A study of the per cent of plants grazed method of utilization determination and its application
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A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Range Management
Montana State University

Abstract:
The data presented in this thesis include (1) variations and adaptability of the "per cent of plants grazed method" of utilization determination influenced by the grazing behavior of unherded sheep and (2) variations in" degree of utilization as influenced by variation in height-weight relationships .

The study area was located on the Shaw Ranch at White Sulphur Springs, Montana. The midcontinental climate was characterized by moderately low rainfall. The soils were gravelly or stony loams. The Palouse bunchgrass species and mixed prairie species were intermingled in the area.

A small band of unherded ewes and lambs was allowed to graze at will on the study area. They spread out widely in small groups and varied their choice of bed grounds. Factors influencing grazing habits included the feeding of hay, lambing camp locations, elevation, water barriers, exposure, slope, vegetation roughs, and plant species preferences,.

The vegetation and degree of utilization were systematically sampled and mapped. A composite plant for each species, representing all plants of this species in the study area, was developed and used as a basis for the development of a height-weight chart. This chart was used to determine percentage utilization from stubble height measurements. This height-weight chart was also used to develop graphs depicting the relationship of stubble height to per cent utilization.

Utilization values determined by use of the author' s height-weight table were compared to utilization values, for the same stubble heights, as taken from two different adaptations of Lommasson's utilization gauge. These paired values were statistically compared. The author's height-weight table for utilization determination appeared to be equally as accurate as the Lommasson utilization gauge for the areas studied.

The over-all utilization on the study area was 31.39 per cent, based upon the author'S height-weight table values for the measured stubble heights. A total of 79.5 animal unit months of grazing use occurred on the area during the study period. The area was stocked at the rate of 4.6 acres per animal unit month. The kentucky blue grass-timothy type was the most heavily utilized of the vegetation types. Sandberg bluegrass was the most heavily utilized of the plant species.

Graphs for the "per cent of plants grazed method" of utilization determination were prepared. The influence of the method of data summation was reflected in these graphs. Per cent of plants grazed graphs were prepared from data collected on the Shaw Ranch study area and from previously collected computed data for the Chadbourne Lease north of Livingston, Montana." The resulting graphs were compared statistically and were found to be significantly different between areas in nearly all cases.

The possibility of using the per cent of plants grazed graphs developed on the Shaw Ranch study area on another area of similar vegetation, for which they were not specifically prepared, was tested. This application of the method gave poor results with junegrass and sandberg bluegrass but good results

with some of the other plant species.

A STUDY OF THE PER CENT OF PLANTS GRAZED METHOD OF UTILIZATION DETERMINATION AND ITS APPLICATION.

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ABSTRACT

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The study area was located on the Shaw Ranch at White Sulphur Springs, Montana. The midcontinental climate was characterized by moderately low rainfall. The soils were gravelly or stony loams. The Palouse bunchgrass species and mixed prairie species were intermingled in the area.

A small band of unherded ewes and lambs was allowed to graze at will on the study area. They spread out widely in small groups and varied their choice of bed grounds. Factors influencing grazing habits included the feeding of hay, lambing camp locations, elevation, water barriers, exposure, slope, vegetation roughs, and plant species preferences.

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INTRODUCTION

The determination of degree of utilization on range forage plants is one of the most difficult problems encountered in managing grazing lands on a sustained yield basis. A number of methods for utilization measurement have been suggested and tried with varying degrees of success and satisfaction to the user, but no single method has been entirely satisfactory. In general, most of the accepted methods are too tedious and time consuming for the average rancher or administrator to apply. The large units of range ordinarily involved require a method which is rapid, easily used, easily understood, and reliable. Ordinarily, extreme accuracy is not as important as a well-distributed sample, yielding reliable results, on these large range units.

The "per cent ungrazed method" has been advanced as a possible solution to the problem of determining utilization on these large areas. A variation of this method uses the per cent of plants grazed. For purposes of simplification, this variation will be called the "per cent of plants grazed method" throughout this thesis. The per cent of plants grazed is determined by dividing the number of grazed plants by the total number of plants measured. The "per cent of plants grazed method" employs a graph of the relationship between the percentage of all the plants grazed and the total percentage of forage removed.

The primary objective of this study was to develop graphs, by the "per cent of plants grazed method," which would be applicable to measurement of utilization by sheep within the study area involved. The grazing behavior of unherded sheep was examined because of its influence on the application and accuracy of the method. In addition, variation in the graphs, as influenced by various procedures of data summation, were to be studied. These graphs were also to be used to test the validity of using them on another area of similar vegetation for which they were not specifically prepared.

An objective of a secondary nature was involved. It was desired to test the reliability of the method of utilization determination used in this study. The reliability of these utilization values limits the value of the "per cent of plants grazed method" of utilization determination. Another procedure of utilization determination, the Lommasson gauge, involving the same basic concepts of height-weight relationships was used for this comparison. The same stubble height measurements were used.

This study was conducted with the Montana State College Experiment Station experimental sheep band on the Shaw Ranch at White Sulphur Springs, Montana. This ranch is leased by the Montana State College Experiment Station for sheep research. Data from a portion of the Chadbourne Ranch, just north of Livingston, Montana, is also included. This property was formerly leased by the Montana State College Experiment Station.

REVIEW OF LITERATURE

The use of utilization determinations as an aid in managing grazing lands is not new. Man has made use of this tool, with varying degrees of application and success, ever since grazing animals were first domesticated. These applications were of a general nature and were applied only as necessity required their use. Around the turn of the century, the conservation movement began to flourish, and the need for more complete information on utilization determinations became apparent. Progress in this field of research accelerated greatly in the early 1930's as several men began to study the problem and develop new methods of determining degree of utilization. The two general types of utilization determinations in use are the qualitative approach, by means of estimation, and the quantitative approach, by means of actual measurements.

QUALITATIVE METHODS

The qualitative approach was used by the old-time stockman as he judged how much of his feed was fully used and how much more grazing he could get from a particular unit of grazing land. These estimates were of an ocular nature and were greatly influenced by the man's judgment and experience. Various standards for proper use based upon these ocular estimates have been suggested. Sampson and Malmsten (1926) stated, "It is generally conceded that if from 10 to 25 per cent of the herbage of the more important palatable species remains in the fall, proper utilization has been affected." The U. S. Forest Service (1936) recommended that 25 per cent of the seed heads be allowed to reach maturity in addition to the specifications suggested by Sampson and Malmsten. This general reconnaissance method may involve any plant species or any portion of an area. The estimates may be in terms of percentage of height or volume removed or both, or they may be generalized in terms such as light, moderate, or heavy utilization. Presumably, estimates of the use will vary to a considerable extent in the application of this method. Smith (1944) found this to occur in estimating density.

Several variations of the general reconnaissance method have been devised and studied in recent years. The weight estimate method (Pechanec and Pickford, 1937) of determining range production substantiates the variation known as the ocular-estimate-by-plot method (Pechanec and Pickford, 1937a and Soil Conservation Service, 1944). In this method the weight estimates are limited to a plot of such limited area that all the plot is visible from one point. The average of several plots is the average utilization. Pechanec and Pickford (1937a) tested a refinement of the ocular-estimate-by-plot method, known as the ocular-estimate-by-average-of-plants method, and concluded that it was the most accurate of the methods tested. This method involves estimates of weight removal for each plant within the plot. The average of the estimates is taken as the utilization for the plot. Dasmann (1951), Hormay (1943), and others have applied the visual estimate method of utilization determination to browse. The percentage of use on individual shrubs is estimated by mental reconstruction of ungrazed appearance or of uncropped leader length.

A number of methods involving the use of general appearance have been used widely to determine the degree of utilization on generalized range areas. The primary forage plant method was described by Deming (1939) and has been widely used by several federal agencies and by private ranchers. Specific information on factors which influence use, such as composition, abundance, vigor, reproduction mortality, poisonous plants, soil erosion, topography, water, rodents, fires, and season of use, are described. In addition, specific information about degree of utilization on each of the main forage plants is recorded. After a study of all the factors examined, the area is assigned to one of nine described classes of degree of use.

In the subalpine grassland ranges of Oregon and Washington (Pickford and Reid, 1942), a range was properly grazed when 50 per cent of the green fescue, the key plant, was utilized. This was determined by estimating the per cent of plants grazed to 1 inch or less, the per cent of plants grazed to less than 3 inches, and the per cent of plants ungrazed. For the same general vegetation types, Pickford and Reid (1942a) list guides to determine proper use by means of appearance and visual estimation of per cent used. The range-condition method of utilization survey, as suggested by Humphrey (1949), employs a flexible proper-use factor for each key species; the factor to be used depending on the range condition of the given forage type. The basis of this method is also appearance and estimation of per cent used.

A method of judging range utilization (Hormay and Fausett, 1942) of annual-type ranges in California was based on the appearance of the range as compared to standard photographs. Young (1945) further expanded this method for the U. S. Soil Conservation Service in California and developed several photographic guides for use in these vegetative types. A guide to degrees of range use as applied in southwestern Texas (Osborn, 1947) also made use of this procedure of photographic comparison. Costello and Turner (1949) used photographs and charts as aids to determining current forage utilization of the short-grass range on the Central Great Plains. Indicators of degree of use are listed according to current forage production within range condition classes.

Lantow (1939) felt that utilization should be estimated separately for several species rather than on the over-all basis used in the primary forage plant and photographic methods. These values were then weighted by the percentage composition and totaled. Proper use was weighted and totaled in the same manner. The two sums were then divided to obtain the proper per cent utilization of the available forage.

QUANTITATIVE METHODS

The quantitative approach has been used by numerous researchers in their efforts to develop accurate, scientific methods of utilization determination. These methods involve measurements which vary from those which are very extensive to those which are very intensive.

One of the most recently developed methods for determining degree of forage utilization involves the counting of pellet groups and droppings and correlating them with estimated forage taken. Several researchers, among them McCain (1948), U. S. Forest Service Region 4 (Undated), and Parker (1953), have suggested and studied this method. The method is quantitative in regard to the counts but qualitative with respect to the estimated forage removal values. The conversion of animal population, determined by pellet counts, to forage consumed can be based only on estimates of pounds of forage normally eaten by each class of animal during a 24 hour period.

Purely quantitative methods, such as weight measurement, have also been used as a means of determining percentage utilization. Much work has been done with the weight measurement system. Morgan and Beruldsen (1931) and Beruldsen and Morgan (1934) used a method in Australia which necessitates two clippings of the forage; 25 samples before and 35 samples after grazing. In the 1931 study the 25 before grazing samples were re-cut at the end of the grazing period to allow for regrowth during the grazing period. The 1934 study did not have a regrowth problem as the small pastures were grazed by sufficient numbers of sheep so that only one day elapsed between the clippings. The percentage of volume reduction in air-dry weight is taken as the percentage of forage utilized. If growth is appreciable between clippings, forage production and utilization may be determined by a method suggested by a Joint Committee of the American Society of Agronomy, American Dairy Science Association, and the American Society of Animal Production (1943). Two meter-square enclosure cages are placed at random in each pasture, and a third meter-square unprotected plot is located within 10 feet of the enclosures. The cages are moved after each clipping. Methods of a similar nature have been successfully used in the midwest by Fuelleman and Burlison (1939) and others. Klingman, et al. (1943) show statistically that the cages should be randomly located but the unprotected plot should be selected for its likeness to the two caged plots to give the best results. Nevens (1945) compared the relative values of 3 variations of cage management and clipping procedure which have been used.

A modification of the weight method (Stapledon, et al., 1927 and Cassady, 1941) has been used to determine utilization on sheep range. This system is known as the "before and after grazing" method. The method involves collecting and weighing predetermined numbers of units (one twig, stem, leaf, other plant part, or the entire plant) just prior to and immediately following grazing. This method has given good results in range studies in Utah (Cook, C. Wayne, et al., 1948; Cook, Clyde J., et al., 1948; and Green, et al., 1951). It has also been used, by these same researchers, to determine the composition of a sheep's diet and the closely related dietary preferences of sheep. Morgan and Beruldsen (1931) and Beruldsen and Morgan (1934) separated their clippings by species in order to determine dietary preferences. Esplin, et al. (1937) attempted to determine the diet by multiplying species composition by the percentage of each species which has been consumed at the end of the grazing period.

The measurement of height has also been used to determine utilization. The height measurement method, as originally applied to the utilization of grass, was based on the premise that percentage utilization of grass is equal to the reduction in average leaf height as a result of grazing (Pechanec and Pickford, 1937a). If the volume were distributed equally throughout the height of the plant, this would be true. However, Lommasson and Jensen (1938, 1942, and 1943), Crafts (1938), Valentine (1946), and others found this assumption to be invalid.

A modification of this height measurement method has been applied to browse. This modification involves tagging twigs and measuring the current year's growth before grazing and the same current year's growth after grazing. The differnece in length is converted to a percentage use figure for each tagged twig. All of these values are averaged for a total use figure. Nelson (1930), Julander (1937), members of the Inter-Agency Committee, Oregon-California Interstate Deer Range, (1948), and Dasmann (1951) are only a few of the research workers who have used this method.

A line transect method, involving a variation of the height measurement method, (Canfield, 1941; 1944; and 1950) has been used in southern Arizona and was found to be highly applicable as a research procedure. Stubble heights and diameters are measured along a 50- or 100-foot line transect and then arranged according to species and stubble-height classes. Total use is determined by weighting these values according to the proportion of each species present. This method has also been used by members of the Interstate Inter-Agency Committee (1948) in checking winter deer range forage utilization. A suggested method of measuring grazing use on bitterbrush (Hormay, 1943) involves a modification of the line transect in measuring the average diameter of the plant crown.

The conversion of stubble height measurements of grasses to weight removed was a very progressive step forward in the field of use determination. This was made possible by studies dealing with the height-weight distribution within individual grass plants. Lommasson and Jensen (1938) were the first to correlate height removal with weight removal in the principal grasses of the western range area. At almost the same time, Crafts (1938) reported upon a study which endeavored to tentatively determine the relationship between height and volume (by weight) in some of the important southwestern range grasses. Further, this study endeavored to develop a possible method for measuring volume utilization directly while measuring the stubble heights on the range. Crafts (1938) stated that, "The curve of height against volume approaches a parabola in all cases, and there is always a great concentration of volume close to the ground."

Crafts (1938a) studied and reported upon the height-weight relationships in 11 important grasses in Arizona and New Mexico. Height-weight scales were developed for these grasses. Individual utilization guides using this method were written by Crafts (1938b, 1938c, and 1938d) and by Campbell and Crafts (1938) for 4 of the most important grass species of the Southwest.

In connection with these height-weight scales, definitions and concepts about proper use, utilization indicators, soils, range types, class of stock, topography, time to judge use, utilization panels, and the use of key species were presented in another publication (Crafts and Wall, 1938). Parker and Glendening (1942a) discuss these factors and give crop heights, proper use factors, and proper stubble heights for each plant species by condition class and slope.

Campbell (1942) and Lommasson and Jensen (1942 and 1943) gave instructions in constructing and using the tables and scales needed to determine utilization by the height-weight method. Lommasson and Jensen (1942 and 1943) tested their method and concluded that height alone could be used as the variable for the determination of the required number of plants to be used in constructing height-weight tables. They concluded that the height-weight principle, when properly used, was sound and more accurate and uniform than the ocular estimate method for utilization determination. The ocular-estimate-by-plot method was compared with the height-weight method on green fescue range (Reid and Pickford, 1941). They reported varying results depending upon the uniformity of the stubble height and recommended the use of the ocular method because of its rapidity. Nevertheless, Pickford and Reid (1942) recognized the height-weight relationship in green fescue and plotted a height-weight distribution curve for the species. Heady (1950) studied the relationship between the growth form of five perennial grasses and yearly changes in climate, differences in habitats, composition of the species in the stand, and degree of herbage removal. He found the height-weight method useful when properly applied and evaluated.

Other researchers have suggested major modifications in the field procedure of the height-weight method. In a method employed to make it more applicable to mixed grass stands (Parker and Glendening, 1942) all the important species were used, rather than a few "key species," and the percentage composition was used to weight the respective utilization values. A modified application of the height-weight method, as used by Collins and Hurtt (1943) at the United States Range Livestock Experiment Station near Miles City, Montana, involved the use of marked links on a chain as plot centers, stubble-height measurements on "key species," and weighting by percentage of all grazed stems of the species involved. Valentine (1946) scaled the percentages of utilization on a card which is placed at the side of the plant so that the actual stubble height directly indicates the percentage of weight that has been removed. This greatly reduces the amount of calculations needed. The method is also helpful in that the examiner is able to directly associate stubble height with utilization. Woolfolk (1949) used a modification of the height-weight method in the sheep research at the United States Range Livestock Experiment Station near Miles City, Montana. The method involves correction for yearly variation.

Not all workers have found the form factor principle to be an entirely sound approach to the determination of degree of utilization. The work at Miles City, Montana, indicated that the height-weight distribution and the ratio of culmed to culmless plants varied greatly from year to year (Collins and Hurtt, 1943 and Holscher and Woolfolk, 1953). Work in the Texas Panhandle (Caird, 1945) indicated that grasses growing on poor sites had only a very small proportion of the foliage above the first inch, while on good sites, much more of the foliage was distributed higher on the plant. Plants on poor sites were also much shorter in total height. Grazing to a certain percentage of the height may result in either under, proper, or over utilization depending upon the climate, site, and plant species because of the possible high variation in the large volume of herbage produced in the lowest part of the grass plant (Costello and Turner, 1944). Heady (1950) found that the percentage of weight of plants in 1-inch intervals of height did not vary consistently, either directly or indirectly, with average height, average weight, soil, temperature, precipitation, or species composition of the stand. He concluded, however, that the height-weight method is valid and useful provided its limitations and variations are considered. In 4 years of work in Utah, Clark (1945) found that composite samples of all years and all zones would often show errors of 10 to 25 per cent when use was made of average height-weight tables. Each species exhibited its own variation in growth form as a result of differences in soil, exposure, shading, moisture conditions, and temperature. He concluded that the 10 species studied under the conditions described do not have a growth form that even approaches consistency and that the ocular-estimate-by-plot method is more accurate.

