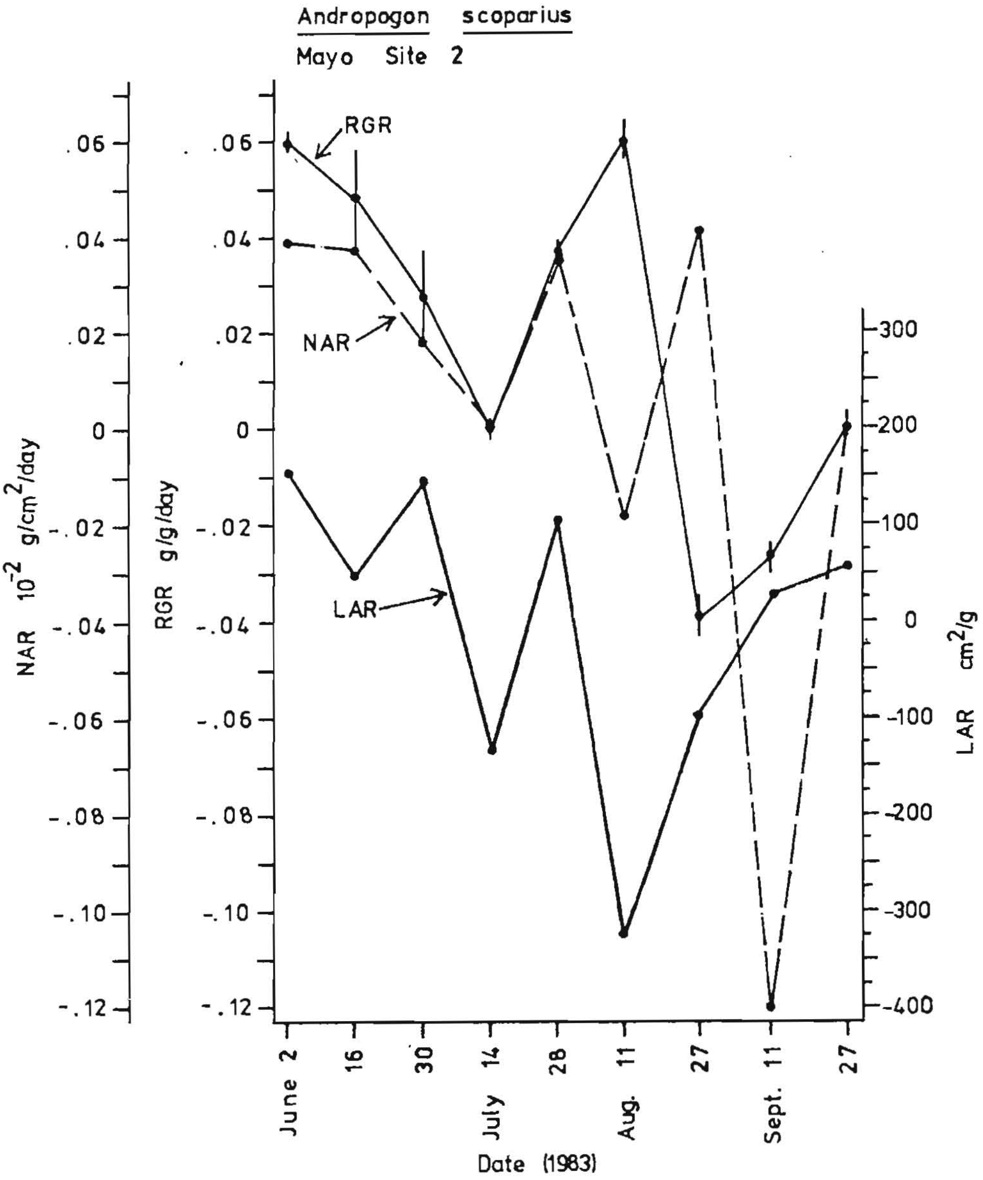

Andropogon scoparius
Mayo Site 2
RGR
NAR
LAR
NAR 10^-2 g/cm^2/day
RGR g/g/day
LAR cm^2/g
.06
.04
.02
0
-.02
-.04
-.06
-.08
-.10
-.12
300
200
100
0
-100
-200
-300
-400
June 2
16
30
July 14
28
Aug. 11
27
Sept. 11
27
Date (1983)

Figure 38. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for Sorghastrum nutans at Melvern site 1. 95 % confidence intervals are shown on the RGR.

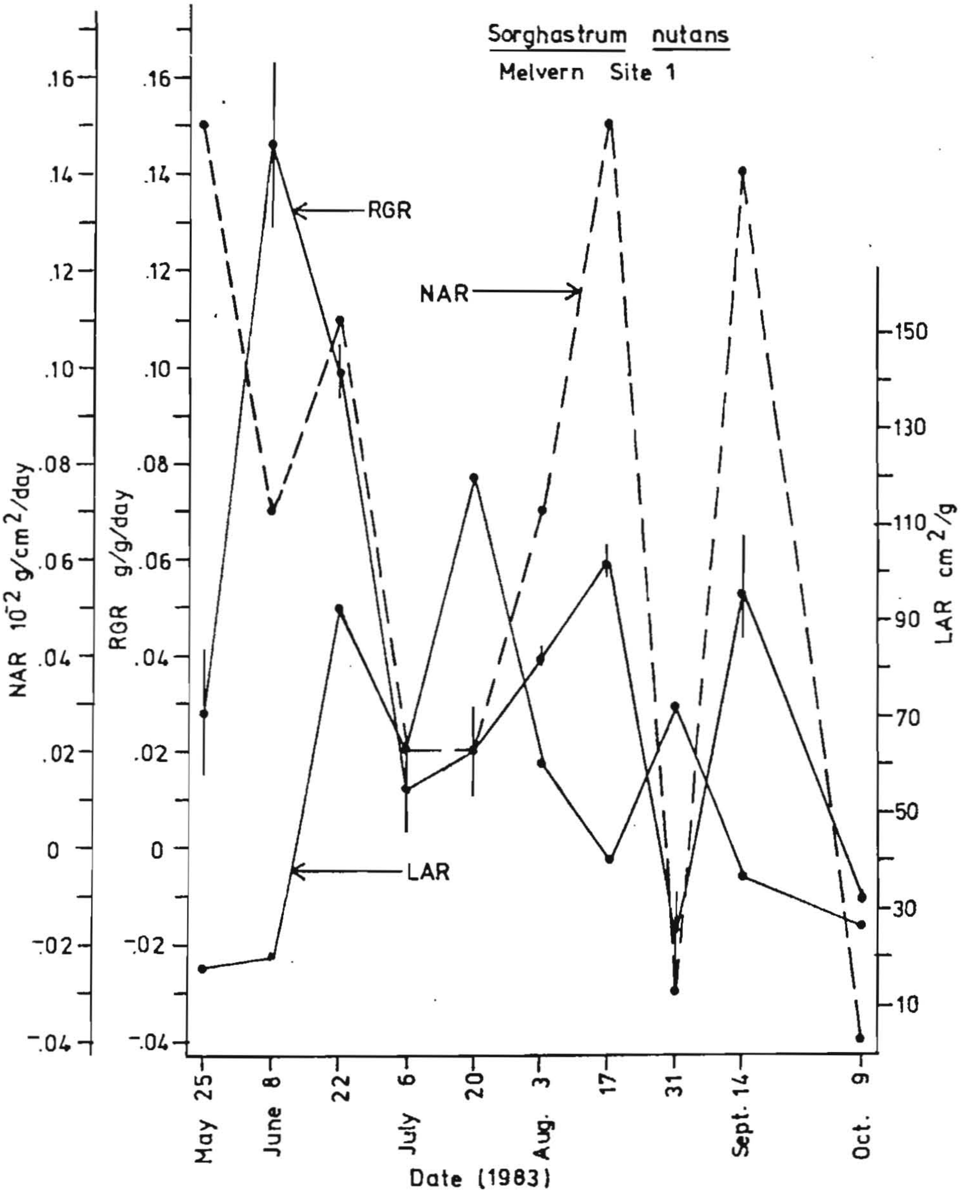

Sorghastrum nutans
Melvern Site 1
RGR
NAR
LAR
NAR 10⁻² g/cm²/day
RGR g/g/day
LAR cm²/g
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
150
130
110
90
70
50
30
10
May 25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 39. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for Sorghastrum nutans at Melvern site 2. 95 % confidence intervals are shown on the RGR.

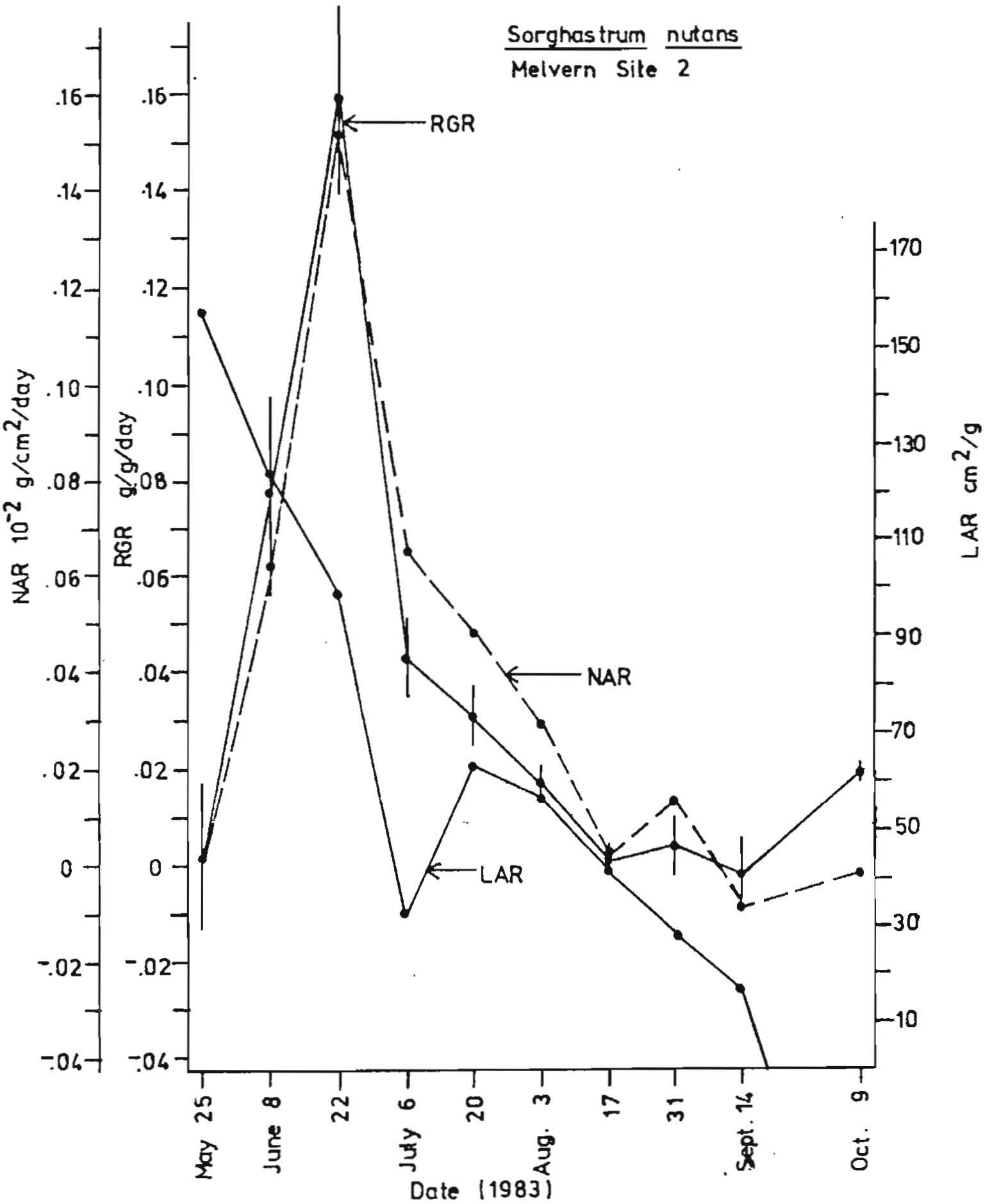

Sorghastrum nutans
Melvern Site 2
RGR
NAR
LAR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
170
150
130
110
90
70
50
30
10
May 25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 40. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for <u>Sorghastrum nutans</u> at Mayo site 1. 95 % confidence intervals are shown on the RGR.