The stem-count method of utilization determination was introduced by Stoddart (1935). In this method he showed that percentage utilization was a direct function of the total number of stems grazed. This work was done with western wheatgrass (*Agropyron smithii*) and was deemed to be quite suitable. Pechanec (1936) tested this method with thickspike wheatgrass (*Agropyron dasystachyum*) and found it insufficiently accurate to merit its use. The stem-count method was further tested on bunchgrass, and it was found to be neither sufficiently accurate nor rapid to justify its use on this type of plant (Pechanec and Pickford, 1937a). Stem and twig counts were used in the Missouri Ozarks (Dalke, 1941) as a basis for determining degree of utilization of woody plants.

Canfield (1942 and 1944a) suggested a short-cut method for estimating utilization. This method is based upon the number of plants in a grass stand grazed to a stubble height of 2 inches or less, the number of plants grazed above a 2-inch stubble height, and the ungrazed balance. To use this system, the average per cent of plants grazed to a stubble height of 2 inches or less is estimated, by observation or systematic count, in terms of basal tuft area without regard for species, density, and composition. This value is referred to the chart for the balance of the data. Stoddart's method (1935) and this method were the original suggestions for the "per cent ungrazed method" as developed by Roach in 1950. Osborn (1947a) further suggested the "per cent ungrazed method" with his work on frequency tallies. In this method, the frequency of occurrence of different species and the percentages of each completely grazed, partially grazed, and ungrazed is systematically tallied in the field and then converted to per cent utilization.

The "per cent ungrazed method," as developed by Roach (1950), was a direct outgrowth of Canfield's findings (1942 and 1944) and later studies by S. Clark Martin (Roach, 1950). It is based on the grazing habits of cattle and on the relationship between the per cent of accessible perennial grass clumps grazed and the amount by weight of forage removed. Roach (1950) did not differentiate between species in his work. Hurd and Kissinger (1953) applied a variation of the method to idaho fescue (<u>Festuca idahoensis</u>) only, on the basis of the "key species" concept of grazing management. A modification of the method (Collins and Hurtt, 1943 and Holscher and Woolfolk, 1953) utilized the per cent of plants grazed multiplied by per cent of plant weight removed. Holscher and Woolfolk (1953) stated that "per cent of plants grazed was the most sensitive indicator of the degree to which a forage species had been grazed." They propose an adaption of their method involving only a tally of grazed and ungrazed plants. This tally is referred to a table listing the proper per cent of plants to be grazed, by topographic subtypes on both summer and winter ranges. Hunt, <u>et al.</u>, (1954) determined utilization through a combination of counting grazed and ungrazed plants and taking leaf height measurements.

Various authors have studied the problem of utilization determination and critically examined and compared the various methods which have been suggested. Cook and Stoddart (1953) outline and illustrate many of the problems encountered in this field of study. They state, "Adequacy of standard utilization measurement methods depends upon what information is desired and what application is to be made of the data." Heady (1949) and Humphrey (1949) have made comprehensive comparisons of the methods of utilization determination which have been used, as have Stoddart and Smith (1943), Sampson (1952), and Brown (1954). Stoddart (1952) discusses the various methods available and the problems involved. These methods are discussed from an agronomic angle by Ahlgren (1947). Dasmann (1948) has compared the various utilization methods in their application to deer range. Pickford and Reid (1948) studied the problem of utilization determination and pointed out the problem of non-uniformity of grazing and its effect on the determination of proper utilization. Campbell (1937) and Bailey (1945), in studying the riddle of utilization measurement, discuss the invalidity of using specific proper-use factors because of the variable influence of site and climate. According to Campbell (1943), the real problem is not the measurement of use but the interpretation of the measurements taken. According to Lantow (1938), "A method for utilization surveys is not solely a mathematical question, and I doubt whether it ever can be made so."

GRAZING HABITS

The grazing habits of livestock have been studied by men in various agronomic fields. James Anderson (1797), a Scottish farmer, developed a system of rotation pasture grazing based largely on his observations of cattle grazing habits. No practical development of a similar nature has been found in the annals of the western range in North America. Even the recorded, planned studies are of a rather recent date.

The grazing habits of cattle permitted development of the "per cent ungrazed method" of utilization determination (Roach, 1950). Cattle grazing freely with ample forage available will, as a general rule, graze a clump of grass only once and then move on to a fresh plant. They will not return to a grazed plant unless forage is short or until the grass has grown new succulent growth. Because of these grazing habits, the percentage of plants grazed and remaining ungrazed provide indices to the total grazing use of a plant species or a range area (Roach, 1950).

Environmental factors which can be influential in the behavior of a herd of bullocks were examined at Stratford-on-Avon. These factors were the natural conditions of climate, including seasonal changes in weather, and the system of grazing management (Tayler, 1953). Cold winds and driving rains cause cattle to stop grazing and drift with the wind in search of shelter (Hancock, 1950 and 1952). Cully (1937) studied the forage preferences of cattle and the factors that influenced grazing habits in southern Arizona. Weather conditions and exposure were closely related to the areas which were grazed heavily. Seasonal preferences for forage were noted. These fluctuations in forage preference were noted also by

Johnson (1953) and Harris (1954). Timber is an environmental factor influencing both grazing use and other environmental factors. Pickford and Reid (1948) studied the relative palatability of grasses for cattle on the timbered lands and grasslands of eastern Oregon. They found a lowered palatability of certain forage plants in the timbered areas. Holscher and Woolfolk (1953) and Peterson and Woolfolk (1955) discussed utilization variations due to the environmental factors of range subtypes, stocking rates, and distance from water. They found, as did Cully (1937), that cattle tended to heavily graze the bottom or stringer subtypes.

Temperatures in the temperate zones (Castle, et al., 1950; Hancock, 1950; and Waite, et al., (1951) had little effect on the time cattle spent grazing, but Hein (1935) reported that cattle grazing during the night lie down very soon after a cooling fog descends. Although grazing time was not influenced, loafing time was increased during warm days, either because of excess warmth or the prevalence of flies (Castle, et al., 1950 and Waite, et al., 1951). This increase in loafing time was due to the expenditure of less time on activities other than grazing.

Cattle prefer to graze in daylight, and a strong positive relationship exists between the length of day and the time cattle spend grazing in daylight (Hancock, 1953). Grazing steers were found to graze at night only at twilight or in moonlight (Hein, 1935). Hancock (1950) and Waite, et al., (1951) found that during the two months centered around the longest day of the year little or no grazing occurs in darkness, but with shortening days cows spend a greater part of their grazing time in darkness. This was contradicted by Peterson and Woolfolk (1955). Although cattle prefer to graze during daylight, grazing follows a distinct pattern in that periods of intense eating alternate with periods of idling, rumination, and rest (Hancock, 1953 and Peterson and Woolfolk, 1955).

A statement by Johnstone-Wallace (1944) to the effect that the time spent grazing was almost constant irregardless of feed availability has not been substantiated by other researchers including Hancock (1953), Atkeson, et al., (1942), and Waite, et al., (1951). The relationship between rate of stocking and cattle habits tended toward more vigorous foraging by cows on heavily stocked range in the study conducted by Peterson and Woolfolk (1955). In New Zealand (Hancock, 1950) it was found that grazing times were definitely influenced by the quality of the forage. It has been suggested (Waite, et al., 1951) that cattle graze longer on green, succulent growth because it packs tighter in the rumen than coarse, dry plants, therefore requiring more grass to satisfy their appetites.

Studies dealing with the grazing behavior of cattle may be highly variable as to subject matter and application. A study may cover a single factor or many factors influencing grazing behavior. Hancock's (1950) study of inherent individuality of cattle as an influence in grazing behavior varies widely from the common type of study. A study such as length of grazing period and its influence on the amount of consumption (Waite, et al., 1951) is a more common and practical approach. Weaver and Tomanek (1951) used a common method by studying cattle behavior in Nebraska throughout 24-hour periods for a typical day, a hot day, and a cool day. Hubbard (1952), in reporting on cattle behavior on Canadian Plains ranges, was primarily interested in the practical aspects of forage preference and amount eaten. Several other researchers have also studied grazing cattle behavior. In England there is an organization known as "The Association for the Study of Animal Behavior." Most of this work with behavior of cattle has been of a basic nature and only a limited amount of practical application has been accomplished. Tribe (1950) and Hancock (1950a) point out the need for care in the interpretation of livestock behavior studies.

Much less work has been done with the grazing behavior of sheep, as compared to cattle. Cory (1927) made comparisons of beef cattle, sheep, and goat activities and habits on the range. However, he did not study them during the hours of darkness after they once bedded down. He concentrated his effort on timing their various activities, although he did observe some forage preferences and grazing habits. Davies (1925) emphasized that stage of growth has an important influence on animal preference and that selectivity by sheep is in direct proportion to the amount of desirable herbage available. Doran (1943) timed the various activities of sheep and pointed out that the relative length of feeding time spent by grazing ewes on various forage plants was closely related to abundance of each plant species. He mentions that actual utilization is influenced by abundance and composition of the forage, habits of the sheep, season, stage of plant growth, climate, and management practices. Teigen (1949) noted the forage preferences of sheep while they grazed on mountain ranges.

Sheep preferences for certain portions of certain plant species was noted and studied in Utah (Cook, C. Wayne, _et al._, 1948; Cook, Clyde J., *et al.*, 1948; and Green, *et al.*, 1951). They noted that forage consumption was highly influenced by the amount of time spent grazing. Selectivity was influenced by season of use, plant association, intensity of grazing, external characteristics of the vegetation, and various site factors. Generally forbs, browse, and grasses were preferred in that order, and leaves were highly preferred to stems. They state that a relatively small number of species compose the bulk of the sheep's diet. Stapledon and Jones (1927) also found that more grass leaves than stems were eaten by sheep even though more stems were present.

Jardine (1910) observed the tendency for sheep to bed near any handy obstruction which happened to be close at hand whenever night overtook them rather than return to an established bedground. He indicated that mountain summer range grazed by sheep under fence supported from 25 to 50 per cent more sheep than were being grazed on the same acreage of similar range on which the sheep were herded by the methods generally practiced at that time. He states the pastured sheep made better gains in weight than the herded sheep. Improved methods of herding overcame much of this difference. This author also indicated that salting away from water in order to improve distribution on sheep range is not successful. Jardine and Anderson (1919) recognized a tendency for sheep to graze without regard to temperature as long as insects did not bother.

Relative grazing values and relative abundance of plant species, as related to sheep utilization, are discussed in connection with a sheep study at the United States Range Livestock Experiment Station near Miles City, Montana (Woolfolk, 1949). This study involved sheep that were grazed in a sheep-tight pasture and not herded. They were located and counted twice daily. The grazing periods, resting periods, bedding periods, and temperature, insect and predator relationships were discussed. Low temperature and a cold wind would cause the sheep to drift with the wind. The fences served to obstruct natural sheep movement and served as a natural protection, resulting in severe overuse in localized areas along the fences. The author felt that herding is better than pasturing sheep in this range area.

DESCRIPTION OF THE AREA

GEOLOGY AND SOILS

The grassland area included in this study lies in the foothills of the Smith River Valley in Meagher County, Montana. The Smith River Valley occupies an intermountain basin between the Big Belt, Little Belt, and Castle Mountains. The basin is 40 miles long and 2 to 8 miles wide. Elevations range from 4,800 feet to 5,200 feet (Gieseker, et al., 1953). It is characterized by smooth gently sloping benchlands and ridges of sedimentary rock extending out from the mountains. These benchlands and ridges are separated by small intervening stream valleys. A few ridges and out-crops of igneous rocks occur locally in the basin. The benchland covering consists of limestone and argillite fragments, which occur over lake-bed sediments in most sections (Gieseker, et al., 1953). During the Wisconsin glaciation, ice accumulated in the Crazy and Castle Mountains to such an extent that it extended down to the mouth of the large canyons.

The Missouri River and its branches drain a large part of central Montana. One of its branches, Smith River, is the perennial stream that drains this intermountain basin between the Big Belt Mountains and the Little Belt and Castle Mountains. It rises in the Little Belt Mountains and wanders through wet bottom lands in the basin before turning northward to join the Missouri River in Cascade County. At Fort Logan it enters a canyon that becomes a gorge 800 to 1,000 feet deep in northern Meagher County. Its larger branches, such as the Tenderfoot River, flow through deep canyons and rock-walled gorges. Its South Fork heads in the southern part of the Castle Mountains and flows through the open valley before it enters the main river.

The soils of central Montana differ greatly due to their physical, chemical, and biological properties as influenced by parent material and the prevailing climate. There are four general groupings of soils in the Smith River Basin. They are as follows: (1) farming soils, (2) farming-grazing soils, (3) grazing soils, and (4) miscellaneous soils and land types (Gieseker, et al., 1953). These groups reflect productive capacity to a great extent. This correlation is closely related to differences in climate and native vegetation.

The study area occurs on two of the benchlands extending out from the western side of the Castle Mountains, as shown in Figures 1 and 2. This area is cut lengthwise from east to west by a small intermittent stream known locally as Lone Willow Creek. One high bench of sedimentary rock (Figure 3) occurs in the northeast portion of the study area on the north side of Lone Willow Creek. There are four kinds of soils occurring on and adjacent to the study area. They are as follows: (1) Crago gravelly loam, a grazing soil; (2) Gilcrest loam and gravelly loam-undifferentiated, a grazing soil; (3) Alluvial soils-undifferentiated (dark-colored), a grazing and hayland soil, and (4) Hilger loam and stony loam-undifferentiated (some sharply rolling and broken), a farming-grazing soil (Gieseker, et al., 1953). These soils are all quite fertile and capable of supporting a good stand of grass with proper management practices.

CLIMATE

The climate of the Smith River Basin is midcontinental. Over most of this area the semiarid climate is characterized by moderately low rain-

Figure 1. Looking northeast across the study area. Castle Mountains are in the right background, and the lambing sheds are along the creek in the left background.

Figure 2. Looking southeast from the study area toward the Castle Mountains. A typical big sagebrush vegetation type may be seen in the foreground.

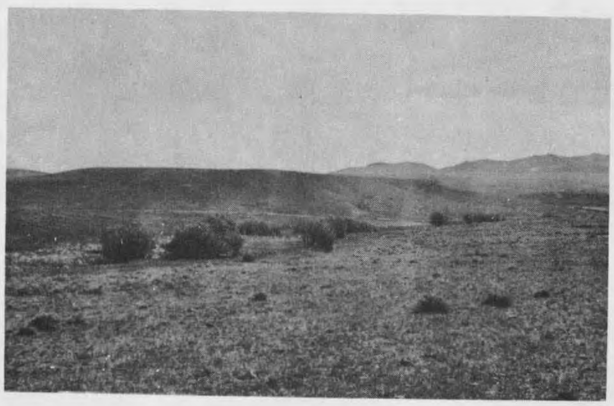

Figure 3. Looking northeast across Lone Willow Creek at the high bench of sedimentary rock occurring in the study area.

fall, great extremes in summer and winter temperatures, many sunny days, and relatively low humidity. The midsummer temperatures are not oppressive because of the low humidity, and winter is often moderated by warm winds. The more general storms and winter chinooks come from the north and west. The normal monthly and annual precipitation and temperature and the 1953 monthly and annual precipitation and temperature, as well as temperature extremes and freeze data for 1953, are given in Table I for White Sulphur Springs, Montana. This weather station is located about 3 miles northwest of the study area. The climate on the study area is thought to be very similar to the climate as discussed herein.

Table I. Climatic data from White Sulphur Springs weather station in Meagher County, Montana. 1/

Month	Normal Precip.	Total 1953 Precip.	Normal Temp.	Average 1953 Temp.	Temp. Extremes 1953	Number of days between dates 1953
January	.58	1.11	21.0	32.7	-14	24 degrees
February	.59	1.35	23.4	27.4		or below
March	1.00	0.70	33.0	32.8		163
April	1.12	1.27	41.4	35.7		28 degrees
May	1.75	3.47	50.3	44.1		or below
June	2.66	3.31	52.9	54.9		120
July	1.42	0.39	65.2	65.4	97	32 degrees
August	1.16	1.00	63.2	65.6		or below
September	1.28	0.73	53.6	56.2		70
October	1.06	0.39	43.4	47.7		
November	0.68	0.15	32.3	38.5		
December	0.88	1.43	22.8	27.2		
Annual	14.18	15.30	41.9	44.0		

1/ U. S. Dept. Commerce, Weather Bureau. 1954. Climatological Data Montana, Annual Summary 1953. 56:208-219.

The average annual precipitation is 14.18 inches and the average annual temperature is 41.9 degrees at White Sulphur Springs. During the 5-year period immediately preceeding this study, 1949-1953 inclusive, the coldest temperature, -36°, was recorded on January 24, 1949, and the warmest temperature, 97°, was recorded on July 13, 1953. During this same 5-year period the number of days between dates of low temperatures of 24° or below, 28° or below, and 32° or below were 146.2, 111.8, and 69.4 days respectively.

The distribution of annual precipitation is of great importance in the Smith River Valley with the largest amount of it coming during May, June, and July. Daily showers of a local nature are characteristic of the rainfall during this period. Some localized areas may receive good rains and others nearby may receive none. Part of the precipitation falls as snow during the fall, winter, and spring months but rarely does it lie in place on the lower agricultural and foothill areas. Strong winds usually collect it in drifts on the north slopes of the hills and ridges and in the coulees. Only occasionally do hail storms occur in this intermountain basin.

Brisk westerly and northwesterly winds predominate in the Smith River Valley but easterly winds occur frequently during the summer months. These winds blow more or less constantly during the late winter months and throughout the spring months. This basin lies in the path of chinook winds, which often prevent heavy snow accumulation in the lower areas. These warm, dry winds have a marked influence on the effectiveness of the winter precipitation.

As shown in Table I, the total annual precipitation was 1.12 inches above normal and the average annual temperature was 2.1 degrees above normal in 1953. Thus, the growing conditions were slightly better than average as a whole for the year immediately preceeding this study. The temperature extremes were relatively mild. The period which elapsed between temperatures of 24 degrees and below was about 8 to 10 days longer than would normally be expected, thus also improving growing conditions.

VEGETATION

The kinds of native and introduced plants present in any given area, their density, and their value as forage are generally determined by the prevailing climate but the soils and their degree of development can cause some local variation in the vegetation. The shorter growing grasses predominate in the drier portions of the Smith River Basin, although they are thoroughly intermingled with many taller growing species. In the areas of more soil moisture, such as the bottoms of coulees and on the north slopes, the taller, moisture-loving plants make up the larger portion of the plant composition.

The grassland climax in the Smith River Valley has not been definitely classified in regard to its association. Weaver and Clements (1938), Clements and Shelford (1939), Wright and Wright (1948), and Heady (1950) list the most important species occurring in the mixed prairie and Palouse Prairie associations. Daubenmire (1942) listed the plant species of importance as they occur in the Palouse Prairie association. Morris (1946) classified the lands in the Smith River Valley on the basis of soils, climate, and grazing. The vegetation present in this intermountain basin indicates an intermingling of both the Palouse Prairie and the mixed prairie associations.

The plant species occurring within the Smith River Valley vary with site and exposure. The principal grasses of the valley include bluebunch wheatgrass (Agropyron spicatum), junegrass (Koeleria cristata), sandberg bluegrass (Poa secunda), kentucky bluegrass (Poa pratensis), idaho fescue (Festuca idahoensis), blue grama (Bouteloua gracilis), and plains reedgrass (Calamagrostis montanensis). Forbs of importance include a club moss (Selaginella densa), hoods phlox (Phlox hoodii), pussytoes (Antennaria spp.), lupines (Lupinus spp.), western yarrow (Achillea lanulosa), and whitepoint loco (Oxytropis sericea). Important shrubs include silver sagebrush (Artemisia cana), fringed sagewort (Artemisia frigida), and broom snakeweed (Gutierrezia sarothrae). Numerous other plant species of minor importance occur throughout the valley.

Poisonous plants which occur within this valley include several species of (Astragalus), (Oxytropis), (Lupinus), (Delphinium), and (Zygadenus). Water hemlock (Cicuta occidentalis) and arrowgrass (Triglochin maritima) occur occasionally on marshy lands. Only a limited amount of trouble with poisonous plants is experienced by the livestock operations in this area.

The plant species present on the study area are the same as those found throughout the entire Smith River Valley. The pattern of species distribution within the study area varies with site in much the same manner as it does throughout the entire valley. The Festuca idahoensis type is found on most of the moist north slopes, and the Agropyron spicatum, Artemisia tridentata, and Artemisia cana types are found on the drier sites. A Poa pratensis type occurs along the creek in the study area.

EXPERIMENTAL PROCEDURE

LIVESTOCK MANAGEMENT

The "per cent ungrazed method" of determining degree of utilization has been tested with cattle grazing under a pasturage management plan (Roach, 1950). The "per cent of plants grazed" variation of the method has been tested under similar conditions (Hurd and Kissinger, 1953). Neither this method nor the variation has been tested with sheep. Sheep were chosen for this 1954 study both for this reason and for convenience.

The Montana State College Experiment Station experimental sheep band was conveniently available and located for a study of this type. These sheep were run on a ranch leased by the Montana State College Experiment Station. This ranch is adjacent to the town of White Sulphur Springs, Montana and is known locally as the Shaw Ranch. A portion of this ranch immediately adjoining the lambing area (Figure 1) was enclosed by a sheep-tight fence. This pasture was approximately 1 mile long and ½ mile wide. This area was chosen as the area to be studied because of the availability of ewes and lambs and the grazing management practiced. This pasture was used as a holding area for the lambed-out ewes and their lambs. In the early part of the grazing period, May 4-6, inclusive, hay was fed as a supplement to grass. This hay was placed along the north side of Lone Willow Creek and near the lambing sheds, thus influencing grazing use in this area. No hay or concentrate was fed after this period.

Two different groups of sheep were used in this project. On May 4, 1954, a total of 175 ewes with their lambs were placed in the area. The following day an additional 125 more ewes with their lambs were added. These 300 ewes and their lambs were allowed to move, graze, and bed as they chose without interference until the morning of May 8 at which time they were removed from the area. A period of 4 days elapsed before any additional grazing occurred on the area. On May 12, a group of 385 ewes with their lambs were placed in the area. These sheep (Figures 4 and 5) were handled in a manner similar to that described above. This group of 385 ewes and their lambs was pastured continuously on this area until they were removed on the morning of June 3. No data is available as to the number of lambs with the first group of 300 ewes. However, some indication of the number of lambs present in the second group was noted in the fact that 512 lambs were counted when this group of sheep was taken out of the area.

During the periods when the sheep were on the study area, they were left alone as much as possible. Salt was distributed daily on the ridge in the northwest portion of the study area (Figure 6). This area was chosen (1) because it was dry, for purposes of salting on the ground; (2) because it was handy, crossed by a road; and (3) because it was at the opposite end of the study area in relation to the lambing sheds, which helped keep these sheep away from the vicinity of the lambing sheds. The sheep were allowed a free choice as to when they ate salt. Water was readily available in Lone Willow Creek, extending the length of the study area, and in a large irrigation ditch which crossed the full width of the area near the west end. Water was also available in a small irrigation

Figure 4. Sheep grazing out from one of their favorite bedding areas. The foothills of the Castle Mountains may be seen in the background.

Figure 5. Sheep grazing on the Shaw Ranch study area. This small group of sheep illustrates the widely scattered manner of grazing that occurred during this study.

Figure 6. Looking northwest across the study area. The salt was distributed on the ridge in the center background. White Sulphur Springs may be seen in the right background and the ranch headquarters to the left. A small unit of the silver sagebrush vegetation type is present in the foreground.

ditch which crossed the northeast corner of the area.

VEGETATION MEASUREMENT

The stratification and distribution patterns of plant populations and communities on the grazing areas of the West are such that it is difficult to make accurate studies of them without intensive application of sound experimental procedures. Osborne and Reid (1952) have discussed the various experimental designs and procedures used in range research, and several of these are incorporated in this study. Both an observer and a recorder were used in this study, because of the intensive procedures involved.

Plot Location System

In order to study the vegetation of this area, it was necessary to decide upon a method of sample plot location which would give accurate results with a minimum expenditure of time. Hasel (1938) discussed the validity of statistical analysis based upon systematically spaced plots. Pechanec (1941) also discussed this and stated that subdivision by type or condition will decrease needed sampling intensity for the same degree of error. Pechanec and Stewart (1940 and 1941) tested various methods and concluded that the line-plot sampling unit with systematic spacing of subunits was the most efficient method. Representativeness for statistical purposes was not achieved under the conditions studied.

A grid system of establishing compass lines across the area was selected because of the need for a systematic method of sampling as an aid to developing a map of the vegetation types in the area, as well as the previously indicated efficiency of this method. These north and south compass line transects were located 264 feet (4 chains) apart with the first and last ones 132 feet (2 chains) from the east and west fence lines. The sample plots were systematically located by means of pacing along these predetermined compass lines. The advisability of using this method is further borne out by Bourdeau (1953). He states that the systematic method is the most accurate, followed by the stratified random and purely random methods in that order. Cochran (1946) concluded that on the average systematic sampling is more accurate than stratified random sampling for any given size of sample. He points out that plant populations do exist in which the systematic sample may be more accurate than the stratified random sample at a given sampling rate but less accurate at another sampling rate.

Types of Plot

The examination of the vegetation present on the area in terms of: (1) per cent composition, (2) per cent basal density, and (3) number, kind, and location of vegetation types involved selection of an accurate and efficient kind of sample plot. Various kinds of plots have been used in this type of work but no one kind was the best under all conditions of vegetation or for all the types of information desired. Stapledon (1931) has shown experimentally that small plots concentrate the observer's efforts on small areas and thus make his estimates more intensive. Stapledon was the first to suggest a point as the most accurate size of plot, and Levy and Madden (1933) developed the "point quadrat method" of vegetation survey based upon his suggestion. Their method was modified

(Clarke, et al., 1942) by measuring only basal point contacts. The inclined point modification (Tinney, et al., 1937) has been found to be more accurate and easy to apply in short grasses than the vertical point form (Drew, 1944). Arny and Schmid (1942) and Arny (1944) suggest the application of correction factors to yield data determined by using the "point quadrat method," but Sprague and Myers (1945) found the use of a constant to be of no value.

The "point quadrat method" was chosen as the method to use in studying the vegetation composition of this area. Several workers (Hanson, 1934; Ellison, 1942; Leasure, 1949; Goodall, 1952; Whitman and Siggeirsson, 1954; and Johnston, 1954) have satisfactorily tested various modifications of the "point quadrat method.". Numerous other workers have made satisfactory use of the method and its modifications (Hanson and Whitman, 1938; Hein and Henson, 1942; Henson and Hein, 1944; Rhoad and Carr, 1945; Musser, 1948; Coupland, 1950; and Hanson, 1950). Crocker and Tiver (1948) list many advantages of the method. Many of these advantages were applicable to the study area. The inclined point modification of this method was chosen as the kind of plot to use in this study.

The inclined point frame used in the composition study consisted of 20 pins, 16 inches long and extending 10 inches below the lower support bar of the frame(Figure 7). The 20 pins were spaced at $1\frac{1}{2}$ inch intervals throughout a distance of 30 inches in the point frame.

Only the basal hits of the pin points were recorded on all vegetation. Hits on litter and bare ground were recorded as well as vegetation con-

Figure 7. The point analysis frame used to determine vegetation composition on the study area. The inclined angle of the needles is accentuated by the fact that the frame is sitting on a slope. The needles extend further down the slope than the legs.

tacts. Only vegetation contacts were used to compute per cent composition. All hits, including litter and bare ground, were used to compute per cent basal density.

The plots were systematically located at intervals of 132 feet (2 chains) except for the first plot on each transect line. This plot was located 66 feet (1 chain) from the point of beginning. This procedure was necessary in order that the last plot of each transect would not fall on a fence line. At each plot location, the point analysis frame was placed with the points sloping toward the operator, with the left front leg of the frame at the center of the right boot toe.

After the foregoing process had been completed, the same compass transect lines were rerun in order to determine the degree of utilization and number of grazed plants in each vegetation type of the study area. This procedure was accomplished by taking systematic stubble-height observations according to Lommasson and Jensen's method (1942 and 1943). A measurement was taken of the average stubble-height of the grass or grass-like plant falling nearest the center of the right boot toe at intervals of 66 feet (1 chain), with the exception of the first plot on each transect line. This plot was located 33 feet ($\frac{1}{2}$ chain) from the point of beginning. Again this variation was necessitated by the presence of fence lines.

Development of Utilization Table

A total of 20 ungrazed samples of the grass and grass-like plant species which the sheep had eaten were collected in order to study their height-weight relationships. Only 10 sods of blue grama were collected because of time limitations. Plants with seed heads were not involved in this study. These plants were excluded from this study because seed heads were not yet formed at the time grazing occurred. In addition, the majority of plants on the area were of the non-seedstalk form.

The plant samples were selected by means of a stratified random sample technique. The method involved an arbitrary choice of sites, wherever it was possible, and a random selection of plants by tossing a hat, within each of these sites. These samples were then dug up and taken into the laboratory complete with roots. When compared to the Lommasson and Jensen method (1942 and 1943), this system was found to simplify and shorten the work involved.

Each individual plant was then air dried and cut into sections. These sections were of various lengths depending upon the general height of the plant species involved. This was done in order to avoid excessive work and still secure adequate measurements. The blue grama plants were all cut into ¼-inch sections while all the wire rush (Juncus balticus) and timothy (Phleum pratense) plants were cut into 1-inch sections. The remaining species, bluebunch wheatgrass, western wheatgrass, plains reedgrass, idaho fescue, junegrass, sandberg bluegrass, kentucky bluegrass, needle-and-thread (Stipa comata), and needleleaf sedge (Carex eleocharis), were cut into ½-inch sections.

The plants were sectioned from top to bottom in the order that a grazing animal would normally graze them. The sectioning procedure was carried on until a point was reached that would put the next section immediately at or under the ground level. This section was not measured or considered a part of the plant. This has been previously discussed by Lommasson and Jensen (1942 and 1943).

These individual plant sections were then weighed individually to the nearest 1/100 gram (centigrams). The weights of all the bottom sections for the 20 plants of a species (10 sods of 10 individual plants in the case of blue grama) were totaled. This same procedure was employed for each group of higher sections until the tallest plants were included. These total weights for each section were then converted to a percentage of the total weight of all sections, for all plants of the species in question. Thus, the height-weight distribution was weighted both by the number of the various plant heights present and by the totaled individual weights of the plant sections. This resulted in a composite plant of a non-seedstalk producing form for each species. These composite plants were assumed to represent all the plants of each species occurring within the study area. A discussion of this point may be found beginning on page 80 in the results and discussion section.

These percentages were then used to develop a table for determining the per cent of available plant utilized from the stubble height remaining upon the ground. The degree of utilization on this area was then determined both from this table and from Lommasson and Jensen's gauge (1942 and 1943), using the same stubble height measurements for both methods. It should be emphasized that such a table may be applicable only to the area in which it is developed.

The various data collected and determined through the various procedures listed above were tabulated. These data tabulations were then analyzed for the particular information desired. All statistical analyses were based upon procedures described by Ostle (1954).

Mapping Procedures

The study area was systematically mapped by topographic, cultural and vegetative features during the first coverage of the area. The systematically located compass lines, located 264 feet (4 chains) apart, were measured by means of pacing. Whenever any of the mapping features were encountered, they were placed on scaled graph paper at the accumulated distance from the point of beginning and on the compass line involved. These plotted points on each transect line were connected by means of visual observation as the observer progressed along the lines. By means of this systematic and progressive system of mapping, it was possible to complete the map of the area at the same time that the vegetation analysis was completed. The boundaries of the vegetation types were determined by visual appearance. These types were classified both by visual appearance and by vegetative composition, as determined by the point quadrat readings.

Another phase of study, of minor importance, was also included in this mapping work. This involved the determination and mapping of the various generalized zones of utilization. This process was based upon visual estimates of the degree of use which had occurred on each portion of the area. These estimations were made while following the transects across the area. The boundaries were rechecked by driving back and forth over the area several times in a car. Occasional stops were made for closer examinations. The general use classification terms used for this purpose were excessive, heavy, moderate, light, and unutilized.

RESULTS AND DISCUSSION

SHEEP BEHAVIOR AND GRAZING INFLUENCES

The behavior of the unherded sheep that were fed hay followed a fairly uniform pattern. During the period when hay was fed along the creek bottom, the sheep utilized the hay during the early part of the day and fed out on the adjacent areas in the afternoon, never getting far from the feed ground. They returned to the feed ground in the evening, bedding near the feed ground and immediately adjacent to the lambing area. This resulted in severely over-utilized and heavily utilized areas along Lone Willow Creek in the eastern portion of the study area, as shown in Figure 8. The last day these sheep were on the study area, they were not fed hay, but they reacted in much the same manner as before, apparently from force of habit. While grazing on the range grasses, these sheep spread out into loose groups of from 30 to 80 ewes and their lambs.

The group of sheep placed in the study area at a later date were not fed hay and did not react in as uniform a manner as did the first group. These sheep spread out widely in loose groups of from 5 to 30 ewes (Figure 5) and their lambs. They bedded on the highest portion of the particular area in which they were grazing when twilight approached. If a fence was nearby, they often bedded near it (Figure 8). The high bench of sedimentary rock in the northeast portion of the area was often used as a bedground, although no fences or other obstructions were present. The difference in grazing habits between these two groups of sheep was apparently almost entirely due to the practice of feeding hay to the first group.

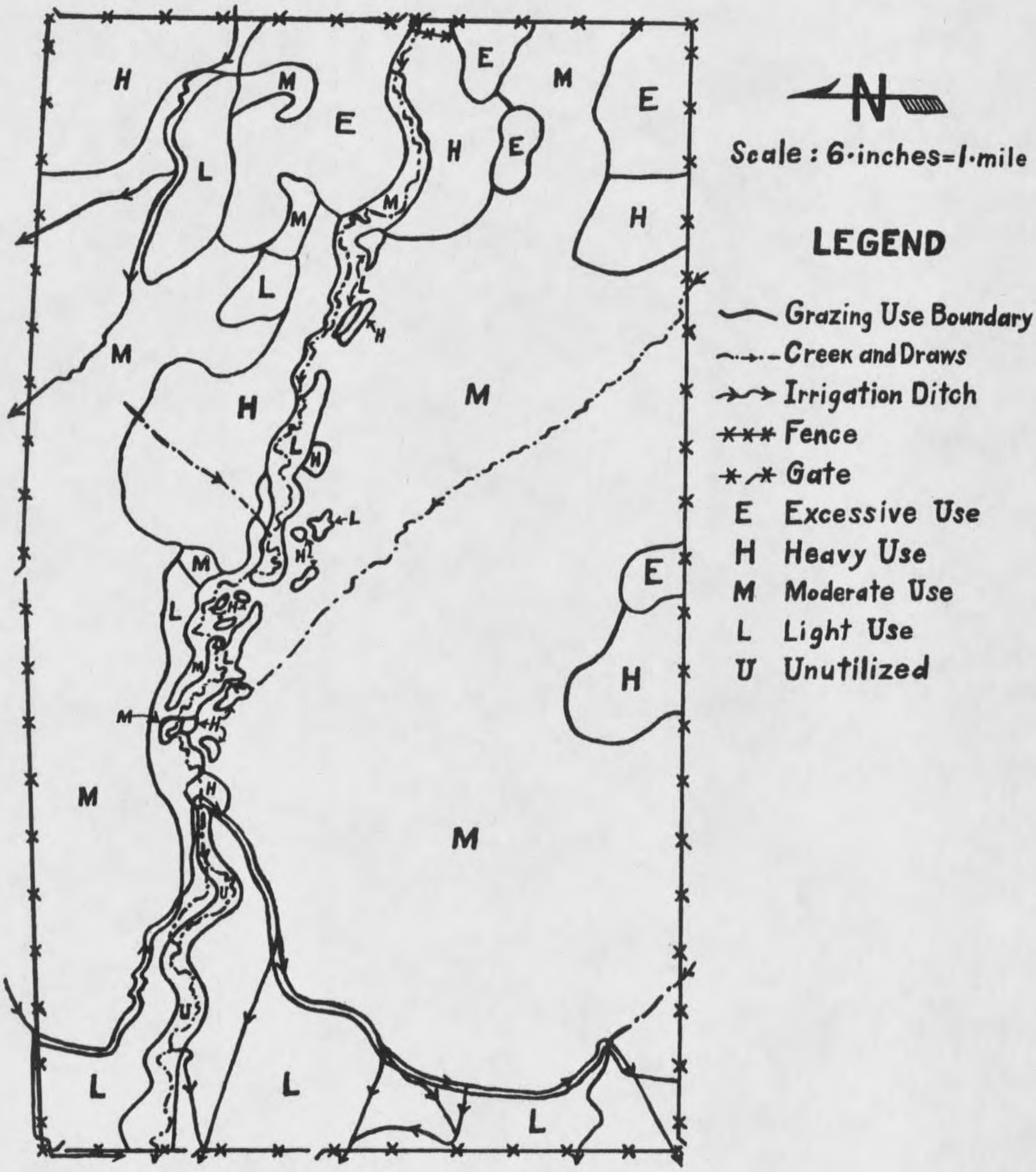

Figure 8. Map of the study area on the Shaw Ranch at White Sulphur Springs, Montana, showing the various zones of utilization by degree of use. The degree of use and zonation boundaries are based upon visual estimates.