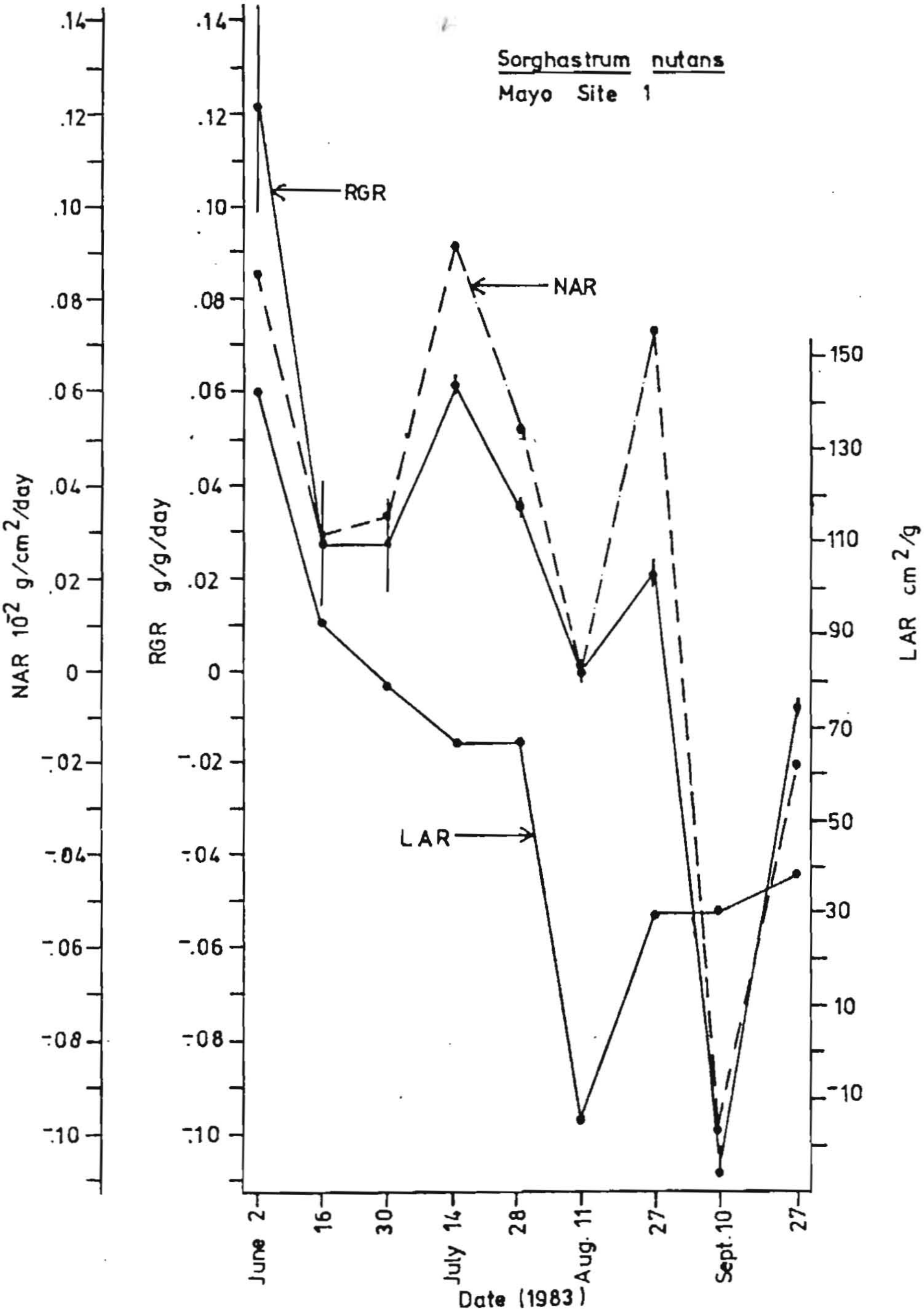

Sorghastrum nutans
Mayo Site 1
RGR
NAR
LAR
NAR 10⁻² g/cm²/day
RGR g/g/day
LAR cm²/g
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
-.08
-.10
150
130
110
90
70
50
30
10
-10
June 2
16
30
July 14
28
Aug. 11
27
Sept. 10
27
Date (1983)

Figure 41. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for *Sorghastrum nutans* at Mayo site 2. 95 % confidence intervals are shown on the RGR.

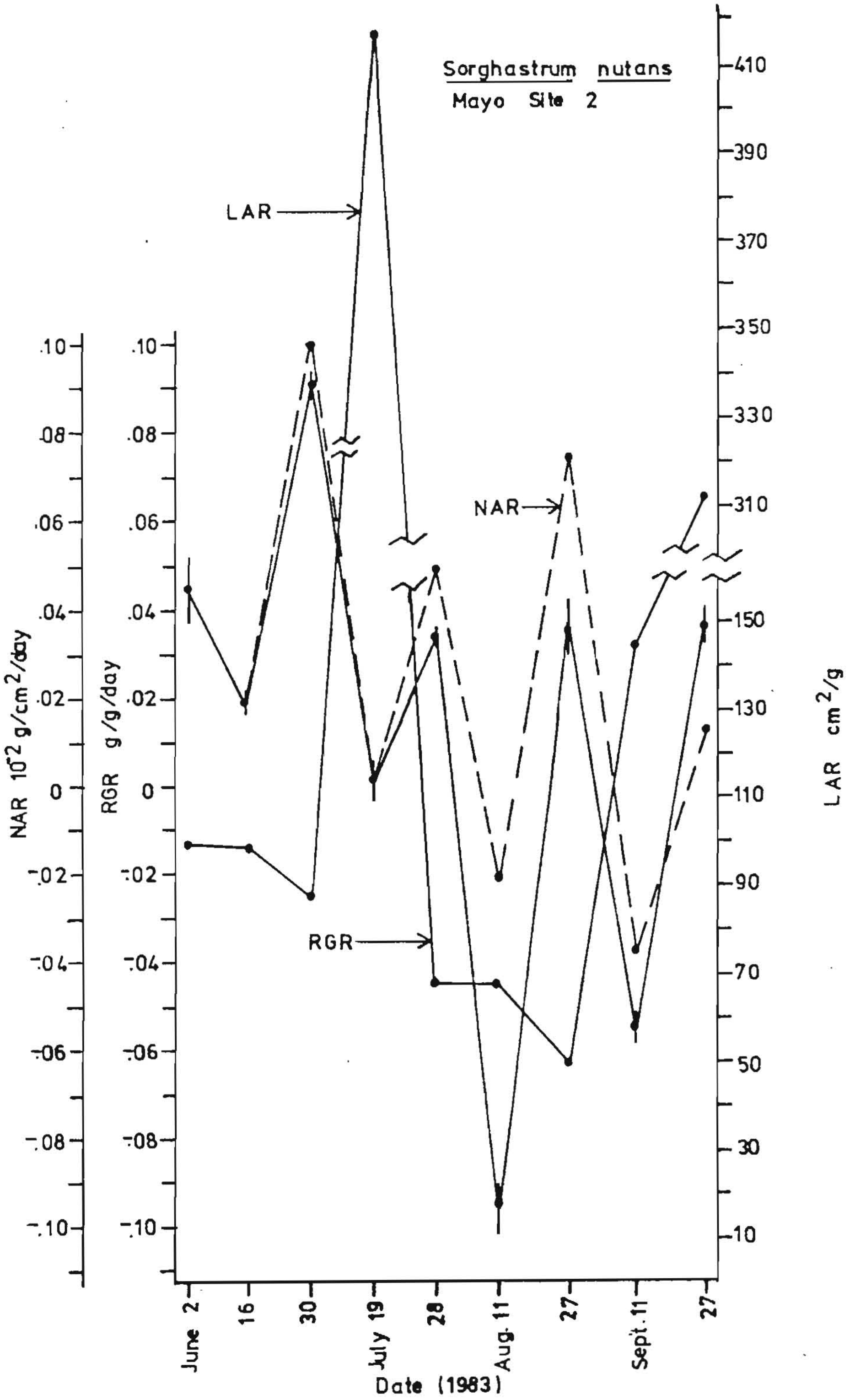

Sorghastrum nutans
Mayo Site 2
LAR
NAR
RGR
NAR 10⁻² g/cm²/day
RGR g/g/day
LAR cm²/g
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
-.08
-.10
410
390
370
350
330
310
150
130
110
90
70
50
30
10
June 2
16
30
July 19
28
Aug. 11
27
Sept. 11
27
Date (1983)

Figure 42. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for *Panicum virgatum* at Melvern site 1. 95 % confidence intervals are shown on the RGR.

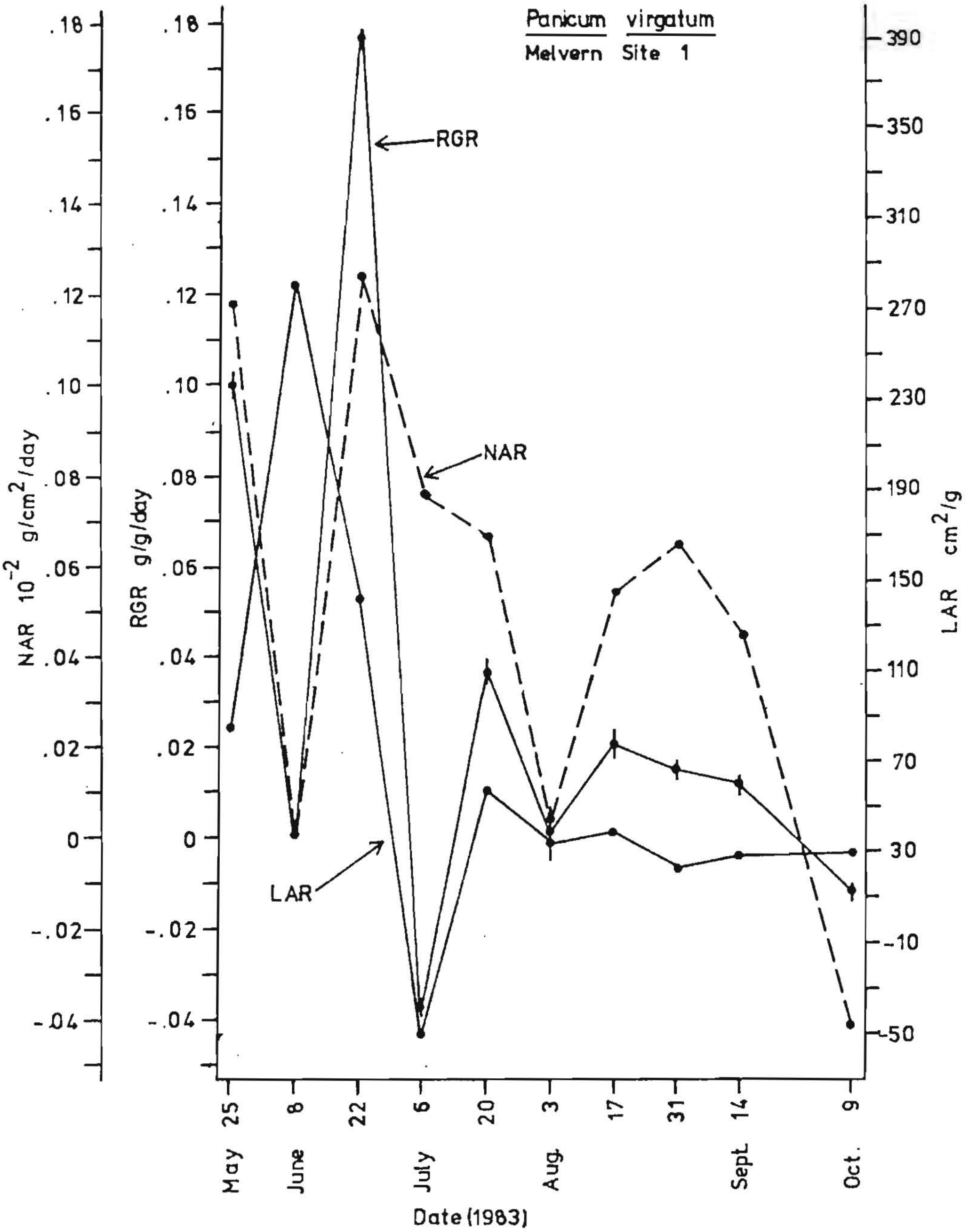

Panicum virgatum
Melvern Site 1
RGR
NAR
LAR
NAR 10^-2 g/cm^2/day
RGR g/g/day
LAR cm^2/g
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
390
350
310
270
230
190
150
110
70
30
-10
-50
May 25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 43. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for *Panicum virgatum* at Melvern site 2. 95 % confidence intervals are shown on the RGR.

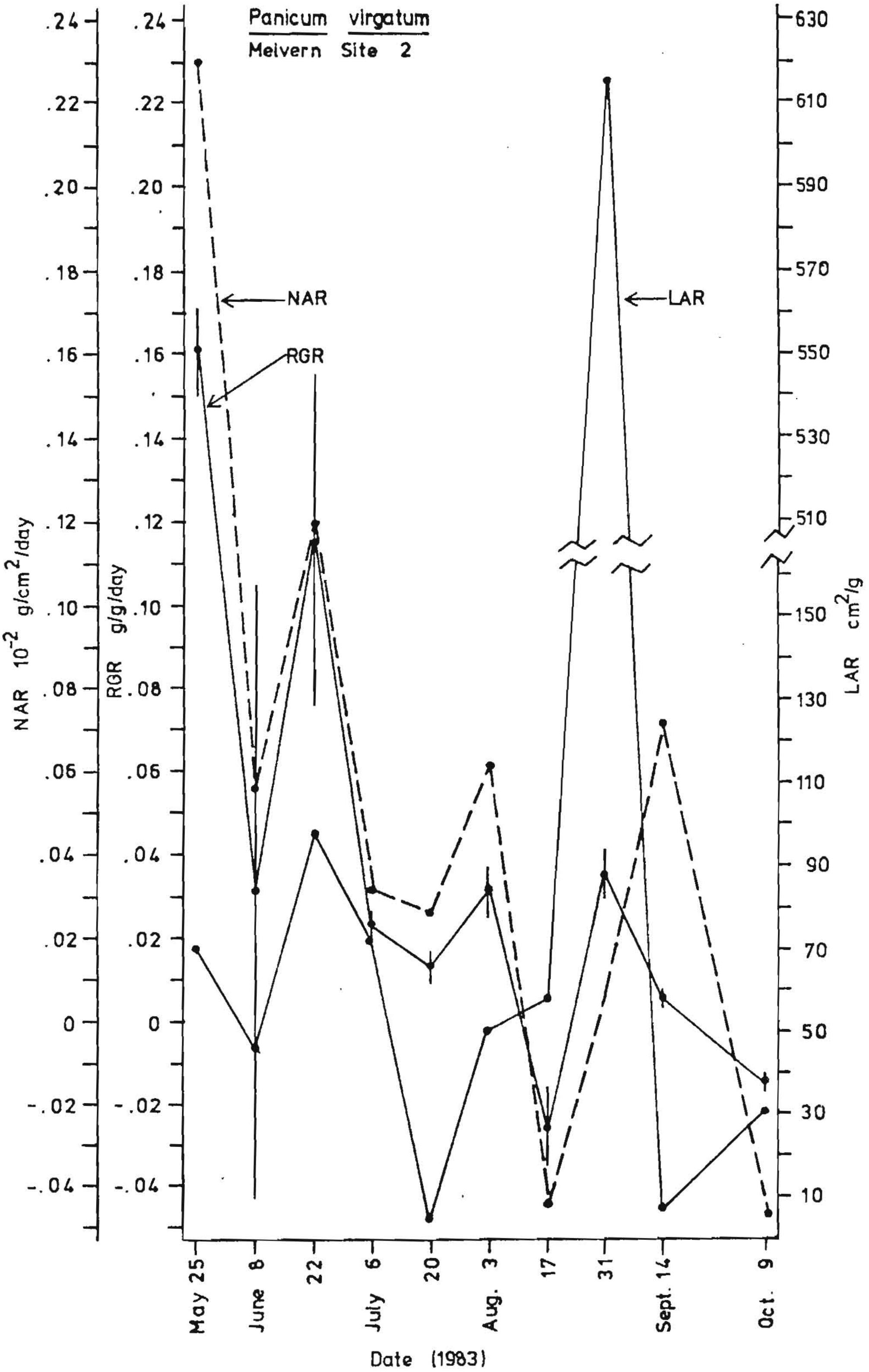

Panicum virgatum
Melvern Site 2
NAR
RGR
LAR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
630
610
590
570
550
530
510
150
130
110
90
70
50
30
10
May 25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

Figure 44. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for Panicum virgatum at Mayo site 1. 95 % confidence intervals are shown on the RGR.

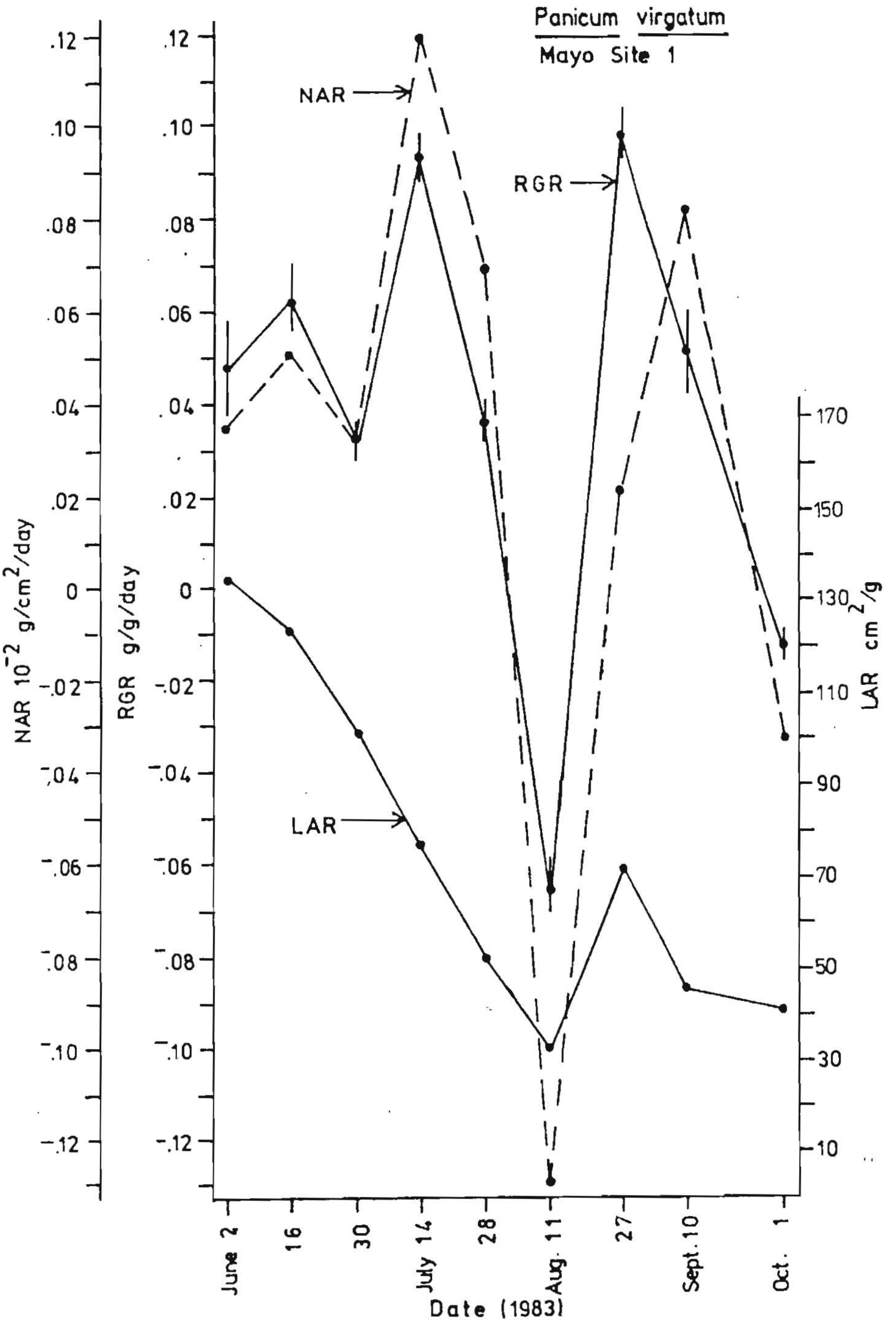

Panicum virgatum
Mayo Site 1
NAR
RGR
LAR
NAR 10⁻² g/cm²/day
RGR g/g/day
LAR cm²/g
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
-.08
-.10
-.12
170
150
130
110
90
70
50
30
10
June 2
16
30
July 14
28
Aug. 11
27
Sept. 10
Oct. 1
Date (1983)

Figure 45. Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) for Panicum virgatum at Mayo site 2. 95 % confidence intervals are shown on the RGR.

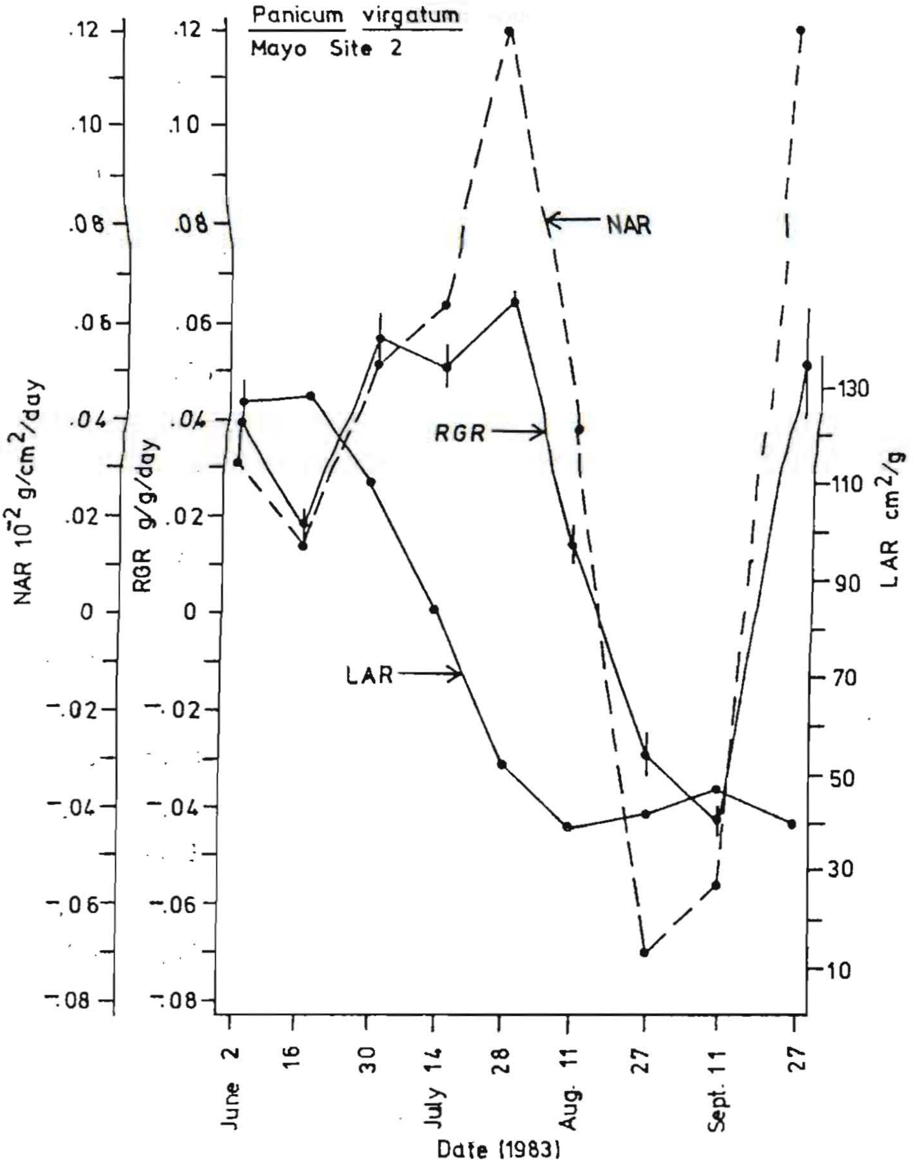
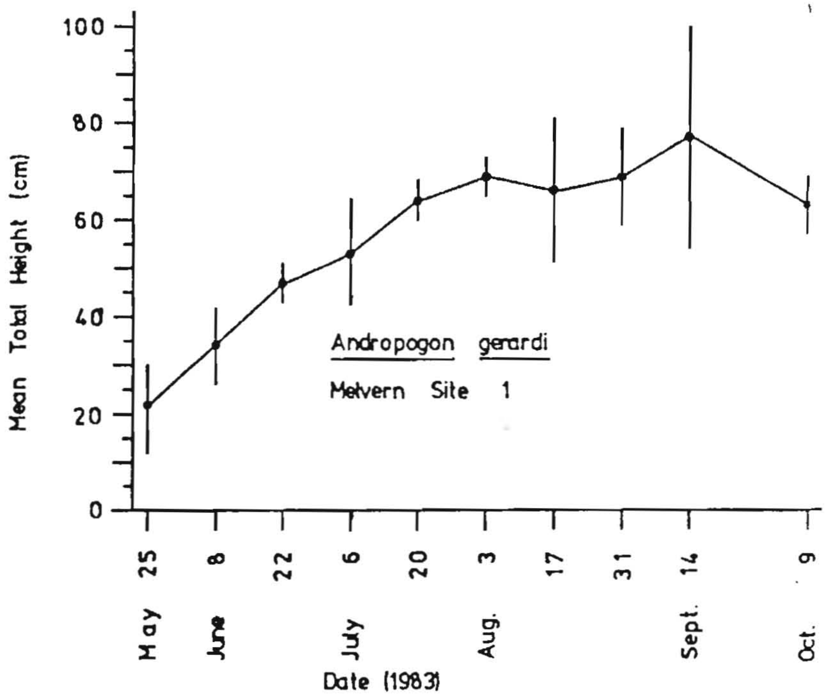