The grazing habits of the sheep were apparently not greatly influenced by the location of drinking water and salt or by temperature, wind, insects, or predators. No excessive temperatures or winds occurred during this period, and insects were almost entirely absent. No shading-up was observed. Sheep could be observed grazing, nursing, ruminating, resting, walking, drinking water, and eating salt at almost any given time during the daylight hours. No predators were observed in the area, and no unnatural disturbances of a predator nature were detected at any time.

Several factors did influence the grazing habits of the sheep, in addition to the previously mentioned factors of hay, lambing camp location, and elevations. These included water barriers, exposure, slope, vegetation roughs, and vegetation types as influenced by the preference of the sheep for certain plant species. The area along Lone Willow Creek and below the large irrigation ditch (Figures 8 and 9) was unutilized because of standing water. The balance of the area below this ditch was only lightly utilized because of the difficulty encountered by the sheep in getting back and forth across the ditch. The north slope of the high bench in the northeast part of the study area was only lightly utilized as were the steep south-facing slopes along Lone Willow Creek (Figures 8 and 10). The vegetation roughs along the creek bottom, as depicted in Figures 10 and 11, caused the development of an extremely variable grazing pattern along the course of the stream (Figure 8). The sheep made heavy use of the vegetation along the creek bottom except for the rough areas of old coarse growth, which they left almost entirely alone. Burning of these areas of coarse growth would probably have materially changed

Figure 9. Looking northwest across the unutilized area below the large irrigation ditch.

Figure 10. Little utilization occurred on these steep south-facing slopes along Lone Willow Creek. The light areas of grass along the creek bottom are rough areas of vegetation which are only very lightly utilized while the darker areas are moderate to heavily utilized.

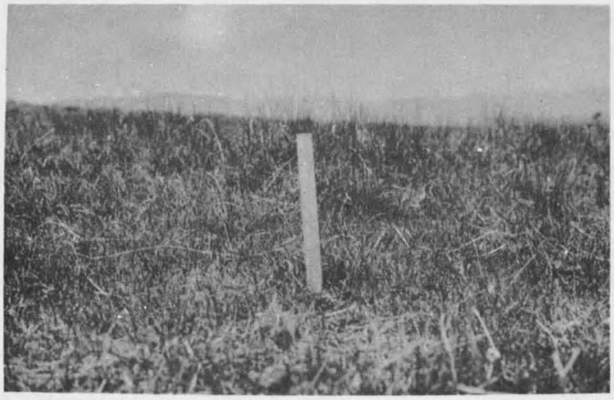

Figure 11. A close-up view of the grazing pattern along Lone Willow Creek. Moderate use in the foreground and a lightly utilized rough in the background.

this spotty grazing pattern.

The sheep used the kentucky bluegrass-timothy vegetation type the heaviest of the major vegetation types. Much grazing time was spent on this type. The grass types dominated by bluebunch wheatgrass, the grass types dominated by idaho fescue, the sagebrush-bluebunch wheatgrass types, and the sagebrush -idaho fescue types appeared to be favored by the sheep in that order. Preferred plant species, by visual observation, included sandberg bluegrass, timothy, wire rush, kentucky bluegrass, junegrass, bluebunch wheatgrass, western wheatgrass, idaho fescue, and needle-and-thread. Less preferred plants included needleleaf sedge, blue grama, and plains reedgrass. Occasionally rocky mountain iris (Iris missouriensis), scarlet globemallow (Sphaeralcea coccinea), lupine (Lupinus spp.), and whitepoint loco (Oxytropis sericea) were heavily utilized. No utilization was observed on the shrubs.

Some death loss occurred during the time the sheep were on the study area. A total of four ewes and seven lambs were found dead. The cause of death was not definitely established. It was believed that the four ewes died from eating excessive amounts of poisonous plants. These plants were fairly large, in relation to the grass plants, at the time the first group of sheep were placed in the area. The lamb losses were probably due to the inability of these "bummed" lambs to care for themselves when their mothers died.

VEGETATION PRESENT

The kind, amount, and distribution of the various plant species occurring on the area were examined prior to the determination of utilization within the area. The entire study area was systematically mapped by vegetation types, as well as by natural and cultural features. These features are located and explained in Figure 12. As previously noted, the area is entirely fenced and is cut lengthwise by Lone Willow Creek. Irrigation ditches in the northeast corner and western end of the study area supplement the stockwater supply in the creek. The small lake bed in the northeast corner dries up early in the grazing season.

Vegetation types vary with slope, soils, and exposure (Figure 12). The moist north slopes support thick stands of idaho fescue (Figure 13) with a scattered dominance of silver sagebrush or big sagebrush in localized areas (Figure 6). The flat and drier areas are dominated by bluebunch wheatgrass, junegrass, and plains reedgrass (Figure 14) with scattered stands of big sagebrush and silver sagebrush intermingling with the grasses on the south side of Lone Willow Creek (Figure 2). The steep, gravelly, south-facing slopes support scattered stands of bluebunch wheatgrass and red three-awn (<u>Aristida longiseta</u>). The lowlands along Lone Willow Creek are dominated by kentucky bluegrass, timothy, wire rush, and rocky mountain iris, as shown in Figures 15 and 16.

The acreage (planimetered on the map) in each vegetation type and within the entire study area was determined. The acreage for each vegetation type (Table II) was obtained by grouping all of the small units of each vegetation type occurring on the north side and by grouping separately those occurring on the south side of Lone Willow Creek. This arbitrary division was used to facilitate the compilation and discussion of the acreages involved. As indicated in Table II, the total acreage in

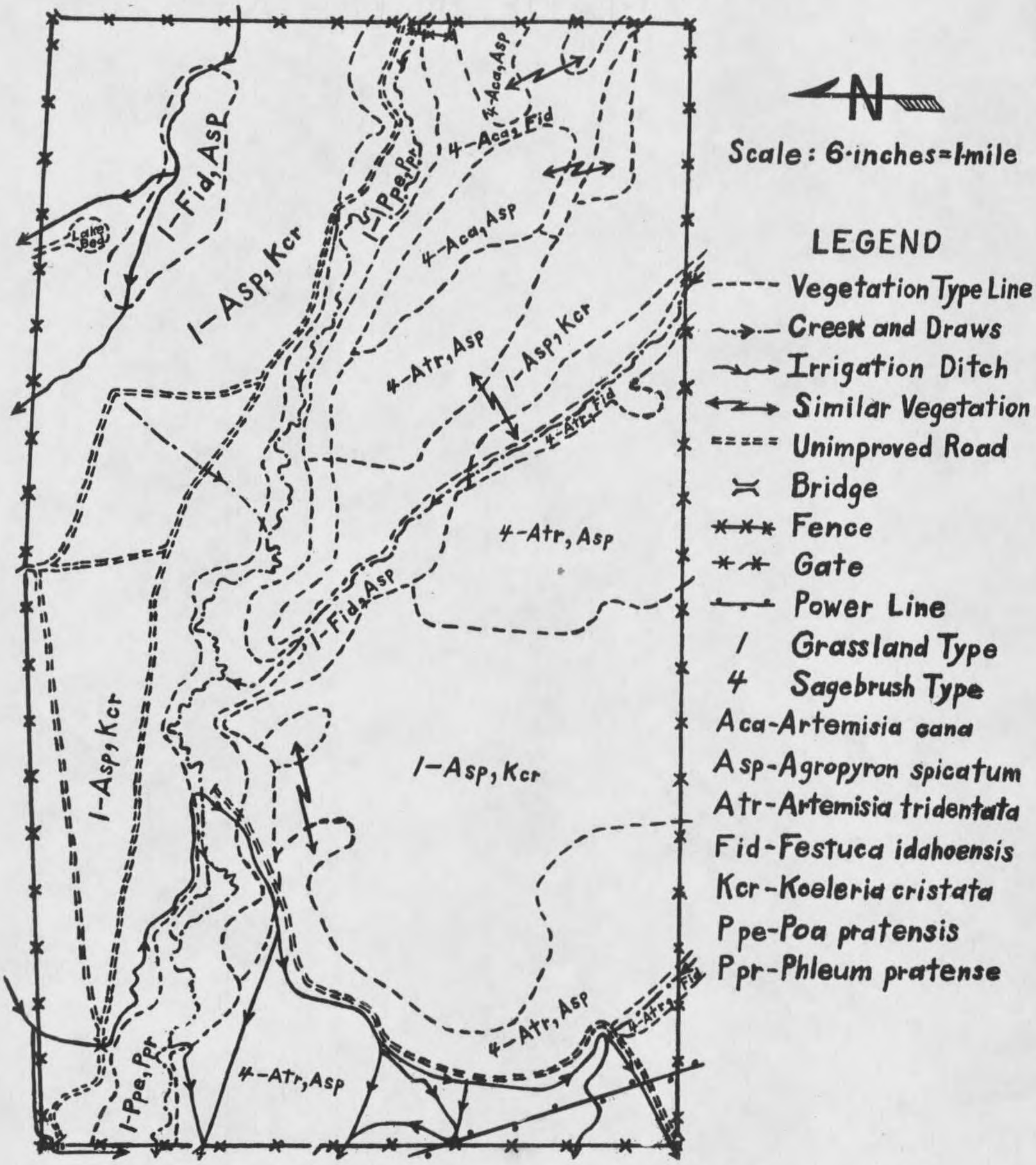

Figure 12. Map of the study area on the Shaw Ranch at White Sulphur Springs, Montana, showing the vegetation types and the natural and cultural features.

Figure 13. Dominant vegetation on the moist north slopes. The vegetation is almost entirely idaho fescue.

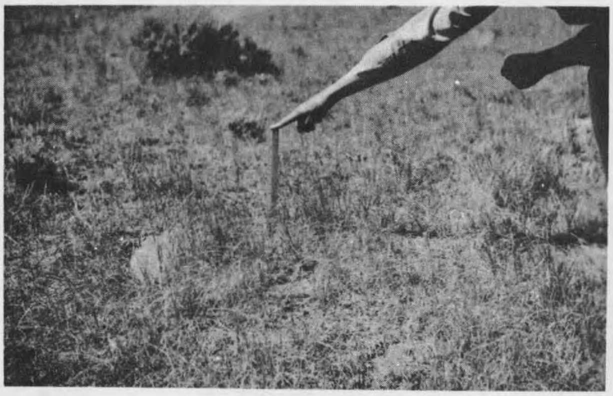

Figure 14. Dominant vegetation on the dry areas. Bluebunch wheatgrass and plains reedgrass dominate the aspect on this type of site.

Figure 15. Dominant vegetation on the lowlands along Lone Willow Creek. Timothy, kentucky bluegrass, and wire rush are prominent.

Figure 16. Dominant vegetation on the lowlands along Lone Willow Creek. kentucky bluegrass, rocky mountain iris, and wire rush are prominent.

the pasture was 366 acres. A total of 365.5 acres was available for grazing use if the small lake bed was excluded. The *Agropyron spicatum*, *Koeleria cristata* vegetation type (1-Asp, Kcr) north of the creek was the largest type, and the various units of the *Artemisia tridentata*, *Agropyron spicatum* vegetation type (4-Atr, Asp) made up the second largest part of the total acreage. The *Artemisia cana*, *Festuca idahoensis* vegetation type (4-Aca, Fid) was the smallest silver sagebrush type. *Artemisia tridentata*, *Festuca idahoensis* vegetation (4-Atr, Fid), the smallest type, comprised 4.7 acres of the total acreage. The *Poa pratensis*, *Phleum pratense* vegetation type (1-Ppe, Ppr) consisted of 32.0 acres along the creek.

TABLE II. ACREAGES OF EACH VEGETATION TYPE AND TOTAL ACREAGE OCCURRING WITHIN THE STUDY AREA ON THE SHAW RANCH AT WHITE SULPHUR SPRINGS, MONTANA.

Type Description	Type Location	Acres
Grassland Vegetation Types		
1-Asp, Kcr	North of Creek	105.5
1-Asp, Kcr	South of Creek	83.0
1-Fid, Asp	North of Creek	7.3
1-Fid, Asp	South of Creek	11.9
1-Ppe, Ppr	Along Creek	32.0
Sagebrush Vegetation Types		
4-Atr, Asp	South of Creek	93.4
4-Atr, Fid	South of Creek	4.7
4-Aca, Asp	South of Creek	15.0
4-Aca, Fid	South of Creek	12.7
Small Lake Bed	North of Creek	0.5
Total		366.0

The per cent composition of each plant species present, in each major vegetation type and the total area, is presented in Table III. This table also lists each class of vegetation in a similar manner. As previously mentioned, these composition values are based upon basal point contacts. The per cent composition varies to a great extent among the various vegetation types present. For the entire area, bluebunch wheatgrass and junegrass make up the most important part of the vegetation available to livestock. The importance of the club moss is clearly pointed out by the fact that it makes up 19.4 per cent of the vegetation composition for the entire study area. The forbs, which are available to livestock, consist primarily of unpalatable species such as hoods phlox, pussytoes, and western yarrow. Lupine is present in fairly large amounts. Of the shrubs, silver sagebrush is the most important. Grass and grass-like plants make up the largest part of the composition in all but one of the vegetation types. The kentucky bluegrass and idaho fescue types have larger percentages of grass than the other vegetation types. This is largely due to the moist conditions which favor the grasses. These data were statistically analyzed by the Montana State College Statistical Laboratory. The analyses are presented in Table IV.

The per cent basal density of each plant species, occurring in each major vegetation type and the total area, is tabulated in Table V. This table also presents the per cent basal density for each class of vegetation. A value of zero per cent basal density indicates that the plant species was present in large enough quantities to make up at least 1 per cent of the composition in at least one vegetation type. All the other plant species did not make up a total of 1 per cent of the composition

TABLE III. PER CENT COMPOSITION OF VEGETATION IN EACH MAJOR VEGETATION TYPE AND FOR THE TOTAL AREA ON SHAW RANCH STUDY AREA AS DETERMINED BY BASAL POINT CONTACTS.

Species	1-Asp, Kcr.	1-Asp, Kcr.	1-Fid, Asp.	1-Fid, Asp.	1-Ppe, Ppr.	4-Atr, Asp.	4-Atr, Fid.	4-Aca, Asp.	4-Aca, Fid.	Total Area 1/
Agropyron smithii	2	3		4	1	3	6	2	2	2.5
Agropyron spicatum	15	20	22	10	1	17	10	9	4	14.7
Bouteloua gracilis	14	2				1				4.7
Calamagrostis montanensis	3	5		3		4		4	2	3.4
Carex eleocharis	3	2			6	1	7	1		2.2
Festuca idahoensis			52	65			42		50	5.4
Juncus balticus					4					0.4
Koeleria cristata	21	14		5	1	16	3	6	1	13.9
Phleum pratense	1				25					2.5
Poa pratensis	3		3		55	1	3			6.0
Poa secunda	8	8	3	3		7	3	4	2	6.3
Stipa comata	4	2				2				2.1
Total of Group	74	56	80	90	93	52	74	26	61	64.1
Achillea lanulosa				1	2	1		1	1	0.5
Antennaria spp.	1	1		3	1	3		2	2	1.6
Artemisia ludoviciana			2	1					2	0.1
Iris missouriensis					1					0.1
Lupinus spp.			10	1		1	23		2	0.9
Oxytropis sericea		2								0.5
Phlox hoodii	4	2				2		1		2.2
Phlox spp.						1	3			0.3
Selaginella densa	8	35	3	4		22		63	23	19.4
Sphaeralcea coccinea	1							1		0.3
Trifolium spp.					3					0.3
Total of Group	14	40	15	10	7	30	26	68	30	26.2
Artemisia cana	4		3			4		3	9	2.7
Artemisia frigida	4	2	2			3				2.4
Artemisia tridentata						8				2.1
Chrysothamnus nauseosus						1				0.3
Gutierrezia sarothrae	4	2				2		3		2.2
Total of Group	12	4	5	0	0	18	0	6	9	9.7
Total of All Vegetation	100	100	100	100	100	100	100	100	100	100.0

1/ Values for total area are weighted by acreage in each type.