Panicum virgatum
Mayo Site 2
NAR
RGR
LAR
NAR 10^{-2} g/cm^2/day
RGR g/g/day
LAR cm^2/g
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
-.08
130
110
90
70
50
30
10
June 2
16
30
July 14
28
Aug. 11
27
Sept. 11
27
Date (1983)

Figure 46. Mean total heights for <u>Andropogon gerardi</u> at Melvern site 1. 95 % confidence intervals are shown.

Figure 47. Mean total heights for <u>Andropogon gerardi</u> at Melvern site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
100
80
60
40
20
0
Andropogon gerardi
Melvern Site 1
25
8
22
6
20
3
17
31
14
9
May
June
July
Aug.
Sept.
Oct.
Date (1983)

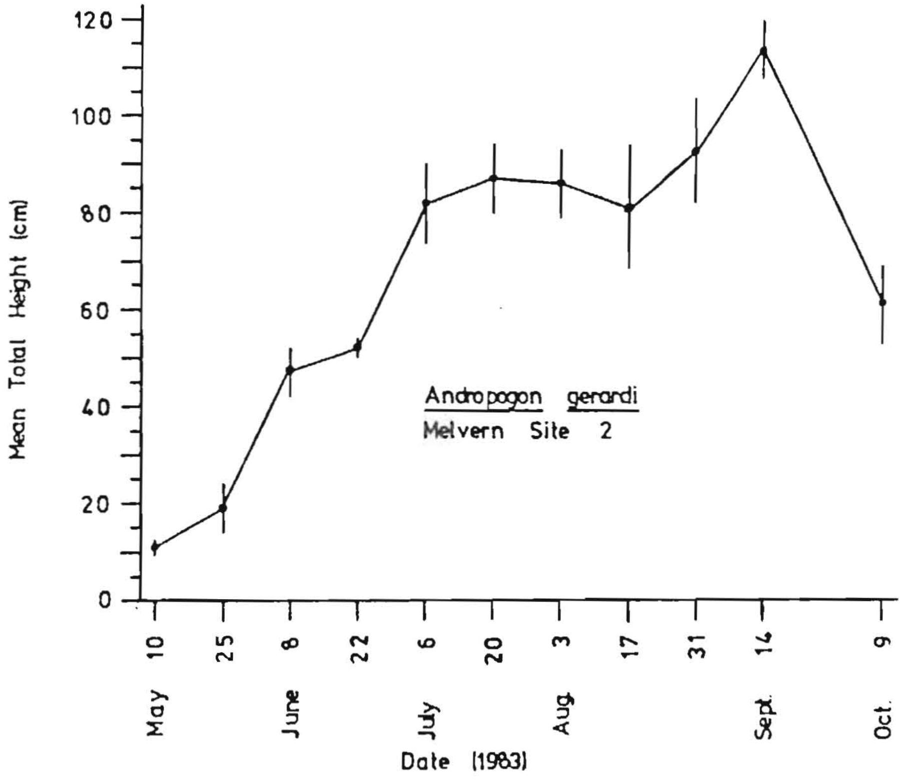
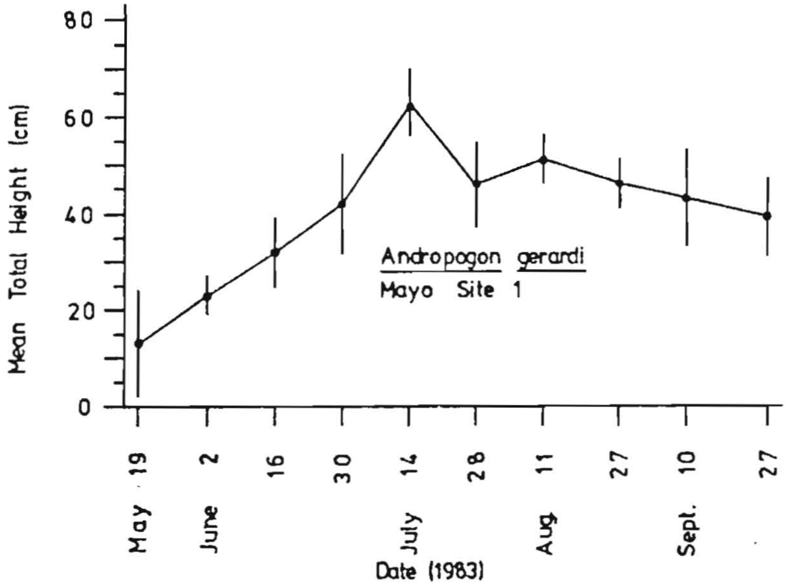

Mean Total Height (cm)
120
100
80
60
40
20
0
Andropogon gerardi
Melvern Site 2
10
25
8
22
6
20
3
17
31
14
9
May
June
July
Aug.
Sept.
Oct.
Date (1983)

Figure 48. Mean total heights for _Andropogon gerardi_ at Mayo site 1. 95 % confidence intervals are shown.

Figure 49. Mean total heights for _Andropogon gerardi_ at Mayo site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
0
20
40
60
80
Andropogon gerardi
Mayo Site 1
May 19
June 2
16
30
July 14
28
Aug. 11
27
Sept. 10
27
Date (1983)

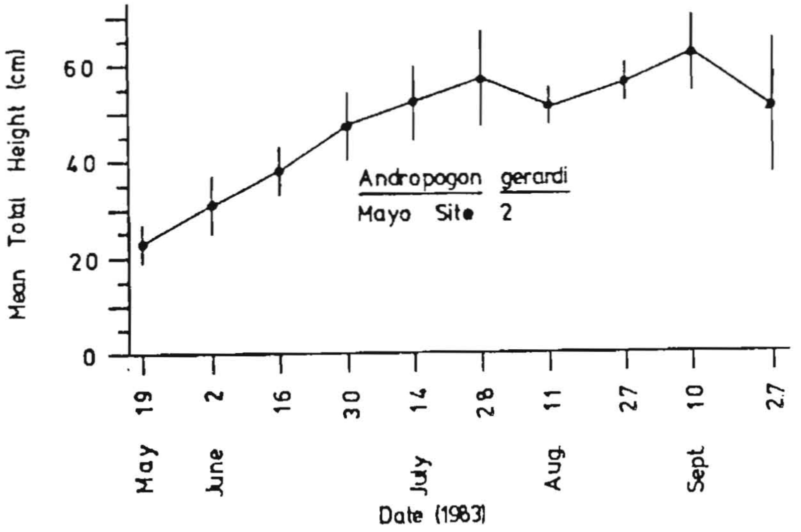
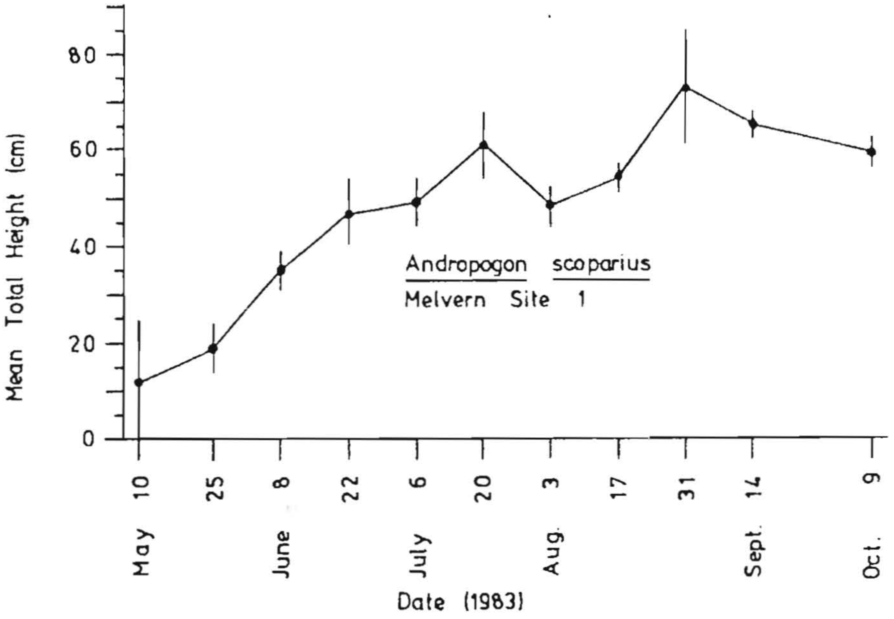

Mean Total Height (cm)
0
20
40
60
Andropogon gerardi
Mayo Site 2
May 19
June 2
16
30
July 14
28
Aug. 11
27
Sept 10
27
Date (1983)

Figure 50. Mean total heights for Andropogon scoparius at Melvern site 1. 95 % confidence intervals are shown.

Figure 51. Mean total heights for Andropogon scoparius at Melvern site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
0
20
40
60
80
Andropogon scoparius
Melvern Site 1
May 10
25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

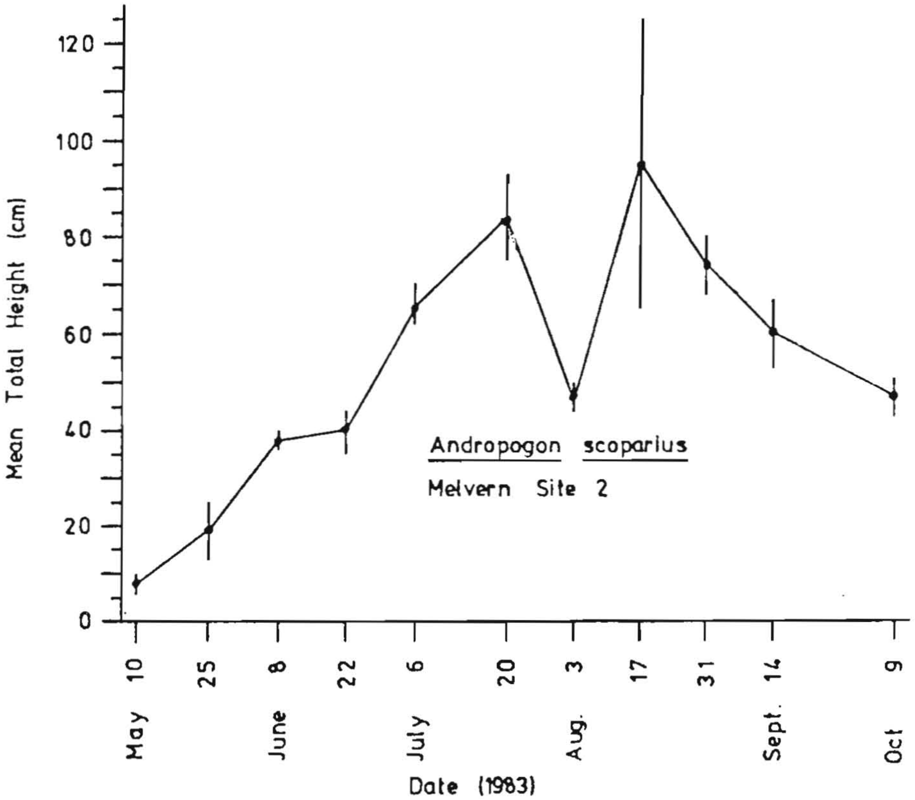
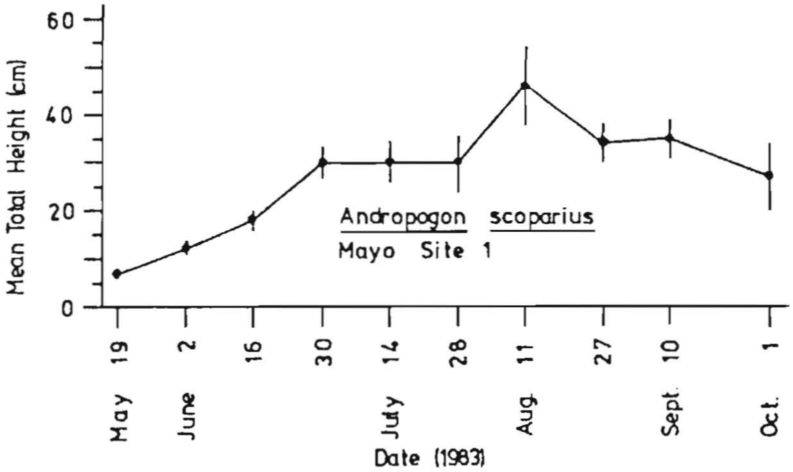

Mean Total Height (cm)
0
20
40
60
80
100
120
Andropogon scoparius
Melvern Site 2
May 10
25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct 9
Date (1983)

Figure 52. Mean total heights for _Andropogon_ _scoparius_ at Mayo site 1. 95 % confidence intervals are shown.

Figure 53. Mean total heights for _Andropogon_ _scoparius_ at Mayo site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
60
40
20
0
Andropogon scoparius
Mayo Site 1
19
2
16
30
14
28
11
27
10
1
May
June
July
Aug.
Sept.
Oct.
Date (1983)

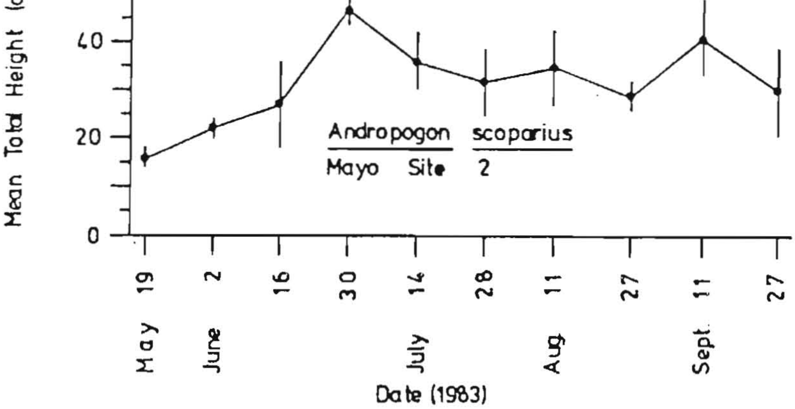
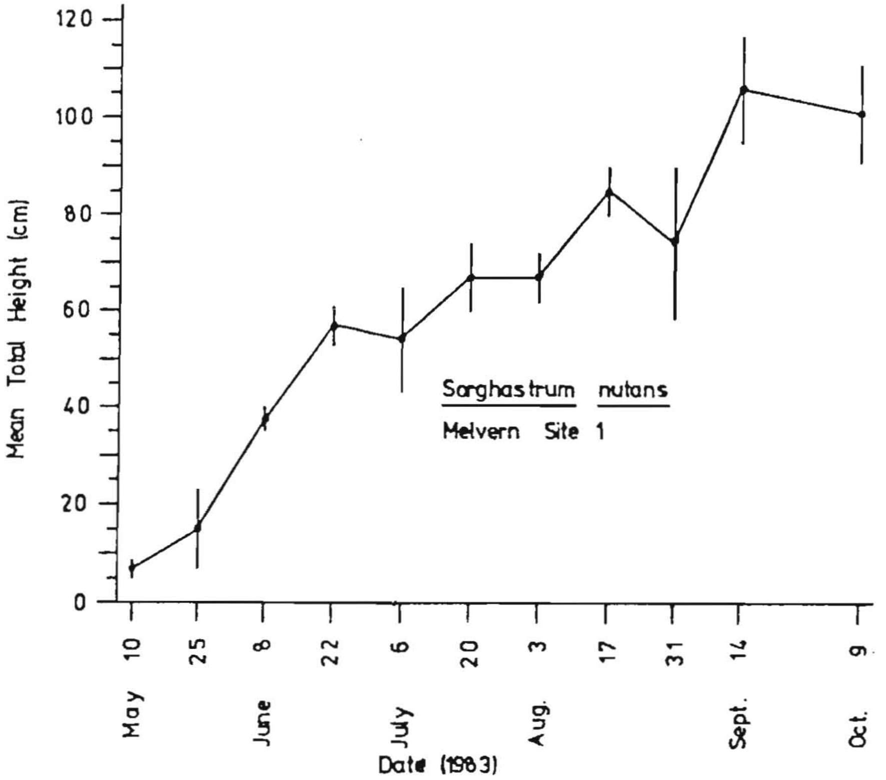

Mean Total Height (cm)
60
40
20
0
Andropogon scoparius
Mayo Site 2
19
2
16
30
14
28
11
27
11
27
May
June
July
Aug.
Sept.
Date (1983)

Figure 54. Mean total heights for Sorghastrum nutans at Melvern site 1. 95 % confidence intervals are shown.

Figure 55. Mean total heights for Sorghastrum nutans at Melvern site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
0
20
40
60
80
100
120
Sorghastrum nutans
Melvern Site 1
May 10
25
June 8
22
July 6
20
Aug. 3
17
31
Sept. 14
Oct. 9
Date (1983)

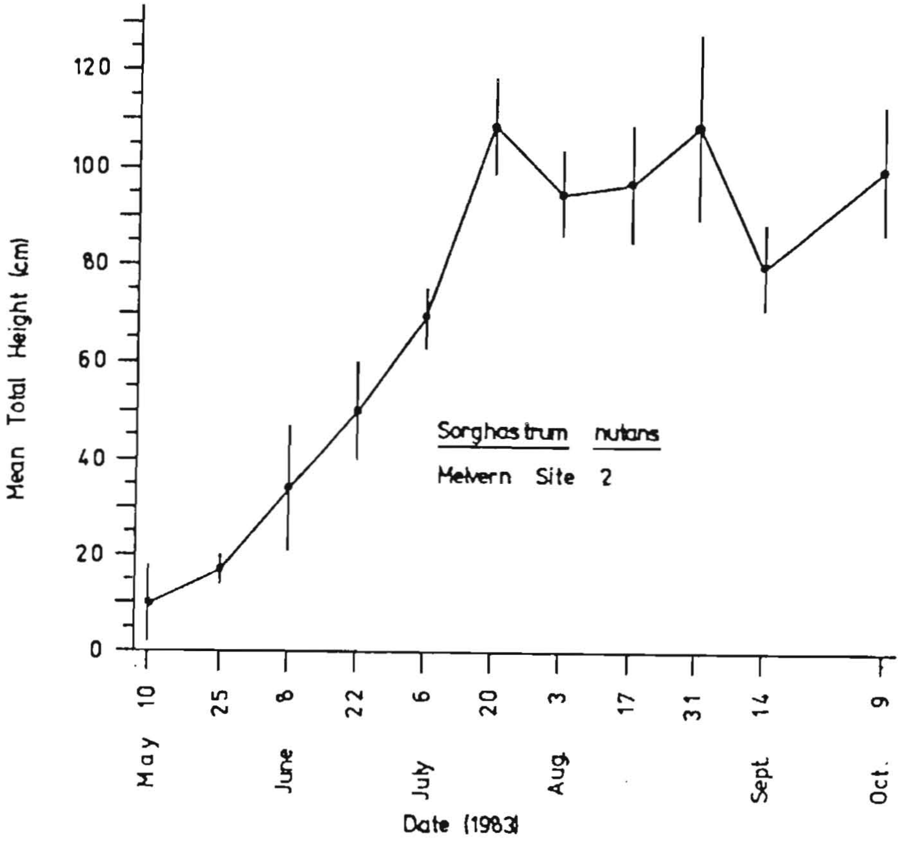
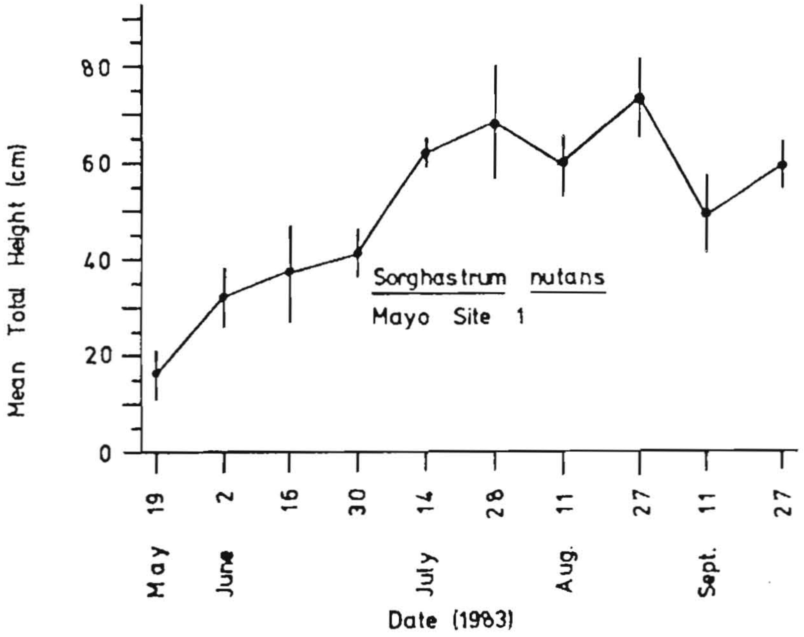

Mean Total Height (cm)
0
20
40
60
80
100
120
Sorghastrum nutans
Melvern Site 2
May 10
25
June 8
22
July 6
20
Aug. 3
17
31
Sept 14
Oct. 9
Date (1983)

Figure 56. Mean total heights for *Sorghastrum nutans* at Mayo site 1. 95 % confidence intervals are shown.

Figure 57. Mean total heights for *Sorghastrum nutans* at Mayo site 2. 95 % confidence intervals are shown.