TABLE IV. ANALYSES OF PER CENT COMPOSITION VALUES FOR EACH PLANT SPECIES, FOR EACH CLASS OF VEGETATION, AND FOR THE TOTAL AREA. 1/

Species	No. of Values	Mean (Per cent) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
Agropyron smithii	8	2.88	1.55	0.55
Agropyron spicatum	9	12.00	7.07	2.36
Bouteloua gracilis	3	5.67	7.23	4.18
Calamagrostis montanensis	6	3.50	1.05	0.43
Carex eleocharis	6	3.33	2.58	1.05
Festuca idahoensis	4	52.25	9.54	4.77
Juncus balticus	1	4.00	0.00	0.00
Koeleria cristata	8	8.38	7.60	2.69
Phleum pratense	2	13.00	16.97	12.00
Poa pratensis	5	13.00	23.50	10.51
Poa secunda	8	4.75	2.49	0.88
Stipa comata	3	2.67	1.15	0.67
Total of Group	9	67.33	21.02	7.01
Achillea lanulosa	5	1.20	0.45	0.20
Antennaria spp.	7	1.86	0.90	0.34
Artemisia ludoviciana	3	1.67	0.58	0.33
Iris missouriensis	1	1.00	0.00	0.00
Lupinus spp.	5	7.40	9.50	4.25
Oxytropis sericea	1	2.00	0.00	0.00
Phlox hoodii	4	2.25	1.26	0.63
Phlox spp.	2	2.00	1.41	1.00
Selaginella densa	7	22.57	21.33	8.06
Sphaeralcea coccinea	2	1.00	0.00	0.00
Trifolium spp.	1	3.00	0.00	0.00
Total of Group	9	26.67	18.94	6.31
Artemisia cana	5	4.60	2.51	1.12
Artemisia frigida	4	2.75	0.96	0.48
Artemisia tridentata	1	8.00	0.00	0.00
Chrysothamnus nauseosus	1	1.00	0.00	0.00
Gutierrezia sarothrae	4	2.75	0.96	0.48
Total of Group	9	6.00	6.14	2.05
Total Area	28	3.57	4.79	0.91

1/ The Montana State College Statistical Laboratory conducted these analyses.

TABLE V. PER CENT BASAL DENSITY OF VEGETATION IN EACH MAJOR VEGETATION TYPE AND FOR THE TOTAL AREA ON SHAW RANCH STUDY AREA AS DETERMINED BY BASAL POINT CONTACTS.

Species	1-Asp, Ker.	1-Asp, Ker.	1-Fid, Asp.	1-Fid, Asp.	1-Ppe, Ppr.	4-Atr, Asp.	4-Atr, Fid.	4-Aca, Asp.	4-Aca, Fid.	Total Area 1/
Agropyron smithii	1	1		2	0	1	3	1	1	0.9
Agropyron spicatum	4	7	7	4	1	5	4	4	2	4.7
Bouteloua gracilis	4	1				0				1.4
Calamagrostis montanensis	1	2		1		1		2	1	1.1
Carex eleocharis	1	1			3	0	3	0		0.8
Festuca idahoensis			18	26			16		22	2.2
Juncus balticus					2					0.2
Koeleria cristata	6	5		2	1	5	1	3	0	4.4
Phleum pratense	0				12					1.0
Poa pratensis	1		1		27	0	1			2.7
Poa secunda	2	3	1	1		2	1	2	1	1.9
Stipa comata	1	1				1				0.8
Total of Group	21	21	27	36	46	15	29	12	27	22.1
Achillea lanulosa				0	1	0		1	0	0.1
Antennaria spp.	1	0		1	0	1		1	1	0.7
Artemisia ludoviciana			1	0					1	0.1
Iris missouriensis					0					0.0
Lupinus spp.			3	0		0	9		1	0.2
Oxytropis sericea		1								0.2
Phlox hoodii	1	1				1		1		0.8
Phlox spp.						1	1			0.3
Selaginella densa	2	12	1	2		7		30	10	6.7
Sphaeralcea coccinea	0							0		0.0
Trifolium spp.					2					0.2
Total of Group	4	14	5	3	3	10	10	33	13	9.3
Artemisia cana	1		1			1		2	4	0.8
Artemisia frigida	1	1	1			1				0.8
Artemisia tridentata						3				0.8
Chrysothamnus nauseosus						0				0.0
Gutierrezia sarothrae	1	1				1		1		0.8
Total of Group	3	2	2	0	0	6	0	3	4	3.2
Total of All Vegetation	28	37	34	39	49	31	39	48	44	34.6

1/ Values for total area are weighted by acreage in each type.

and were not listed. The club moss, with a basal density of 6.7 per cent, makes up the largest basal density of any single plant species. Of the grasses, bluebunch wheatgrass and junegrass make up the bulk of the basal density. The kentucky bluegrass vegetation type has the highest basal density of all the types in the study area. The basal density for the entire study area is 34.6 per cent. The statistical analyses of these values are tabulated in Table VI.

Tables IV and VI list a value of zero for several standard deviations and standard errors of the mean. These zero values are due to the presence of one value only or of several values which were exactly the same. Table VI also lists a value of zero for several means. This is due to the zero values present in Table V.

THE COMPOSITE PLANT

As previously mentioned in the section dealing with experimental procedure, a composite non-seedstalk producing plant was computed for each plant species utilized by the sheep. This was done in order that utilization determinations might be made from the stubble heights measured on the study area. From the percentage of weight, as distributed throughout the height of each of these composite plants, a height-weight table was developed for determining the per cent of available plant utilized from the stubble height remaining (Table VII).

The height-weight relationships of these composite non-seedstalk producing plants were plotted on the basis of Table VII (Figures 17 through 28). The per cent removed by weight, of the composite plant, was plotted in relation to the various possible stubble heights.

TABLE VI. ANALYSES OF PER CENT BASAL DENSITY VALUES FOR EACH PLANT SPECIES, FOR EACH CLASS OF VEGETATION, AND FOR THE TOTAL AREA. 1/

Species	No. of Values	Mean (Per cent) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
Agropyron smithii	8	1.25	0.89	0.31
Agropyron spicatum	9	4.22	1.99	0.66
Bouteloua gracilis	3	1.67	2.08	1.20
Calamagrostis montanensis	6	1.33	0.52	0.21
Carex eleocharis	6	1.33	1.37	0.56
Festuca idahoensis	4	20.50	4.43	2.22
Juncus balticus	1	2.00	0.00	0.00
Koeleria cristata	8	2.88	2.23	0.79
Phleum pratense	2	6.00	8.49	6.00
Poa pratensis	5	6.00	11.75	5.25
Poa secunda	8	1.63	0.74	0.26
Stipa comata	3	1.00	0.00	0.00
Total of Group	9	26.00	10.48	3.49
Achillea lanulosa	5	0.40	0.55	0.25
Antennaria spp	7	0.71	0.49	0.18
Artemisia ludoviciana	3	0.67	0.58	0.33
Iris missouriensis	1	0.00	0.00	0.00
Lupinus spp.	5	2.60	3.78	1.69
Oxytropis sericea	1	1.00	0.00	0.00
Phlox hoodii	4	1.00	0.00	0.00
Phlox spp.	2	1.00	0.00	0.00
Selaginella densa	7	9.14	10.14	3.83
Sphaeralcea coccinea	2	0.00	0.00	0.00
Trifolium spp.	1	2.00	0.00	0.00
Total of Group	9	10.56	9.42	3.14
Artemisia cana	5	1.80	1.30	0.58
Artemisia frigida	4	1.00	0.00	0.00
Artemisia tridentata	1	3.00	0.00	0.00
Chrysothamnus nauseosus	1	0.00	0.00	0.00
Gutierrezia sarothrae	4	1.00	0.00	0.00
Total of Group	9	2.22	2.05	0.68
Total Area	28	1.24	1.60	0.30

1/ The Montana State College Statistical Laboratory conducted these analyses.

TABLE VII. 1/ PER CENT OF PLANT USED: HEIGHT-WEIGHT BASIS. 2/

Stubble Height (Inches)	Bouteloua gracilis	Poa secunda	Koeleria cristata	Agropyron spicatum	Calamagrostis montanensis	Agropyron smithii	Stubble Height (Inches)
0.25	100.00						0.25
0.50	47.15	100.00	100.00	100.00	100.00	100.00	0.50
0.75	17.23						0.75
1.00	4.66	50.16	27.47	81.31	81.95	87.68	1.00
1.25	0.47						1.25
1.50	0.00	19.78	5.04	63.56	65.63	75.17	1.50
2.00		5.38	0.99	47.72	51.41	62.66	2.00
2.50		1.03	0.47	33.55	38.83	50.69	2.50
3.00		0.11	0.15	21.98	28.44	39.62	3.00
3.50		0.00	0.04	13.20	20.33	29.96	3.50
4.00			0.00	6.82	13.58	21.74	4.00
4.50				3.58	8.56	15.12	4.50
5.00				1.52	5.10	9.77	5.00
5.50				0.49	2.55	5.70	5.50
6.00				0.10	1.09	2.99	6.00
6.50				0.00	0.36	1.42	6.50
7.00					0.09	0.55	7.00
7.50					0.00	0.17	7.50
8.00						0.06	8.00
8.50						0.00	8.50

1/ The balance of this table is continued on page 71.

2/ Values were based upon the non-seedstalk producing composite plant which was developed for each of these plant species.

TABLE VII. 1/ PERCENT OF PLANT USED, HEIGHT-WEIGHT BASIS 2/

Stubble Height (Inches)	Carex eleocharis	Stipa comata	Festuca idahoensis	Poa pratensis	Phleum pratense	Juncus balticus	Stubble Height (Inches)
0.50	100.00	100.00	100.00	100.00			0.50
1.00	67.71	60.23	70.76	81.54	100.00	100.00	1.00
1.50	42.29	32.81	49.09	65.66			1.50
2.00	24.37	16.00	33.29	51.84	83.44	90.16	2.00
2.50	12.08	7.40	22.08	40.11			2.50
3.00	4.79	3.13	13.71	30.38	67.38	80.72	3.00
3.50	1.46	1.41	8.47	22.71			3.50
4.00	0.00	0.57	4.95	16.71	52.98	71.68	4.00
4.50		0.18	2.87	11.82			4.50
5.00		0.06	1.47	8.22	40.60	63.05	5.00
5.50		0.02	0.72	5.51			5.50
6.00		0.00	0.34	3.47	29.70	54.92	6.00
6.50			0.15	2.16			6.50
7.00			0.06	1.23	21.32	47.29	7.00
7.50			0.01	0.70			7.50
8.00			0.00	0.32	14.74	39.96	8.00
8.50				0.08			8.50
9.00				0.04	9.70	32.82	9.00
9.50				0.00			9.50
10.00					6.00	26.00	10.00
11.00					3.59	19.57	11.00
12.00					1.88	13.35	12.00
13.00					0.90	8.03	13.00
14.00					0.42	3.61	14.00
15.00					0.11	1.10	15.00
16.00					0.00	0.30	16.00
17.00						0.10	17.00
18.00						0.00	18.00

1/ This table is continued from page 70.
2/ Values were based upon the non-seedstalk producing composite plant which was developed for each of these plant species.

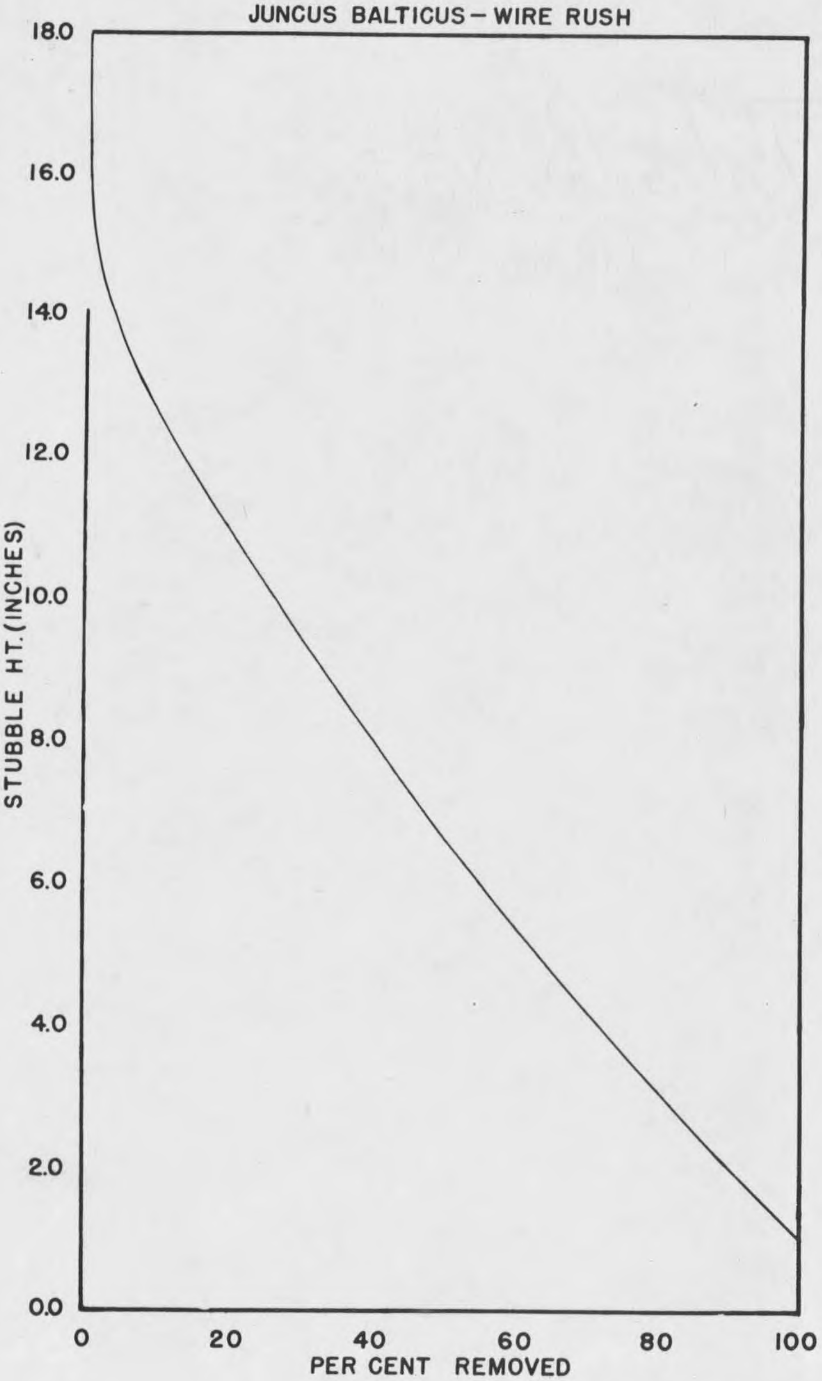

Figure 17. Height-weight relationships for non-seedstalk wire rush, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

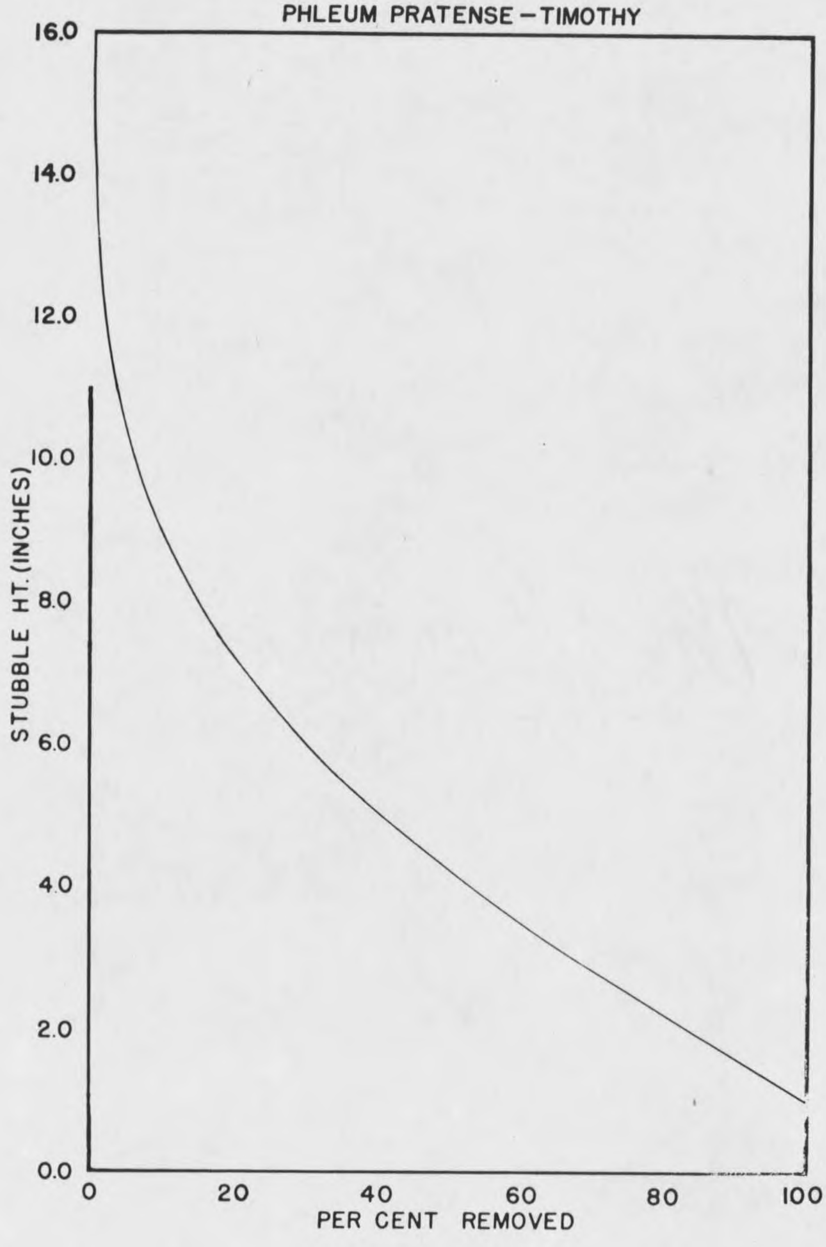

Figure 18. Height-weight relationships for non-seedstalk timothy, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

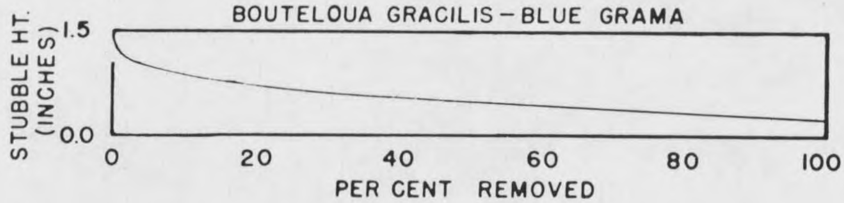

Figure 19. Height-weight relationships for non-seedstalk blue grama, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

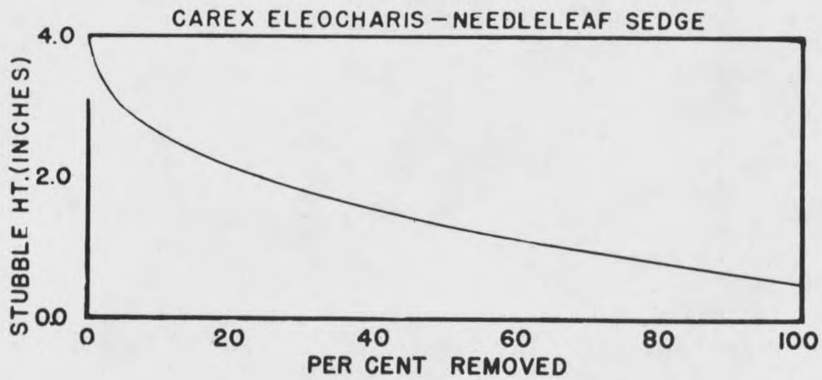

Figure 20. Height-weight relationships for non-seedstalk needleleaf sedge, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June 1954.