Sorghastrum nutans
Mayo Site 1
Mean Total Height (cm)
0
20
40
60
80
19
2
16
30
14
28
11
27
11
27
May
June
July
Aug.
Sept.
Date (1983)

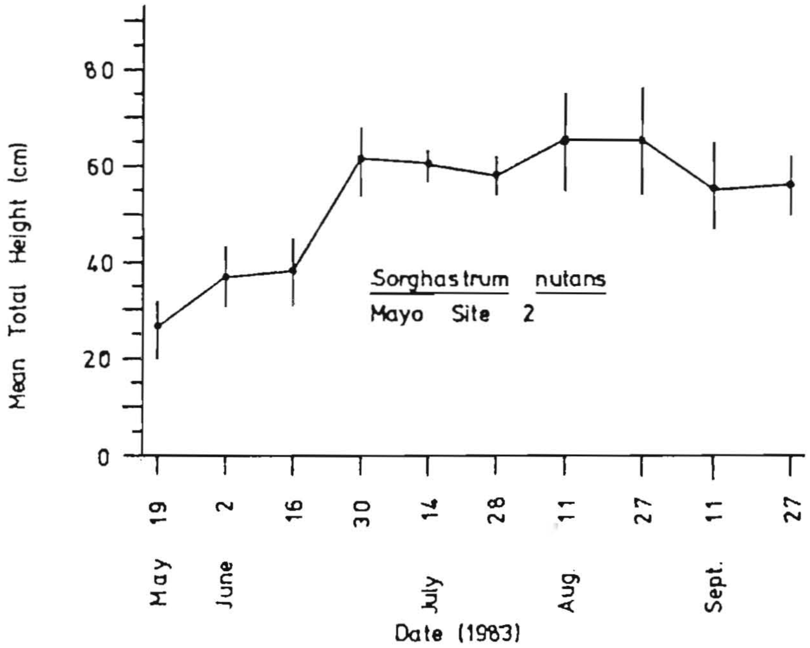
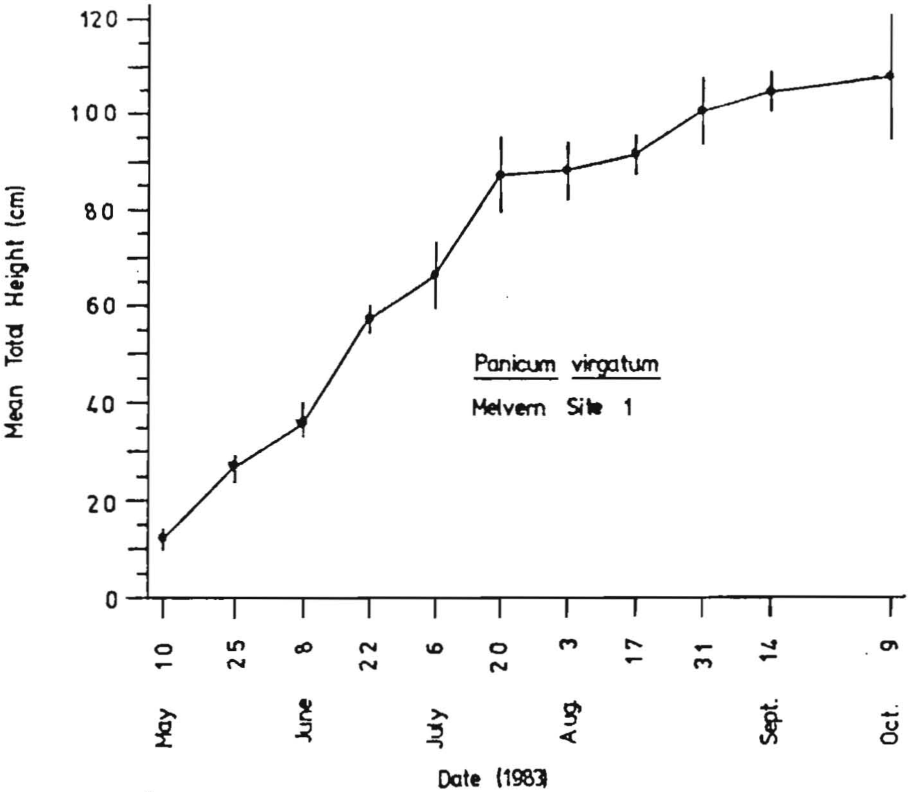

Sorghastrum nutans
Mayo Site 2
Mean Total Height (cm)
0
20
40
60
80
19
2
16
30
14
28
11
27
11
27
May
June
July
Aug.
Sept.
Date (1983)

Figure 58. Mean total heights for Panicum virgatum at Melvern site 1. 95 % confidence intervals are shown.

Figure 59. Mean total heights for Panicum virgatum at Melvern site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
0
20
40
60
80
100
120
Panicum virgatum
Melvern Site 1
10
25
8
22
6
20
3
17
31
14
9
May
June
July
Aug.
Sept.
Oct.
Date (1983)

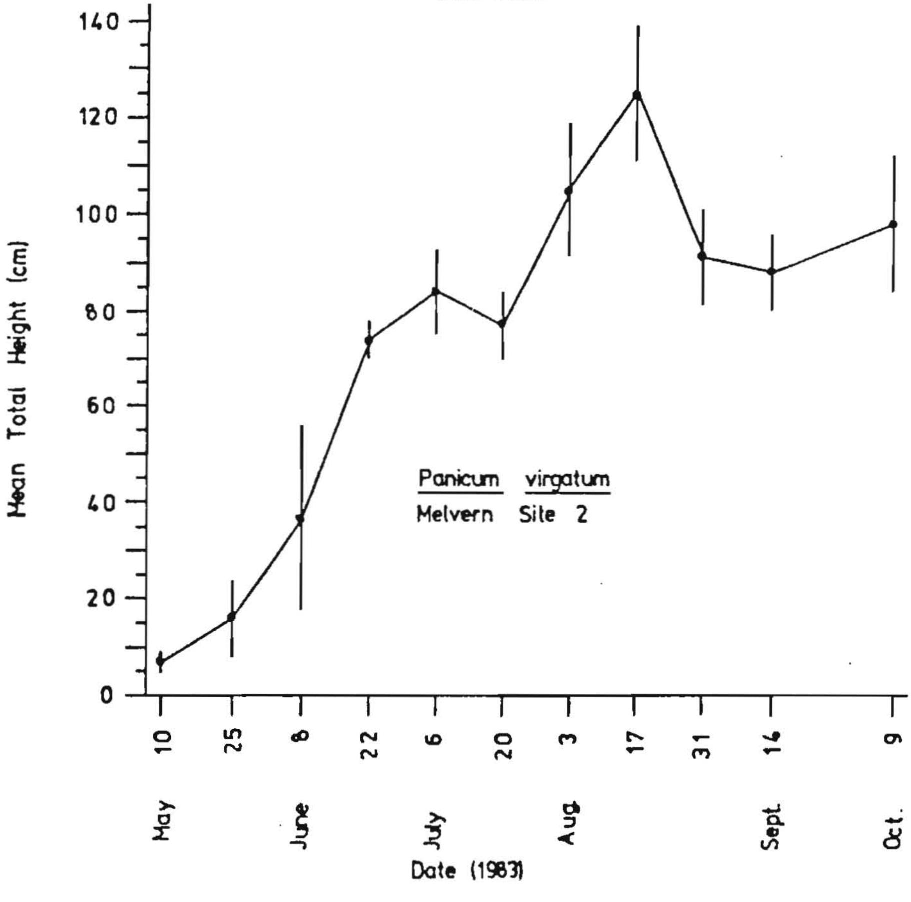
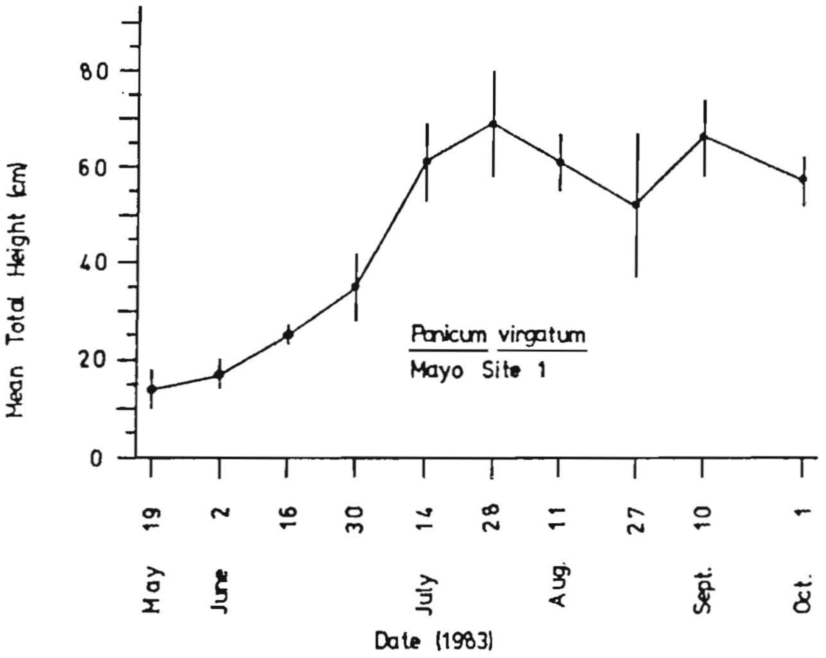
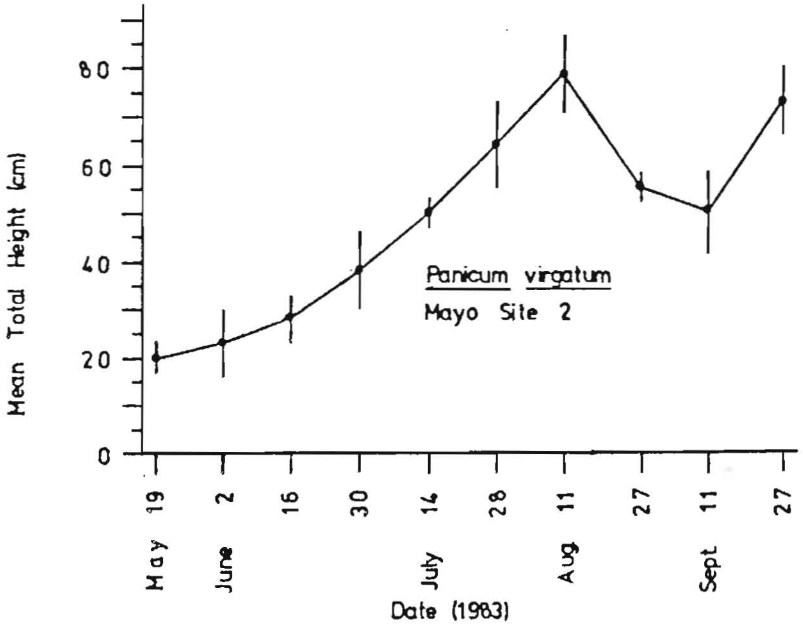

Mean Total Height (cm)
0
20
40
60
80
100
120
140
Panicum virgatum
Melvern Site 2
10
25
8
22
6
20
3
17
31
14
9
May
June
July
Aug.
Sept.
Oct.
Date (1983)

Figure 60. Mean total heights for Panicum virgatum at Mayo site 1. 95 % confidence intervals are shown.

Figure 61. Mean total heights for Panicum virgatum at Mayo site 2. 95 % confidence intervals are shown.


Mean Total Height (cm)
80
60
40
20
0
Panicum virgatum
Mayo Site 1
19
2
16
30
14
28
11
27
10
1
May
June
July
Aug.
Sept.
Oct.
Date (1983)


Mean Total Height (cm)
80
60
40
20
0
Panicum virgatum
Mayo Site 2
19
2
16
30
14
28
11
27
11
27
May
June
July
Aug
Sept
Date (1983)

respiratory activity but are rather a mathematical expression of assimilation. For each species, the NAR closely follows the RGR (see Figures 30-45). This is as one would expect since the rate of growth is dependent upon the rate of assimilation of carbon into the plant body. The leaf area ratios show how the photosynthetic area of the plant change in relation to changes in the weight of the plant.

As can be seen in Table 10, the maximum RGR for most of the plants at the various sites was in May and June. Since these months were the most favorable in regard to precipitation and temperature, these results are as expected. *Panicum virgatum* at both Mayo sites did not reach its maximum RGR until July 28 (Mayo site 2) and August 27 (Mayo site 1). However, if the RGR graphs in Figures 44 and 45 are studied, it can be seen that in June and July the RGR's were nearly as high as the July 28 and August 27 RGR's. Since 1983 was an unfavorable growing year, most of the plants did not produce an inflorescence. It is possible that in a favorable year when the plants do produce an inflorescence, a second maximum RGR peak might occur in the late summer during the flowering period. In 1983, *P. virgatum* was the only species which produced any flowering stalks at all; this may account for its late summer maximum RGR's at the two Mayo sites. However, *P. virgatum* at the Melvern sites produced rather vigorous flowering stalks and they did not show a late summer maximum RGR peak. *A. scoparius* at Mayo site 2 showed a late summer maximum RGR peak as well as the early summer peak, even though it produced no inflorescences.

The minimum RGR's nearly all occurred in the latter part of the summer (Table 10) when precipitation was at its lowest and temperatures were at their highest.

Table 10. The dates and values of the maximum and minimum relative growth rates (RGR) in g/g/day for *Andropogon gerardi* (Ange), *A. scoparius* (Ansc), *Sorghastrum nutans* (Sonu), and *Panicum virgatum* (Pavi) at Melvern site 1 (ME 1), Melvern site 2 (ME 2), Mayo site 1 (MY 1), and Mayo site 2 (MY 2).