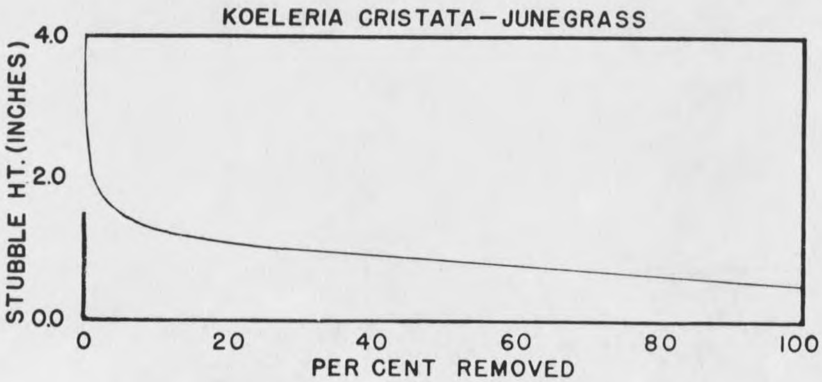

Figure 21. Height-weight relationships for non-seedstalk junegrass, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June 1954.

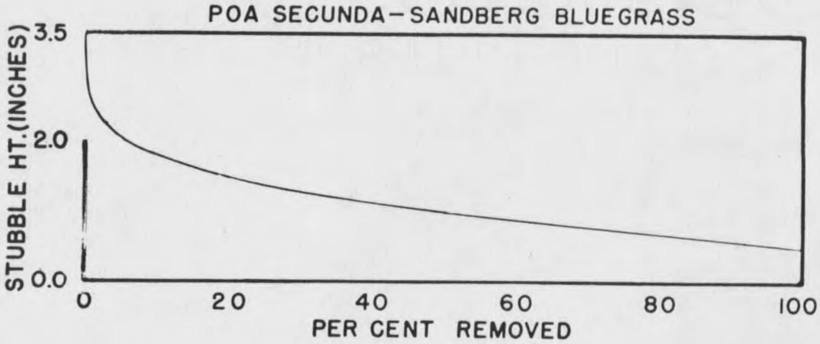

Figure 22. Height-weight relationships for non-seedstalk sandberg bluegrass, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

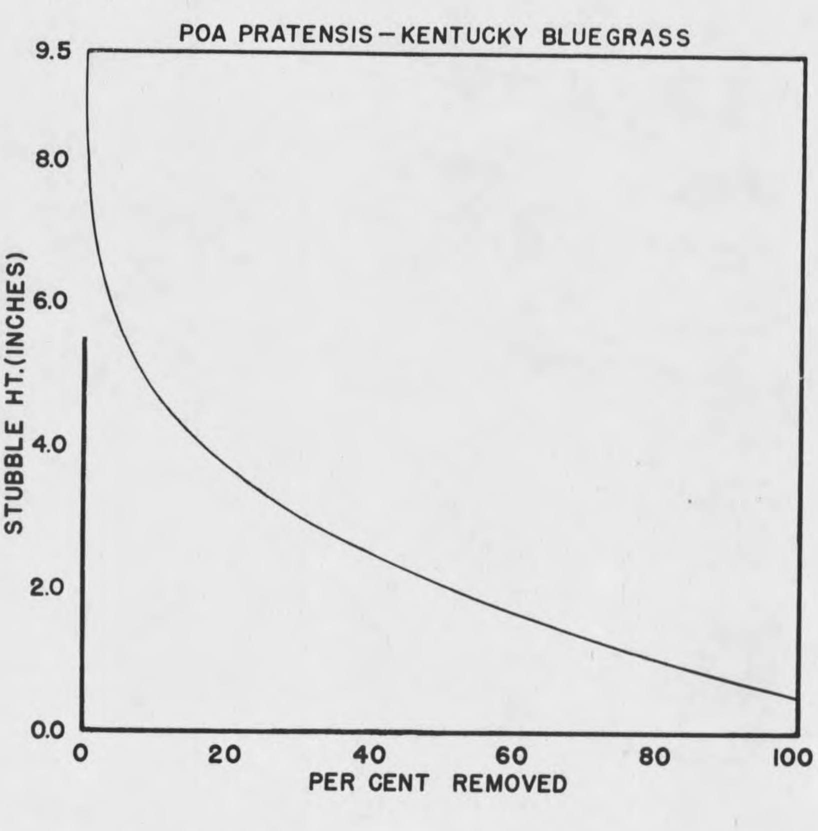

Figure 23. Height-weight relationships for non-seedstalk kentucky bluegrass, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

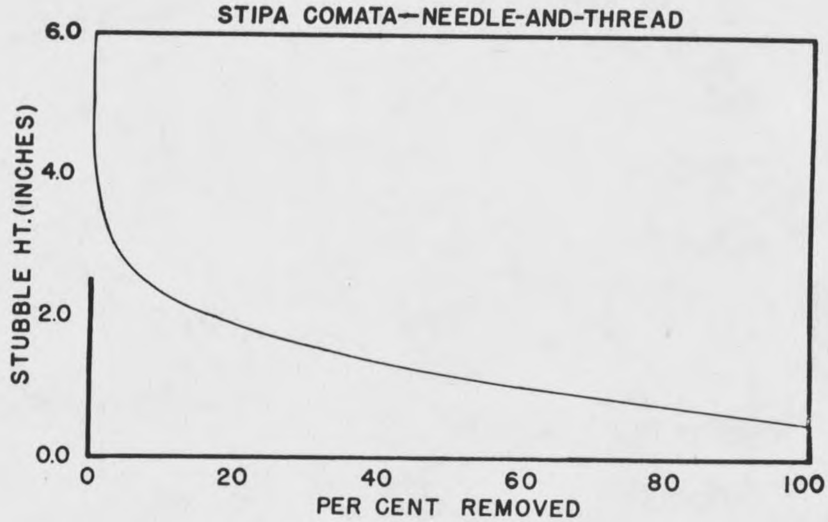

Figure 24. Height-weight relationships for non-seedstalk needle-and-thread, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

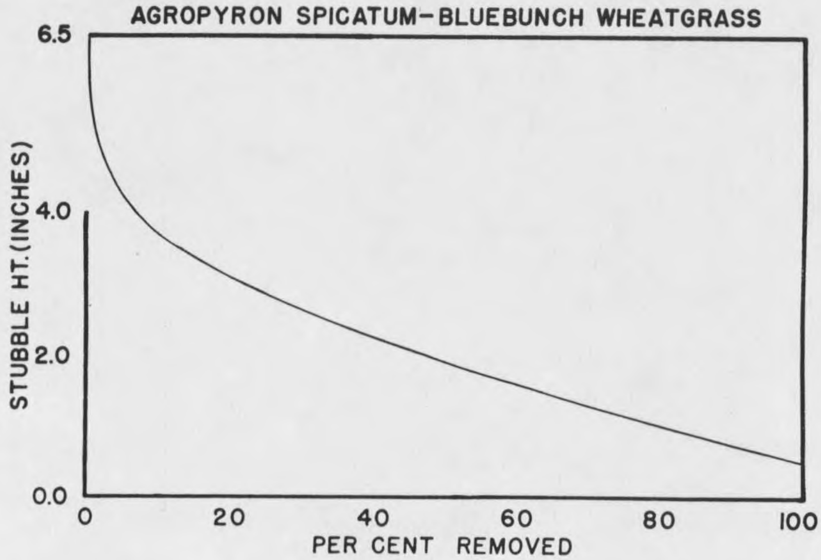

Figure 25. Height-weight relationships for non-seedstalk bluebunch wheatgrass, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

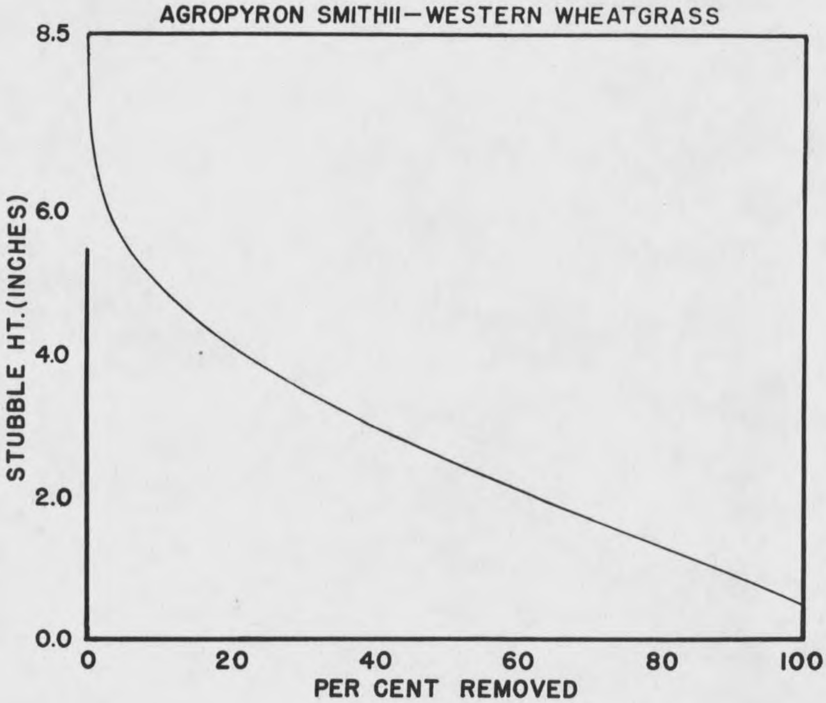

Figure 26. Height-weight relationships for non-seedstlak western wheatgrass, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

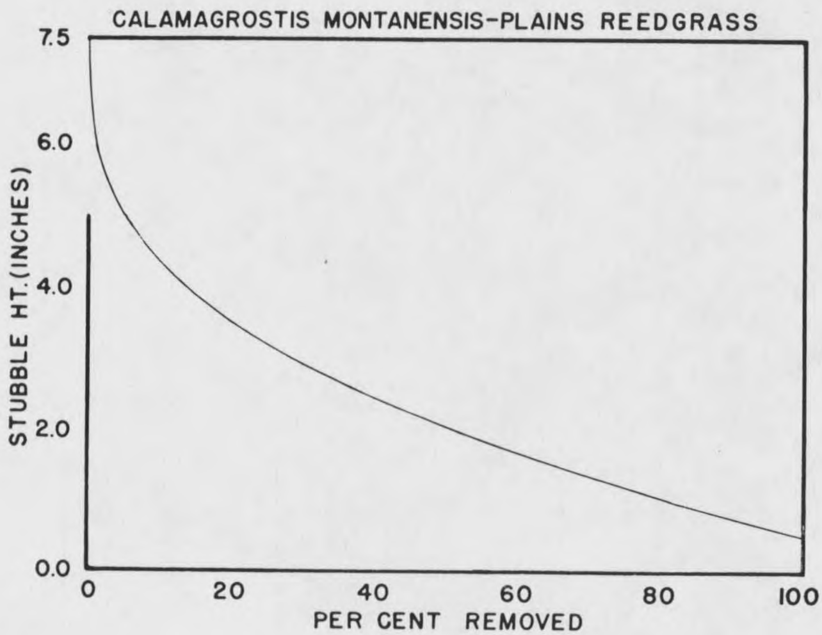

Figure 27. Height-weight relationships for non-seedstalk plains reedgrass, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

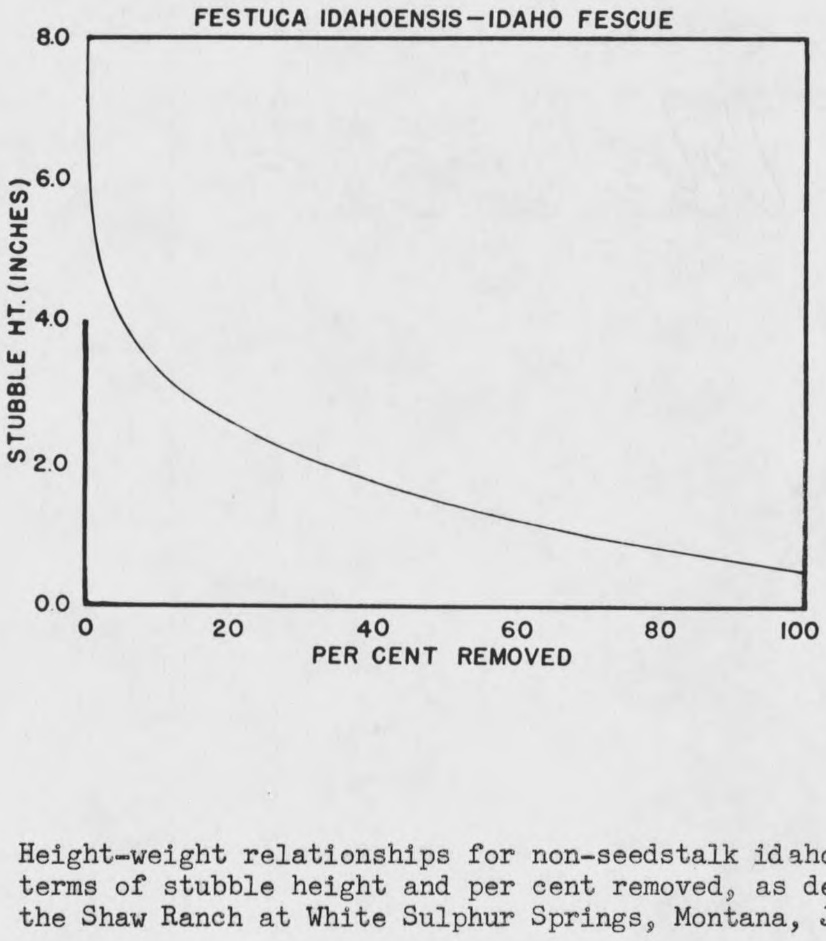

Figure 28. Height-weight relationships for non-seedstalk idaho fescue, in terms of stubble height and per cent removed, as determined on the Shaw Ranch at White Sulphur Springs, Montana, June, 1954.

The resulting curves start with zero per cent removed at the maximum composite plant height and end with 100 per cent removed at the stubble height not considered as part of the plant weight. As explained previously in the section on experimental procedure, this stubble height varied between plant species because of the various lengths used in the sectioning procedure. Thus stubble height for wire rush and timothy was 1 inch. For blue grama it was $\frac{1}{4}$ inch. All other species studied had a $\frac{1}{2}$ inch stubble height excluded from the plant weight.

The height-weight table (Table VII) should be representative of all the plants of each species if it is to be used in determining utilization on these species. If the non-seedstalk producing plant samples used in compiling this table were representative of the total populations, the composite plants produced would have the same ratio of height to weight as though all the plants of each species occurring within the area were measured. If this situation existed, the use of this table for determination of utilization on the area would be a valid procedure. Accordingly, the samples were examined for representativeness of the study area.

Tables VIII and IX list the 12 plant species in question by: (1) number of plants measured, (2) mean height in inches, (3) standard deviation in inches, and (4) standard error of the mean in inches. Table VIII deals with the height of plants collected and sectioned to develop the height-weight table. Table IX lists the plant heights measured on the study area, in order to determine the average ungrazed heights of the plants. The mean heights of these two sample groups, as compared in

TABLE VIII. ANALYSES OF HEIGHT MEASUREMENTS FOR TWELVE RANGE SPECIES SAMPLED TO DEVELOP HEIGHT-WEIGHT DISTRIBUTION CURVES FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	No. of Plants Measured	Mean (Inches) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
Agropyron spicatum	20	4.40	0.87	0.19
Agropyron smithii	20	5.53	1.54	0.34
Calamagrostis montanensis	20	5.33	0.88	0.20
Koeleria cristata	20	1.48	0.71	0.16
Poa secunda	20	2.20	0.48	0.11
Festuca idahoensis	20	4.23	1.81	0.40
Stipa comata	20	3.50	0.97	0.22
Bouteloua gracilis	20	0.84	0.26	0.06
Carex eleocharis	20	2.70	0.58	0.13
Poa pratensis	20	6.40	1.34	0.30
Phleum pratense	20	10.30	2.79	0.62
Juncus balticus	20	13.40	1.62	0.36

TABLE IX. ANALYSES OF HEIGHT MEASUREMENTS FOR TWELVE RANGE SPECIES SAMPLED TO DETERMINE AVERAGE UNGRAZED HEIGHTS FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	No. of Plants Measured	Mean (Inches) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
Agropyron spicatum	119	4.39	1.58	0.15
Agropyron smithii	18	5.47	1.38	0.32
Calamagrostis montanensis	78	5.12	1.18	0.13
Koeleria cristata	80	1.48	0.45	0.05
Poa secunda	39	1.91	0.60	0.10
Festuca idahoensis	44	4.66	1.79	0.27
Stipa comata	13	3.19	1.43	0.40
Bouteloua gracilis	15	0.97	0.49	0.13
Carex eleocharis	11	2.77	0.84	0.25
Poa pratensis	13	6.73	1.49	0.41
Phleum pratense	12	10.75	1.85	0.54
Juncus balticus	15	13.30	1.61	0.42

Table X, tend to indicate that the samples which were collected and sectioned were representative of the entire study area. Many of the means are extremely close, and in no case did they differ as much as $\frac{1}{2}$ inch.

This question of representativeness was further studied by comparing the Table VII values to values determined from Lommasson's utilization gauge. The Lommasson utilization gauge was chosen as the basis for comparison because it was developed from plant collections made in much the same manner as the collections made in this study. Lommasson's collections were thought to be representative of a very wide range of sites. The common use of his gauge, has generally substantiated this theory. Therefore the Lommasson gauge should be representative of the pasture involved in this study. If the use values from Table VII were found to be approximately the same as those from Lommasson's utilization gauge, the possibility of representativeness would be further substantiated. The five most important plant species were used in making this comparison.

Tables XI through XIV list the statistical analyses for each method and between the two methods. The author's percentage use values, as analyzed in these tables, were taken at the $\frac{1}{2}$-inch stubble-height intervals listed for these plant species in Table VII. These same stubble heights were used to determine per cent utilization from Lommasson's gauge. The average ungrazed plant height used on the Lomasson gauge for each of these plant species was taken from Table X.

The use values for Lommasson's utilization gauge were shifted 0.5 inch in Table XI in order to determine if a more accurate comparison

TABLE X. SAMPLE SIZE AND HEIGHT MEASUREMENT MEANS FOR TWELVE RANGE SPECIES SAMPLED TO DEVELOP HEIGHT-WEIGHT DISTRIBUTION CURVES AS COMPARED TO SAMPLE SIZE AND HEIGHT MEASUREMENT MEANS OF PLANTS SAMPLED TO DETERMINE AVERAGE UNGRAZED HEIGHTS FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	(n) Number Measured		($\bar{x}$) Mean Height (Inches)	
	Ht.-Wt. Plants 1/	Ungrazed Plants 2/	Ht.-Wt. Plants 1/	Ungrazed Plants 2/
Agropyron spicatum	20	119	4.40	4.39
Agropyron smithii	20	18	5.53	5.47
Calamagrostis montanensis	20	78	5.33	5.12
Koeleria cristata	20	80	1.48	1.48
Poa secunda	20	39	2.20	1.91
Festuca idahoensis	20	44	4.23	4.66
Stipa comata	20	13	3.50	3.19
Bouteloua gracilis	20	15	0.84	0.97
Carex eleocharis	20	11	2.70	2.77
Poa pratensis	20	13	6.40	6.73
Phleum pratense	20	12	10.30	10.75
Juncus balticus	20	15	13.40	13.30

1/ Refers to ungrazed plants which were collected on the study area and sectioned in the laboratory in order to determine the height-weight distribution for each plant species.

2/ Refers to ungrazed plants which were measured on the study area by systematic sampling in order to determine the average ungrazed height for each plant species.

TABLE XI. ANALYSES OF PERCENTAGE USE VALUES FOR FIVE RANGE SPECIES FROM AUTHOR'S HEIGHT-WEIGHT TABLE AND LOMMASSON'S UTILIZATION GAUGE 1/ FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	No. of Values	Mean (Per cent) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
		Author's Height-Weight Table		
Agropyron spicatum	11	24.89	26.90	8.11
Agropyron smithii	15	26.89	28.63	7.39
Koeleria cristata	6	5.69	9.89	4.04
Poa secunda	5	15.29	18.81	8.41
Festuca idahoensis	14	14.86	21.07	5.63
		Lommasson's Utilization Gauge 1/		
Agropyron spicatum	11	20.18	25.56	7.71
Agropyron smithii	15	24.60	28.07	7.25
Koeleria cristata	6	7.83	12.92	5.27
Poa secunda	5	11.00	13.19	5.90
Festuca idahoensis	15	17.07	23.68	6.33

1/ Use values shifted 0.5 inch in order to correlate 100 per cent use on this gauge with 100 per cent use on author's table.

TABLE XII. ANALYSES OF PERCENTAGE USE VALUES FOR FIVE RANGE SPECIES FROM AUTHOR'S HEIGHT-WEIGHT TABLE AND LOMMASSON'S UTILIZATION GAUGE 1/ FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	No. of Values	Mean (Per cent) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
		Author's Height-Weight Table		
Agropyron spicatum	12	31.15	33.08	9.55
Agropyron smithii	16	31.46	32.89	8.22
Koeleria cristata	7	19.17	34.24	12.94
Poa secunda	6	29.41	35.93	14.67
Festuca idahoensis	15	20.53	29.42	7.60
		Lommasson's Utilization Gauge 1/		
Agropyron spicatum	12	18.50	25.10	7.25
Agropyron smithii	16	23.06	27.82	6.96
Koeleria cristata	7	6.71	12.27	4.64
Poa secunda	6	9.17	12.72	5.19
Festuca idahoensis	15	15.93	23.28	6.01

1/ Use values not shifted as in Table XI.

TABLE XIII. CORRELATION COEFFICIENTS AND ANALYSES OF VARIANCE OF PERCENTAGE USE VALUES FOR FIVE RANGE SPECIES FROM AUTHOR'S HEIGHT-WEIGHT TABLE AND LOMMASSON'S UTILIZATION GAUGE 1/ FOR NON-SEEDSTALK PRODUCING PLANT FORMS. 2/

Species	Correlation Coefficients	Source of Variation	Degrees of Freedom	Mean Squares	F Values
Agropyron spicatum	0.99083**	Gauges	1	122.1068	15.44**
		Pairs	10	1506.3179	190.50**
		Error	10	7.9073	
Agropyron smithii	0.99889**	Gauges	1	39.2163	34.52**
		Pairs	14	1721.2990	1514.96**
		Error	14	1.1362	
Koeleria cristata	0.98439**	Gauges	1	13.7388	1.74
		Pairs	5	309.6263	39.25**
		Error	5	7.8890	
Poa secunda	0.99830**	Gauges	1	46.0531	2.28
		Pairs	4	639.2931	31.61**
		Error	4	20.2232	
Festuca idahoensis	0.98504**	Gauges	1	34.3879	2.94
		Pairs	13	1070.7079	91.48**
		Error	13	11.7041	

1/ Use values shifted 0.5 inch in Lommasson's gauge in order to correlate 100 per cent use on this gauge with 100 per cent use on author's table.

2/ The Montana State College Statistical Laboratory conducted these analyses.

** Significant at the 1% level.

TABLE XIV. CORRELATION COEFFICIENTS AND ANALYSES OF VARIANCE OF PERCENTAGE USE VALUES FOR FIVE RANGE SPECIES FROM AUTHOR'S HEIGHT-WEIGHT TABLE AND LOMMASSON'S UTILIZATION GAUGE 1/ FOR NON-SEEDSTALK PRODUCING PLANT FORMS. 2/

Species	Correlation Coefficients	Source of Variation	Degrees of Freedom	Mean Squares	F Values
Agropyron spicatum	0.979**	Gauges	1	960.5146	17.86**
		Pairs	11	1826.8142	33.97**
		Error	11	53.7769	
Agropyron smithii	0.995**	Gauges	1	563.6403	30.88**
		Pairs	15	1961.2707	107.43**
		Error	15	18.2555	
Koeleria cristata	0.996**	Gauges	1	542.6332	1.91
		Pairs	6	1260.0906	4.44*
		Error	6	283.8068	
Poa secunda	0.997**	Gauges	1	1229.3777	3.78
		Pairs	5	1418.5936	4.36
		Error	5	325.0936	
Festuca idahoensis	0.988**	Gauges	1	158.5620	5.42*
		Pairs	14	1478.5965	50.57**
		Error	14	29.2406	

1/ Use values not shifted in Lommasson's gauge as in Table XIII.
2/ The Montana State College Statistical Laboratory conducted these analyses.

** Significant at the 1% level.
* Significant at the 5% level.

of the two methods could be accomplished by making this shift. This shift correlated 100 per cent use on the gauge with 100 per cent use on Table VII. This shift was accomplished by transposing each utilization value determined from Lommasson's gauge for a given stubble height to the next higher measurement of stubble height. After the use values in Lommasson's gauge were shifted 0.5 inch, all of the mean per cent use values between the two methods were relatively close for each plant species. In no case do the means differ as much as 5 per cent. However, in Table XII, where the Lommasson gauge values were not adjusted, a much higher variation is present.

An analysis of variance and a correlation coefficient were computed for each of these five plant species. These analyses (Tables XIII and XIV) involved both sets of values determined by use of the Lommasson gauge and the single set of values from the author's height-weight chart in Table VII. The analyses in Table XIII were made in order to determine if the differences in means between the two methods, shown in Table XI, were real and if there was any correlation between them. Table XIV lists these same analyses for the means of the two methods as developed in Table XII. The F-values indicated a highly significant difference (P = .01) between Lommasson's gauge and the author's height-weight table for bluebunch wheatgrass and western wheatgrass, using both adjusted and unadjusted values in the Lommasson gauge. With the exception of the unadjusted idaho fescue values, which had a significant difference (P = .05), no significant differences existed for junegrass, sandberg bluegrass, and idaho fescue. A very high correlation existed between these two systems for all the plant species tested, and in all cases, these correlations were highly significant (P = .01).

The high correlations present between these two systems, for each of the plant species involved, indicated that as the values determined by one of the systems increased or decreased, the values determined by the other system also increased or decreased at approximately the same rate. This does not necessarily mean that the values were equal or nearly so, although that could be the situation. These values may be extremely different in some cases. As noted in the previous paragraph, some of the differences were large enough to be significant. The two methods produced significantly different values, but these values varied uniformly in relation to each other.

Although some significant differences between the use values determined by these two methods are noted above, the actual means of the per cent use values (Table XI) are not sufficiently different to warrant the elimination of either method. For instance, the use values for <u>Agropyron spicatum</u> differ only 4.71 per cent, and all of the other plant species differ even less. A difference of five per cent is close when you consider that sampling errors may be as great as ten per cent and still give useable information. Becuase of this fact, as well as the earlier discussion of the closeness of the mean heights (Table X) and the sampling technique used, it is felt that the author's height-weight chart (Table VII) is representative of all the plants occurring on the study area. Therefore, the application of the values in Table VII to this study area is apparently a valid procedure. These values were applied to measurements taken on the study area.

UTILIZATION DETERMINATIONS

Samples were obtained in each of the vegetation types in order to determine the degree of utilization in each type. Table XV lists the mean per cent utilization, from stubble heights measured and applied to Table VII, for each of the vegetation types involved, for unit combinations of the same types, and for the total area. The standard deviation and the standard error of the mean are also given for each type and grouping. The two units of the Artemisia tridentata, Festuca idahoensis type (4-Atr, Fid) may not have been adequately sampled, as is indicated by the number of plants measured. These mean per cent use values indicated an almost uniform grazing pattern throughout all of the vegetation types. These mean per cent utilization values generally substantiate the visual observations of forage preference discussed previously.

Average utilization for the entire study area was 31.39 per cent (Table XV). This degree of utilization was related to the actual use by sheep. A total of 9,545 sheep days or 318.17 sheep months of use, based upon ewes alone, was made in the study area during the period studied. Using a conversion factor of 4 ewes and their lambs per animal unit month, a total of 79.5 animal unit months of feed was eaten by the sheep. Thus, 79.5 animal unit months of use resulted in 31.39 per cent utilization on this study area. The area was stocked at the rate of 4.6 acres per animal unit month. These figures will be highly valuable as aids to determining the carrying capacity of similar ranges in this area.

Per cent utilization was also estimated for each of the grass and

TABLE XV. ANALYSES OF PERCENTAGE USE COMPUTATIONS FOR THIRTEEN SEPARATE RANGE TYPES AND VARIOUS COMBINATIONS OF THEM FROM STUBBLE-HEIGHT AND A HEIGHT-WEIGHT TABLE FOR NON-SEEDSTALK PRODUCING PLANTS. 1/

No. of Types	Type Description	No. of Plants Measured	Mean (Per cent) ($\bar{x}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{x}}$)
1	1-Ppe, Ppr Single Unit	83	43.13	34.42	3.78
2	4-Aca, Fid Single Unit	34	32.95	42.13	7.22
3	4-Aca, Asp Single Unit	36	42.94	43.42	7.24
4	4-Atr, Fid First Unit	3	33.33	47.14	27.22
5	4-Atr, Fid Second Unit	9	50.69	36.45	12.15
6	4-Atr, Asp First Unit	131	17.31	27.53	2.41
7	4-Atr, Asp Second Unit	57	24.01	32.80	4.34
8	4-Atr, Asp Third Unit	36	28.38	32.25	5.37
	4-Atr, Asp All Units	224	20.79	30.05	2.01
9	1-Fid, Asp First Unit	19	13.32	26.97	6.19
10	1-Fid, Asp Second Unit	29	33.31	41.25	7.66
	1-Fid, Asp All Units	48	25.39	37.57	5.42
11	1-Asp, Kcr First Unit	262	33.65	40.19	2.48
12	1-Asp, Kcr Second Unit	141	30.43	37.88	3.19
13	1-Asp, Kcr Third Unit	60	41.09	41.38	5.34
	1-Asp, Kcr All Units	463	33.63	39.79	1.85
	All Types Except 1-Ppe, Ppr	817	30.20	38.10	1.33
	All Types Totaled	900	31.39	37.96	1.27

1/ Percentage use computed from author's height-weight table.

grass-like species present. These data were computed both by the author's height-weight table and Lommasson's gauge but from the same stubble height measurements. Twelve species were studied with the author's height-weight table, but only the five most important species were considered with Lommasson's gauge. These two sets of data are partially analyzed in Tables XVI and XVII. The mean utilization values for the grass and grass-like plant species utilized are given in these tables. As indicated in Table XVI, sandberg bluegrass and wire rush were utilized the most. The plant species utilized least were plains reedgrass and blue grama.

Analyses of variance and correlation coefficients were also run for each of these five plant species (Table XVIII). The F-values indicate a significant difference between the utilization determined by adjusting Lommasson's gauge, and the utilization derived from the author's height-weight table. The difference for idaho fescue was significant (P = .05), and bluebunch wheatgrass, western wheatgrass, junegrass, and sandberg bluegrass differences were highly significant (P = .01). The correlation coefficients are highly significant (P = .01) for all five of the species studied. This relationship of high correlations and significant differences has been previously explained. Although these differences are significant, the actual means do not vary as much as 5 per cent. Thus, both methods appear to be about equally accurate in determining utilization on this type of vegetation.

THE PER CENT OF PLANTS GRAZED METHOD

The "per cent of plants grazed method" of utilization determination employs a graph of the relationship between per cent of plants grazed and

TABLE XVI. ANALYSES OF PERCENTAGE USE COMPUTATIONS FOR TWELVE RANGE SPECIES FROM STUBBLE-HEIGHT AND AUTHOR'S HEIGHT-WEIGHT TABLE FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	No. of Plants Measured	Mean (Per cent) ($\bar{\bar{x}}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{\bar{x}}}$)
Agropyron spicatum	265	31.62	35.54	2.18
Agropyron smithii	30	21.12	31.35	5.72
Calamagrostis montanensis	92	5.51	15.58	1.62
Koeleria cristata	127	20.85	35.74	3.17
Poa secunda	156	56.24	41.53	3.32
Festuca idahoensis	71	27.51	40.04	4.75
Stipa comata	28	25.40	29.61	5.60
Bouteloua gracilis	23	10.86	19.19	4.00
Carex eleocharis	18	17.31	27.44	6.47
Poa pratensis	46	44.02	38.08	5.61
Phleum pratense	32	46.89	32.47	5.74
Juncus balticus	11	50.86	26.31	7.93

TABLE XVII. ANALYSES OF PERCENTAGE USE COMPUTATIONS FOR FIVE RANGE SPECIES FROM STUBBLE-HEIGHT AND LOMMASSON'S UTILIZATION GAUGE 1/ FOR NON-SEEDSTALK PRODUCING PLANT FORMS.

Species	No. of Plants Measured	Mean (Per cent) ($\bar{\bar{y}}$)	Standard Deviation (S)	Standard Error of the Mean ($S_{\bar{\bar{y}}}$)
Agropyron spicatum	265	28.53	34.55	2.12
Agropyron smithii	30	20.23	30.62	5.59
Koeleria cristata	127	22.37	36.05	3.20
Poa secunda	156	52.12	42.85	3.43
Festuca idahoensis	71	28.23	40.27	4.78

1/ Use values shifted 0.5 inch in order to correlate 100 per cent use on this gauge with 100 per cent use on author's table.