	Max. RGR	Min. RGR
Ansc		
ME 1	June 8 (.077)	Aug. 3 (-.025)
ME 2	May 25 (.123)	Aug. 3 (-.061)
MY 1	June 2 (.113)	Aug. 27 (-.03)
MY 2	June 2 (.060) Aug. 11	Aug. 27 (-.039)
Ange		
ME 1	June 22 (.209)	Oct. 9 (-.028)
ME 2	May 25 (.131)	Oct. 9 (-.054)
MY 1	June 16 (.044)	Sept. 27 (.027)
MY 2	June 2 (.124)	Aug. 11 (-.031)
Sonu		
ME 1	June 8 (.145)	Aug. 31 (-.020)
ME 2	June 22 (.150)	Sept. 14 (-.002)
MY 1	June 2 (.121)	Sept. 10 (-.107)
MY 2	June 30 (.091)	Aug. 11 (-.096)
Pavi		
ME 1	June 22 (.177)	July 6 (-.037)
ME 2	May 25 (.161)	Aug. 17 (-.026)
MY 1	Aug. 27 (.098)	Aug. 11 (-.066)
MY 2	July 28 (.065)	Sept. 11 (-.043)

As the RGR data was being collected in 1983, it looked as though the plants at the Melvern sites were quite a bit taller than the plants at the Mayo sites. Because of this it was theorized that the plants at the two sites might be different in overall size, yet have similar relative growth rates. Further, it was thought that these differences in overall sizes might be an adaption to a drier habitat in the case of the Mayo sites and a slightly wetter habitat in the case of the Melvern sites.

To see if these differences were in fact real, student t tests at the p = .05 level of signifigance were used to analyze the data. The results of these tests are shown in Table 11. As expected, the RGR's were not significantly different when any species from the Melvern sites was compared to the same species at the Mayo sites. However, when the total height data for the two sites was compared by the student t test, only a very few resulted in a significant difference. Thus, <u>no</u> overall size difference between plants of the two sites. It was then thought that maybe the mean dry weights or the leaf area ratios might reflect differences in overall sizes between plants of the same species at the two sites. But, as can be seen in Table 11, only a few of these tests resulted in significant differences.

Despite the results of these tests, it is felt that this theory warrants further investigation. In a favorable year, such differences may be more pronounced. It is also felt that if plants of each species from each site are placed in a growth chamber and subjected to exactly the same conditions of light, temperature, and moisture, greater differences might be evident. This type of laboratory work could possibly lead to the discovery of different chromosome races of the various

Table 11. Results of student t tests at the p = .05 level of signifigance for relative growth rates (RGR), leaf area ratios (LAR), mean total heights, and mean dry weights of *Andropogon gerardi* (Ange), *A. scoparius* (Ansc), *Sorghastrum nutans* (Sonu), and *Panicum virgatum* (Pavi) at Melvern site 1 (ME 1), Melvern site 2 (ME 2), Mayo site 1 (MY 1), and Mayo site 2 (MY 2).

Test	RGR	LAR	Mean Total Heights	Mean Total Weights
Ange				
ME 1 vs. ME 2	Sig. Diff.	Not Sig.	Not Sig.	Not Sig.
ME 1 vs. MY 1	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 1 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 2 vs. MY 1	Not Sig.	Not Sig.	Sig. Diff.	Not Sig.
ME 2 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
MY 1 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
Ansc				
ME 1 vs. ME 2	Not Sig.	Sig. Diff.	Not Sig.	Not Sig.
ME 1 vs. MY 1	Not Sig.	Not Sig.	Sig. Diff.	Not Sig.
ME 1 vs. MY 2	Not Sig.	Not Sig.	Sig. Diff.	Not Sig.
ME 2 vs. MY 1	Not Sig.	Not Sig.	Sig. Diff.	Sig. Diff.
ME 2 vs. MY 2	Not Sig.	Sig. Diff.	Not Sig.	Sig. Diff.
MY 1 vs. MY 2	Not Sig.	Sig. Diff.	Not Sig.	Not Sig.
Sonu				
ME 1 vs. ME 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 1 vs. MY 1	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 1 vs. MY 2	Not Sig.	Sig. Diff.	Not Sig.	Not Sig.
ME 2 vs. MY 1	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 2 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
MY 1 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
Pavi				
ME 1 vs. ME 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 1 vs. MY 1	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 1 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
ME 2 vs. MY 1	Not Sig.	Not Sig.	Sig. Diff.	Not Sig.
ME 2 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.
MY 1 vs. MY 2	Not Sig.	Not Sig.	Not Sig.	Not Sig.

species at the different sites.

Finally in regard to RGR's, it was hoped that the t tests would reflect differences between range condition classes due to differences in plant density and vigor. The only RGR's that were significantly different (Table 11) were those of Andropogon gerardi between Melvern site 1 (excellent condition) and Melvern site 2 (fair condition). These two sites were the most different in regard to range condition. It is possible that the other sites did not show differences in RGR because they were too closely related in range condition. It is suggested, therefore, that a very poor condition range and a very excellent condition range be studied in regard to RGR as a follow-up to this study. Such a wide range of condition classification may better reflect differences in RGR.

Thus, it is felt that RGR measurements are a good method for evaluating possible differences in range grasses, even though it is a very time consuming task.

SUMMARY

A scorecard method for determining range condition was developed for general application in the tallgrass prairie of east central Kansas. The method is simple, practical, fast, and easy-to-learn. It is chiefly intended for use by nonprofessional range managers, but can also be used by professional range managers. The scorecard method is preferred over reconnaisance and ocular estimate methods because it forces a closer examination of the range site and because it provides an accurate record of vegetation composition and range condition.

The method involves the collection of data concerning vegetation composition and density by the step-loop method. Step-loop data is entered into a scorecard for vegetation condition and a scorecard for soil stability condition to determine the condition classification (excellent, good, fair, or poor) of both vegetation and soil.

The step-loop data was shown to indicate the same trends in range condition as clipping by the frame-point method did and as basal density estimates did. As the number of step-loop hits on decreaser species plus increaser species increased, so did the dry-weight production in lbs/acre (determined by clipping) and so did the basal vegetation density. Because of these trends, it was felt that the step-loop method can be a reliable index to vegetation density and composition. In addition, the per cent of basal density of vegetation and the per cent of litter was shown to be less on grazed sites than on ungrazed sites.

Two types of poor and fair condition classes were noted -- those that result from woody invasion and those that result from the impact of overgrazing on herbaceous vegetation.

Since range condition trends are often dependent upon the degree of range utilization, a method for determining range utilization was developed. Since the greatest biomass of a grass plant is nearest the ground, it is necessary to express forage utilization as a percentage of weight removal rather than height removal. The stubble height method, which is an expression of the per cent of dry weight remaining throughout the height of the plant, was developed for use in the tallgrass prairie. Stubble height curves were developed for both favorable and unfavorable growing years for Andropogon gerardi Vitman., Andropogon scoparius Michx., Sorghastrum nutans (L.) Nash., and Panicum virgatum L. A favorable year is one in which seedstalks are produced abundantly and an unfavorable year is one in which seedstalks are not produced abundantly. In addition, the growth form of each of these species was graphically illustrated in terms of the per cent of forage throughout the height of the plant.

The close relationship between range condition and range utilization cannot be ignored. The degree of range utilization often determines range condition. In turn, range condition is a factor in determining stocking rates and therefore range utilization. Since both contribute to the trend (i.e. change) of a range site, yearly monitoring of both is necessary for proper range management.

Since range condition is partially dependent upon vegetation density and since the growth rates of some plants have been shown to be density dependent (Clatworthy and Harper, 1962), relative growth rates (RGR) of native tall grasses were measured in hopes that they would reflect density dependent differences between range condition classes. It was also theorized that RGR's of the various grass species may be similar at the two major study sites and yet the plants be rather different in mean total heights, mean dry weights, or leaf area ratios.

Student t tests at the p = .05 level of significance indicated that there was no significant difference between the RGR's of 23 of the 24 condition class comparisons. When mean total heights were analyzed by the student t test, it was discovered that there was no significant difference between 19 of the 24 comparisons. In addition, 22 of the 24 mean dry weight comparisons and 20 of the 24 leaf area ratio comparisons were not significantly different.

In general maximum RGR's occurred in May and June when temperatures were favorable and precipitation was high. Minimum RGR's generally occurred in August and September when temperatures were at their highest and precipitation was at its lowest.

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APPENDIX A

Calculation of Relative Growth Rate and Statistical Analysis

1. Given the basic equation where W = oven-dry weight and t = time (Harper, 1977):

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$ expressed as g/g/day.

Let n_1 = the number at t_1 and n_2 = the number at t_2 then:

$$\overline{\log_e W_1} = \frac{\sum_{i=1}^{n_1} \log_e W_i}{n_1} \text{ and } \overline{\log_e W_2} = \frac{\sum_{j=1}^{n_2} \log_e W_j}{n_2}$$

Therefore,

$$RGR = \frac{\overline{\log_e W_2} - \overline{\log_e W_1}}{t_2 - t_1}$$ (Wyckoff, 1983)

2. Variance is calculated as follows:

$$s_1^2 = \frac{\sum_{i=1}^{n_1} \left[\log_e W_i\right]^2 - n_1 \left[\overline{\log_e W_1}\right]^2}{n_1 - 1}$$

$$s_2^2 = \frac{\sum_{j=1}^{n_2} \left[\log_e W_j\right]^2 - n_2 \left[\overline{\log_e W_2}\right]^2}{n_2 - 1}$$ (Wyckoff, 1983)

3. Pooled variance is calculated as follows:

$$s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$ (Wyckoff, 1983)

4. Standard deviations is calculated as follows:

$$s = \frac{s^2}{t}\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$ (Wyckoff, 1983)

5. Standard error of the mean is calculated as follows:

$S_{\overline{X}} = \frac{s}{n}$ (Wyckoff, 1983)

6. Confidence intervals are calculated as follows:

$C.I. = S_{\overline{X}} \, (t_{.05})$ (Wyckoff, 1983)

APPENDIX B

APPENDIX B

RECORD OF STEP-LOOPS
AND
CONDITION CLASS ANALYSIS

Date 10-16-83

Transect No. 2

Soil Type Clareson- Eram

Examiner S. Wilk

Location Melvern Site 2

SCS Range Site Shallow Flats -Loamy Upl

DECREASERS

Sonu Γ. ⑥
Pavi Γ. ⑥
Ange ⊠ ⑬
Scsc ⊠ Γ ⑰
Amca : ②
Ros : ②

INCREASERS

CAR : ②
Pax : ②

INVADERS

Syor ∴ ③
Rhgl : ②

ROCK · ①

LITTER ⊠ ⊠ ⊠ ⊠ : ㊷

BAREGROUND : ②

Bareground	2
Rock	1
Litter	42
Plant Density Index	55
Total	100

Forage Density Index 50
(No. of decreasers + increasers)

Ground Cover Index 98
(100 - no. hits on bareground)

CONDITION CLASSIFICATION

VEGETATION:

Forage Density Index	5
Composition	4
Total	9

Condition Class Fair +

SOIL:

Erosion Hazard Index	8
Current Erosion	12
Total	20

Condition Class Excellent -

OVERALL RANGE CONDITION: Fair +

NOTES:

Large colony of Rhgl present on this site as well as several other woody invaders including Syor, COR, Gltr

APPENDIX C

APPENDIX C

Table 1. Step-loop data and ocular estimates for Melvern site 1. The figures shown for the ocular estimates are the mean of the ten plots sampled at each transect.

	STEP-LOOPS		
	TRANSECT A	TRANSECT B	AVERAGE
DECREASERS			
Sonu	17	23	20
Pavi	16	11	13.5
Ange	13	12	12.5
Ansc	31	30	30.5
Spas		1	.5
Frvi	1		.5
		TOTAL AVERAGE DECREASERS. .	77.5
INCREASERS			
CAR	1	1	1
Pasc	2	2	2
Arlu	1		.5
		TOTAL AVERAGE INCREASERS. .	3.5
ROCK			
LITTER	18	29	19
BAREGROUND			
		OCULAR ESTIMATES (%)	
ROCK	0	0	0
LITTER	33	13.5	23.25
BAREGROUND	0	0	0
BASAL COVER	67	86.5	76.75

Table 2. Total pounds per acre dry weight production for Melvern site 1.

	TRANSECT A		TRANSECT B		AVERAGE	
	lbs/A	%	lbs/A	%	lbs/A	%
DECREASERS						
Sonu	113.82	14.10	251.87	23.85	182.85	19.63
Pavi	99.70	12.35	139.38	13.20	119.54	12.84
Ange	70.31	8.71	49.60	4.70	59.96	6.44
Ansc	511.24	63.34	591.61	56.03	551.43	59.21
Spas			11.67	1.11	5.84	0.63
Frvi	3.06	0.38			1.53	0.16
Forbs			0.55	0.05	0.28	0.03
TOTAL AVERAGE DECREASERS. . .					921.63	98.94
INCREASERS						
CAR	1.02	0.13	2.37	0.22	1.70	0.18
Pasc	7.55	0.94	5.19	0.49	6.37	0.68
Arlu			1.04	0.10	0.52	0.06
Acmi	0.41	0.05			0.20	0.03
AST			0.82	0.08	0.41	0.04
TOTAL AVERAGE INCREASERS. . .					9.20	0.98
INVADERS						
BRO			1.68	0.16	0.84	0.09
TOTAL AVERAGE INVADERS. . . .					0.84	0.09
GRAND TOTALS	807.11 lbs/A		1055.84 lbs/A		931.27 lbs/A	

Table 3. Step-loop data and ocular estimates for Melvern site 2. The figures shown for the ocular estimates are the mean of the ten plots sampled at each transect.

	STEP-LOOPS		
	TRANSECT A	TRANSECT B	AVERAGE
DECREASERS			
Sonu	1	6	3.5
Pavi	3	6	4.5
Ange	21	13	17
Ansc	20	17	18.5
ROS	1	2	1.5
Frvi	1		.5
Amca	1	2	1.5
		TOTAL AVERAGE DECREASERS. .	47
INCREASERS			
SOL	1		.5
CAR	1	2	1.5
Bocu	1		.5
Pasc	1	2	1.5
AST	2		1
		TOTAL AVERAGE INCREASERS. .	5
INVADERS			
Syor		3	1.5
Rhgl	4	2	3
PRU	2		1
		TOTAL AVERAGE INVADERS. . .	5.5
ROCK		1	.5
LITTER	40	42	41
BAREGROUND		2	1
		OCULAR ESTIMATES (%)	
ROCK	0	0	0
LITTER	70	70	70
BAREGROUND	0	0	0
BASAL COVER	30	30	30

Table 4. Total pounds per acre dry weight production for Melvern site 2.

	TRANSECT A		TRANSECT B		AVERAGE	
	lbs/A	%	lbs/A	%	lbs/A	%
DECREASERS						
Sonu	6.57	1.39	8.59	1.26	7.58	1.32
Pavi			48.48	7.13	24.24	4.21
Ange	219.89	46.48	76.01	11.19	147.95	25.67
Ansc	146.59	30.99	204.02	30.03	175.31	30.42
Spas	0.93	0.20	15.08	2.22	8.01	1.39
Amca	4.10	0.87			2.05	0.36
ROS	21.91	4.63	110.19	16.22	66.05	11.46
Forbs	50.19	10.61			25.10	4.36
		TOTAL AVERAGE DECREASERS. . .			456.29	79.19
INCREASERS						
CAR			0.79	0.12	0.40	0.07
Bocu	5.10	1.08			2.55	0.44
AST	17.78	3.76	5.58	0.82	11.68	2.03
Arlu			0.90	0.13	0.45	0.08
		TOTAL AVERAGE INCREASERS. . .			15.08	2.62
INVADERS						
Syor			208.36	30.67	104.18	18.08
Paca			.60	.09	.30	.05
SET			.84	.12	.42	.07
		TOTAL AVERAGE INVADERS. . .			104.90	18.20
GRAND TOTALS	473.06 lbs/A		679.44 lbs/A		576.27 lbs/A	

Table 5. Step-loop data and ocular estimates for Mayo site 1. The figures shown for the ocular estimates are the mean of the ten plots sampled at each transect.

	STEP-LOOPS		
	TRANSECT A	TRANSECT B	AVERAGE
DECREASERS			
Sonu	5	3	4
Pavi	1	2	1.5
Ange	15	24	19.5
Ansc	18	16	17
Spas	5	2	3.5
	TOTAL AVERAGE DECREASERS.		45.5
INCREASERS			
CAR	7	4	5.5
Bocu	1	11	6
Pasc	1	2	1.5
AST	3	3	3
	TOTAL AVERAGE INCREASERS.		16
INVADERS			
AMB	1		0.5
	TOTAL AVERAGE INVADERS.		0.5
ROCK	5	3	4
LITTER	23	4	13.5
BAREGROUND	15	26	20.5
	OCULAR ESTIMATES (%)		
ROCK	0.5	0.5	0.5
LITTER	7	22.5	14.75
BAREGROUND	30	19	24.5
BASAL COVER	62.5	58	60.25

Table 6. Total pounds per acre dry weight production for Mayo site 1.

	TRANSECT A		TRANSECT B		AVERAGE	
	lbs/A	%	lbs/A	%	lbs/A	%
DECREASERS						
Sonu	45.29	8.42	10.96	2.13	28.13	5.34
Pavi	20.78	3.86	36.62	7.11	28.70	5.45
Ange	214.41	39.88	264.06	51.28	239.24	45.45
Ansc	133.16	24.17	137.22	26.65	135.19	25.68
Spas	41.03	7.63	4.51	0.88	22.77	4.31
Amca			10.53	2.04	5.27	1.00
CEO			7.21	1.40	3.61	0.69
Forbs			2.03	0.39	1.02	0.19
		TOTAL AVERAGE DECREASERS. . .			463.93	88.11
INCREASERS						
CAR	38.26	7.12	23.56	4.57	30.91	5.87
Bocu	8.80	1.64	7.99	1.55	8.40	1.60
Buda	1.90	0.35			0.95	0.18
AST	17.35	3.23	4.78	0.93	11.07	2.10
Pasc	10.76	2.00	3.96	0.77	7.36	1.40
		TOTAL AVERAGE INCREASERS. . .			58.69	11.15
INVADERS						
AMB	5.95	1.11	1.55	0.30	3.75	0.71
		TOTAL AVERAGE INVADERS			3.75	0.71
GRAND TOTALS	537.69 lbs/A		514.98 lbs/A		526.37 lbs/A	

Table 7. Step-loop data and ocular estimates for Mayo site 2. The figures shown for the ocular estimates are the mean of the ten plots sampled at each transect.

	STEP-LOOPS		
	TRANSECT A	TRANSECT B	AVERAGE
DECREASERS			
Sonu	4		2
Pavi	3	5	4
Ange	17	19	18
Ansc	20	19	19.5
Spas	1	2	1.5
	TOTAL AVERAGE DECREASERS. . . .		45
INCREASERS			
CAR	1	9	5
Pasc	1	1	1
Arlu	2	1	1.5
Buda		1	0.5
Bocu	9	9	9
	TOTAL AVERAGE INCREASERS. . . .		17
INVADERS			
BRO	1		0.5
	TOTAL AVERAGE INVADERS.		0.5
ROCK	8		4
LITTER	22	16	19
BAREGROUND	11	18	14.5
	OCULAR ESTIMATES (%)		
ROCK	0	0	0
LITTER	22	20	21
BAREGROUND	13	10	11.5
BASAL COVER	65	70	67.5

Table 8. Total pounds per acre dry weight production for Mayo site 2.

	TRANSECT A		TRANSECT B		AVERAGE	
	lbs/A	%	lbs/A	%	lbs/A	%
DECREASERS						
Sonu	104.85	15.36	13.86	1.84	59.36	8.27
Pavi	24.07	3.53	65.44	8.68	44.76	6.23
Ange	140.94	20.65	245.65	32.60	193.30	26.92
Ansc	158.57	23.23	274.36	36.41	216.47	30.15
Spas	75.42	11.05	59.68	7.92	67.55	9.41
Amca	22.08	3.24			11.04	1.54
MUL	18.74	2.75			9.37	1.30
Forbs	1.28	0.19	0.80	0.11	1.04	0.14
		TOTAL AVERAGE DECREASERS. . .			602.89	83.96
INCREASERS						
CAR	8.83	1.29	42.75	5.67	25.79	3.59
Bocu	78.22	11.46	28.46	3.78	53.34	7.43
Pasc	7.60	1.11	2.86	0.38	5.23	0.73
AST	26.98	3.95	9.84	1.31	18.41	2.56
Arlu	1.75	0.26	9.84	1.31	5.80	0.81
Veba	9.39	1.38			4.70	0.65
Buda	2.22	0.33			1.11	0.15
Xadr	0.29	0.04			0.15	0.02
		TOTAL AVERAGE INCREASERS. . .			114.53	15.94
INVADERS						
BRO	1.28	0.19			0.64	0.09
		TOTAL AVERAGE INVADERS. . . .			0.64	0.09
GRAND TOTALS	682.51 lbs/A		753.54 lbs/A		718.06 lbs/A	

Table 9. Step-loop data and ocular estimates for the Lefler site. Transect B was taken with the aid of the ESU range management class and was not taken in detail as was transect A. The figures shown for the ocular estimates in transect A are the mean of the ten plots sampled.

	STEP-LOOPS		
	TRANSECT A	TRANSECT B	AVERAGE
DECREASERS			
Sonu	3	13 total	30 total
Pavi	4		
Ange	5		
Ansc	17		
Spas	17		
ELY	1		
INCREASERS			
CAR	2	21 total	15 total
Bocu	3		
Acmi	1		
AST	2		
Arlu	1		
INVADERS	0	19 total	9.5 total
ROCK			
LITTER	30	22	26
BAREGROUND	14	25	19.5
	OCULAR ESTIMATES (%)		
ROCK	0	NO	0
LITTER	15.5	DATA	15.5
BAREGROUND	30	TAKEN	30
BASAL COVER	54.5		54.5

Table 10. Total pounds per acre dry weight production for the Lefler site.

	TRANSECT A		TRANSECT B		AVERAGE	
	lbs/A	%	lbs/A	%	lbs/A	%
DECREASERS						
Sonu	13.59	1.83	45.32	7.22	29.46	4.27
Pavi	32.94	4.43			16.47	2.38
Ange	102.02	13.71	150.60	24.01	126.31	18.29
Ansc	334.88	45.01	143.46	22.87	239.17	34.63
Spas	92.96	12.50	26.41	4.21	59.69	8.64
ELY			31.76	5.06	15.88	2.30
Amca			24.98	3.98	12.49	1.81
Kocr	0.55	0.07			0.28	0.04
CEO			92.07	14.68	46.04	6.67
Forbs	56.99	7.66			28.50	4.13
TOTAL AVERAGE DECREASERS. . .					574.29	83.16
INCREASERS						
CAR	27.31	3.67			13.66	1.98
Bocu	16.44	2.21	19.98	3.18	18.21	2.64
Pasc	9.10	1.22			4.55	0.66
AST	28.26	3.80	57.46	9.16	42.86	6.21
Arlu	3.96	0.53			1.98	0.29
Agsm			38.54	6.14	19.27	2.79
Buda			2.85	0.45	1.43	0.21
Acmi	7.03	0.94			3.52	0.51
Xadr			3.93	0.63	1.97	0.29
TOTAL AVERAGE INCREASERS. . .					107.45	15.58
INVADERS						
AMB	17.90	2.41			8.95	1.30
TOTAL AVERAGE INVADERS. . . .					8.95	1.30
GRAND TOTALS	743.93 lbs/A		637.36 lbs/A		690.69 lbs/A	

DATA SHEET FOR RANGE UTILIZATION
BY THE
STUBBLE HEIGHT METHOD

Date 10-28-83

Key Species Panicum Virgatum

Location Lefler

Examiner S. Wilk

Transect No. 1

Stubble Height	Per Cent Use	Stubble Height	Per Cent Use	Stubble Height	Per Cent Use
51	23	29	46	46	28
45	28	28	47	39	34
44	29	39	34	40	33
40	33	43	30	39	34
46	28	42	20	64	14
48	26	33	41	39	34
52	23	40	33	56	20
64	14	42	20	55	20
34	40	50	24	47	33
50	24	35	38	38	35
27	20	41	32	57	19
37	36	45	28	63	15
41	32	40	33	36	37
48	26	42	20	33	41
42	20	35	38	52	23
46	28	84	4	42	20
		60	17		
		50	24		

Average Per Cent Utilization 27.9%

Per Cent of Plants Grazed 100 %

Per Cent of Plants Grazed 50 % or More 0

Notes