TABLE XVIII. CORRELATION COEFFICIENTS AND ANALYSES OF VARIANCE OF PERCENTAGE USE VALUES FOR FIVE RANGE SPECIES FROM ACTUAL STUBBLE HEIGHTS AS APPLIED TO AUTHOR'S HEIGHT-WEIGHT TABLE AND LOMMASSON'S UTILIZATION GAUGE 1/ FOR NON-SEEDSTALK PRODUCING PLANT FORMS. 2/

Species	Correlation Coefficients	Source of Variation	Degrees of Freedom	Mean Squares	F Values
Agropyron spicatum	0.994**	Gauges	1	1263.4552	170.41**
		Pairs	264	2458.8610	331.64**
		Error	264	7.4143	
Agropyron smithii	0.999**	Gauges	1	11.4810	13.33**
		Pairs	30	1946.7390	2260.50**
		Error	30	0.8612	
Koeleria cristata	0.997**	Gauges	1	146.4100	32.15**
		Pairs	127	2579.9076	566.45**
		Error	127	4.5545	
Poa secunda	0.989**	Gauges	1	1328.5390	62.81**
		Pairs	155	3562.8446	168.43**
		Error	155	21.1531	
Festuca idahoensis	0.997**	Gauges	1	18.3313	3.98*
		Pairs	70	3267.0194	709.48**
		Error	70	4.6048	

1/ Use values shifted 0.5 inch in Lommasson gauge in order to correlate 100 per cent use on this gauge with 100 per cent use on author's table.
2/ The Montana State College Statistical Laboratory conducted these analyses.

** Significant at the 1% level.
* Significant at the 5% level.

per cent utilization by weight. A high correlation between these two factors should exist if the percentage of plants grazed is to provide a reliable index to the total grazing use of a plant species or a range area. In this study, all plants grazed to any extent whatsoever are included in the per cent of plants grazed values. The per cent utilization values, used in the statistical computation of this phase of the study, are based upon the author's utilization chart (Table VII), unless otherwise stated.

The relationship of per cent of plants grazed to per cent utilization was determined by computing correlation coefficients and regression equations for each set of tabulated data. These analyses for the data collected on the Shaw Ranch at White Sulphur Springs are tabulated in Tables XIX through XXIII. These tables serve to illustrate the variation in these values, as they are influenced by various procedures of data summation.

The use data were summarized for each of the range types involved, for unit combinations of the same types, and for the total area. The average per cent of plants grazed and average per cent utilization values were determined for each plant species occurring within each of the vegetation types and on each transect within each of the vegetation types. These values are not listed. These averages, as determined for all of the plant species present within each unit of a vegetation type, were then statistically analyzed. These analyses are presented in Tables XIX and XX, respectively. Where sufficient values were present to warrant the procedure, all units of a similar vegetation type were grouped and

TABLE XIX. ANALYSES, BY CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS, OF PERCENTAGE USE (Y) AND PER CENT OF PLANTS GRAZED (X) FOR VEGETATION TYPES TABULATED ONLY BY TYPE. 1/

No. of Types	Type Description	No. of Values	Correlation Coefficients	Regression Equations
1	1-Ppe, Ppr; Single Unit	5	0.891*	Y=-7.6024 + 0.5769X
2	4-Aca, Fid; Single Unit	2	1.000**	Y= 0.0004 + 0.7529X
3.	4-Aca, Asp; Single Unit	7	0.493	Y=11.9306 + 0.4456X
4	4-Atr, Fid; First Unit	3	1.000**	Y= 0.0000 + 1.0000X
5	4-Atr, Fid; Second Unit	3	0.428	Y=27.6547 + 0.2592X
6	4-Atr, Asp; First Unit	8	0.525	Y=-4.1101 + 0.5590X
7	4-Atr, Asp; Second Unit	5	0.976**	Y=-3.4933 + 0.6859X
8	4-Atr, Asp; Third Unit	5	0.939*	Y=-2.6464 + 0.6017X
	4-Atr, Asp; All Units			
	Averaged	9	0.789*	Y=-2.8214 + 0.5744X
	Totaled	18	0.884**	Y=-4.3777 + 0.6250X
9	1-Fid, Asp; First Unit	4	0.983*	Y=-0.9087 + 0.5534X
10	1-Fid, Asp; Second Unit	4	0.690	Y= 0.2988 + 0.6884X
	1-Fid, Asp; All Units			
	Averaged	5	0.892*	Y= 0.9923 + 0.5856X
	Totaled	8	0.852**	Y=-0.3848 + 0.6397X
11	1-Asp, Kcr; First Unit	11	0.959**	Y=-4.7513 + 0.8017X
12	1-Asp, Kcr; Second Unit	7	0.936**	Y=-1.9707 + 0.6013X
13	1-Asp, Kcr; Third Unit	5	0.945*	Y=-8.4786 + 0.8056X
	1-Asp, Kcr; All Units			
	Averaged	11	0.946**	Y=-5.6376 + 0.7841X
	Totaled	23	0.946**	Y=-4.0374 + 0.7344X
	All Types Except 1-Ppe, Ppr			
	Averaged	11	0.931**	Y=-6.9684 + 0.7870X
	Totaled	64	0.852**	Y=-2.2201 + 0.6608X
	All Types			
	Averaged	13	0.946**	Y=-1.6803 + 0.5966X
	Totaled	69	0.848**	Y=-2.2828 + 0.6463X

1/ The Montana State College Statistical Laboratory conducted these analyses.

** Significant at the 1% level.
* Significant at the 5% level.

TABLE XX. ANALYSES, BY CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS, OF PERCENTAGE USE (Y) AND PER CENT OF PLANTS GRAZED (X) FOR VEGETATION TYPES TABULATED BY TRANSECT WITHIN TYPE. 1/

No. of Types	Type Description	No. of Values	Correlation Coefficients	Regression Equations
1	1-Ppe, Ppr; Single Unit	45	0.648**	Y=-5.5014 + 0.6100X
2	4-Aca, Fid; Single unit	10	0.699*	Y= 5.0118 + 0.5121X
3	4-Aca, Asp; Single Unit	19	0.788**	Y=-0.0881 + 0.6926X
4	4-Atr, Fid; First Unit	3	1.000**	Y= 0.0000 + 1.0000X
5	4-Atr, Fid; Second Unit	6	0.039	Y=47.4883 + 0.0502X
6	4-Atr, Asp; First Unit	38	0.771**	Y= 1.5222 + 0.4048X
7	4-Atr, Asp; Second Unit	19	0.895**	Y=-2.1048 + 0.6319X
8	4-Atr, Asp; Third Unit	12	0.923**	Y=-0.3190 + 0.5508X
	4-Atr, Asp; All Units			
	Averaged	--	Not Analyzed 2/	Not Analyzed 2/
	Totaled	69	0.827**	Y=-0.1419 + 0.4971X
9	1-Fid, Asp; First Unit	10	0.810**	Y=-0.0010 + 0.5455X
10	1-Fid, Asp; Second Unit	17	0.900**	Y= 0.1628 + 0.7543X
	1-Fid, Asp; All Units			
	Averaged	--	Not Analyzed 2/	Not Analyzed 2/
	Totaled	27	0.858**	Y= 0.6078 + 0.6716X
11	1-Asp, Kcr; First Unit	117	0.905**	Y=-1.3353 + 0.6954X
12	1-Asp, Kcr; Second Unit	32	0.789**	Y=-2.9068 + 0.6386X
13	1-Asp, Kcr; Third Unit	34	0.787**	Y=-1.6877 + 0.7122X
	1-Asp, Kcr; All Units			
	Averaged	--	Not Analyzed 2/	Not Analyzed 2/
	Totaled	183	0.868**	Y=-1.8372 + 0.6931X
	All Types Except 1-Ppe, Ppr			
	Averaged	--	Not Analyzed 2/	Not Analyzed 2/
	Totaled	317	0.840**	Y=-1.0495 + 0.6484X
	All Types			
	Averaged	--	Not Analyzed 2/	Not Analyzed 2/
	Totaled	362	0.822**	Y=-0.9491 + 0.6277X

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ The data were not averaged for this arrangement, eliminating these analyses.

** Significant at the 1% level.

* Significant at the 5% level.

TABLE XXI. ANALYSES, BY CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS, OF PERCENTAGE USE (Y) AND PER CENT OF PLANTS GRAZED (X) FOR PLANT SPECIES TABULATED ONLY BY TYPE. 1/

Species	No. of Values	Correlation Coefficients	Regression Equations
Agropyron spicatum	13	0.939**	Y = 1.1695 + 0.5274X
Agropyron smithii	6	0.803	Y = 0.0208 + 0.3752X
Calamagrostis montanensis	7	0.935**	Y = 0.4443 + 0.2700X
Koeleria cristata	7	0.795*	Y = -19.1469 + 1.1027X
Poa secunda	11	0.798**	Y = -18.2298 + 0.9917X
Festuca idahoensis	7	0.961**	Y = -1.6655 + 0.8555X
Stipa comata	4	Not Analyzed 2/	Not Analyzed 2/
Bouteloua gracilis	4	Not Analyzed 2/	Not Analyzed 2/
Carex eleocharis	4	Not Analyzed 2/	Not Analyzed 2/
Poa pratensis	3	Not Analyzed 2/	Not Analyzed 2/
Phleum pratemse	1	Not Analyzed 2/	Not Analyzed 2/
Juncus balticus	1	Not Analyzed 2/	Not Analyzed 2/
Aristida longiseta	1	Not Analyzed 2/	Not Analyzed 2/

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ The amount of data for this species was to limited to warrant analysis.

** Significant at the 1% level.

* Significant at the 5% level.

TABLE XXII. ANALYSES, BY CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS, OF PERCENTAGE USE (Y) AND PER CENT OF PLANTS GRAZED (X) FOR PLANT SPECIES TABULATED BY TRANSECT WITHIN TYPE. 1/

Species	No. of Values	Correlation Coefficients	Regression Equations
Agropyron spicatum	72	0.795**	Y = -1.2935 + 0.6105X
Agropyron smithii	21	0.870**	Y = 0.6929 + 0.5207X
Calamagrostis montanensis	47	0.905**	Y = 0.5149 + 0.2893X
Koeleria cristata	46	0.781**	Y = -1.9982 + 0.6280X
Poa secunda	52	0.821**	Y = -6.4284 + 0.8758X
Festuca idahoensis	28	0.869**	Y = 1.1166 + 0.6715X
Stipa comata	18	0.826**	Y = 0.6780 + 0.4468X
Bouteloua gracilis	14	0.767**	Y = -0.4003 + 0.3362X
Carex eleocharis	13	0.934**	Y = 1.6485 + 0.4394X
Poa pratensis	24	0.755**	Y = -5.9375 + 0.6703X
Phleum pratense	18	0.603**	Y = 4.2314 + 0.5402X
Juncus balticus	8	1.000**	Y = -46.6875 + 1.0000X
Aristida longiseta	1	Not Analyzed 2/	Not Analyzed 2/

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ The amount of data for this species was too limited to warrant analysis.

** Significant at the 1% level.

TABLE XXIII. ANALYSES, BY CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS, OF PERCENTAGE USE (Y) AND PER CENT OF PLANTS GRAZED (X) FOR PLANT SPECIES TABULATED ONLY BY TRANSECT. 1/

Species	No. of Values	Correlation Coefficients	Regression Equations
Agropyron spicatum	20	0.830**	Y = -13.8564 + 0.8213X
Agropyron smithii	13	0.889**	Y = 0.1427 + 0.6128X
Calamagrostis montanensis	20	0.856**	Y = 0.8897 + 0.2867X
Koeleria cristata	19	0.804**	Y = -6.7187 + 0.7428X
Poa secunda	20	0.821**	Y = -9.6562 + 0.8957X
Festuca idahoensis	18	0.895**	Y = -0.0874 + 0.7318X
Stipa comata	15	0.743**	Y = 3.3478 + 0.3719X
Bouteloua gracilis	12	0.909**	Y = -2.5515 + 0.4281X
Carex eleocharis	9	0.958**	Y = 0.7698 + 0.4615X
Poa pratensis	5	0.997**	Y = 0.9791 + 0.8185X
Aristida longiseta	1	Not Analyzed 2/	Not Analyzed 2/
All Species 3/			
Averaged	20	0.827**	Y = -11.2846 + 0.8605X
Totaled	152	0.850**	Y = -1.2224 + 0.6266X

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ The amount of data for this species was too limited to warrant individual analysis, but was included in the values for all species.

3/ All plants occurring in the 1-Ppe, Ppr vegetation type were excluded from these analyses as this vegetation type was not included in the Chadbourne Lease data, to which this data was compared.

** Significant at the 1% level.

statistically analyzed, both for averages and for totals of the values for each of the plant species present. All of the types were grouped and analyzed in a similar manner.

Tables XXI through XXIII present the statistical analyses for the same data summarized for each of the plant species involved. In Table XXI, the average per cent of plants grazed and average per cent utilization values were determined for each vegetation type having the plant species present. In Table XXII, the same kind of values were determined for each transect within each vegetation type having the plant species present. Table XXIII is based upon the same kind of values when compiled for each transect, irrespective of vegetation type, having the plant species present.

As previously indicated, Table XIX lists the statistical analyses for each vegetation type when the data were compiled only by vegetation type. Table XX lists the statistical analyses for each vegetation type when the data were compiled by transect within each vegetation type. The significance of the correlation coefficients were highly influenced by the number of values used and the relationships of these percentages. This is illustrated in Table XIX by the first and second units of the Artemisia tridentata, Festuca idahoensis vegetation type (4-Atr, Fid). Only three pairs of values were present in each unit. The first unit shows perfect correlation as no disagreement exists between pairs. The correlation is very low for the second unit as some disagreement does exist between pairs and too few values are present to satisfactorily measure these differences. This influences the correlations for the averaged and totaled values as well as the correlations for each unit of the vegetation types. More values have more completely sampled this variation (Table XX), but the type just discussed was still not adequately sampled. In contrast, the first unit of the Agropyron spicatum, Koeleria cristata type (1-Asp, Kcr) had 115 degrees of freedom. The greater number of values involved in Table XX served to lower the correlation coefficients because of more disagreement in values, but the increase in degrees of freedom caused the lower correlation coefficients to be highly significant (P = .01) for more vegetation types. This same situation of too few values resulted in several other perfect correlations and low correlations in these tables. Thus, a correlation coefficient of 1.000 does not give a true representation of this situation.

Both the type only and transect within type methods of data summation appear to be valid in applying the "per cent of plants grazed method" of utilization determination to vegetation types and entire areas. Care should be taken to see that sufficient data are collected and tabulated in order to have an adequate sample.

As stated previously, Tables XXI through XXIII list the statistical analyses for each plant species. No definite relationship between these methods, in terms of correlation coefficients, was observed. The correlation coefficient for western wheatgrass was not significant in Table XXI. This was due to an insufficient number of samples, and one pair of values was entirely out of line with the other data. The high correlation coefficients involved appear to indicate that all three methods of data summation are valid in applying the "per cent of plants grazed method" to individual plant species.

More variation between summation methods existed in the calculated regression equations than in the correlation coefficients. The influence of this variation upon the final graph is illustrated in Figure 29. Regression equations for five of the previously discussed methods of data summation are presented in graphic form for the entire study area with the exception of the Poa pratensis, Phleum pratense vegetation type (1-Ppe-Ppr). The maximum variation in per cent utilization between regression lines is approximately 13 per cent, as determined from this graph. This indicates a need for future study in order to determine which method of data summation is the most accurate for utilization determinations on any particular part of a range area.

The graph of the entire study area (Figure 30), including the Poa pratensis, Phleum pratense type (1-Ppe, Ppr) along the creek bottom, indicates that the values from the moist creek bottom tend to lower the utilization values as compared to the graph in Figure 29. This occurred in spite of the fact that this vegetation type was the most heavily utilized. This may be the result of very heavy use on the plants actually grazed but fewer plants grazed on this vegetation type. The irregular pattern of use may be indicated by this. A high utilization value may be related to a low per cent of plants grazed value when this situation exists. Apparently, the vegetation types in moist creek bottoms should be included with the other vegetation types only if they are small in relation to the total area. Large areas of bottom land should be examined separately. The pattern of grazing use may possibly be important

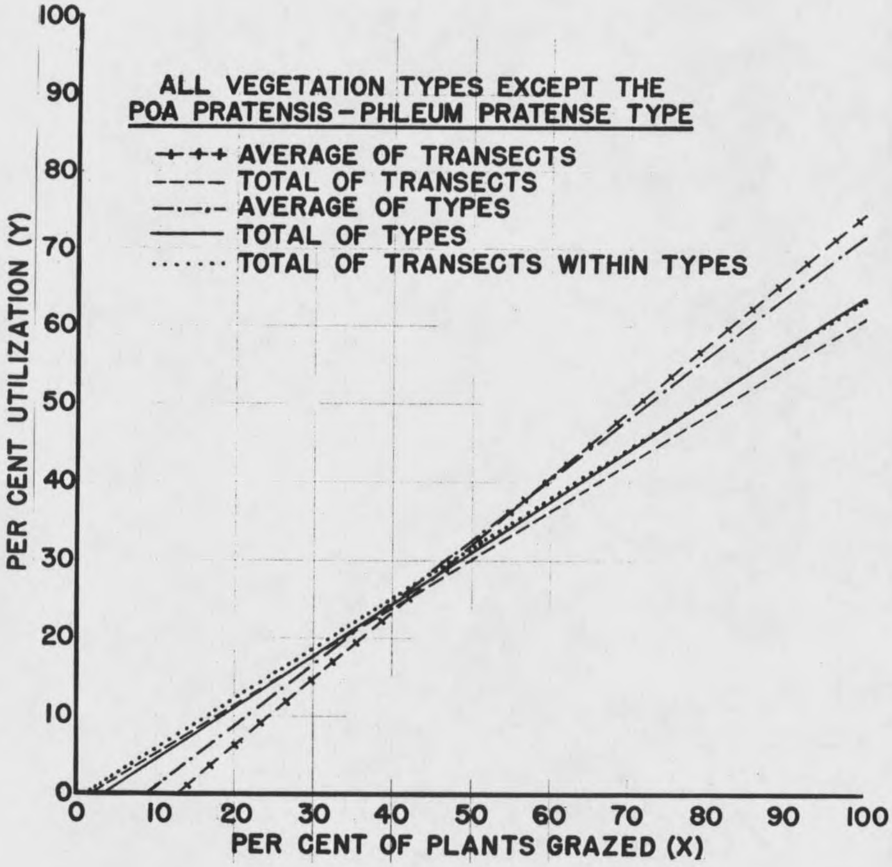

Figure 29. Relationships between per cent of plants grazed and per cent of weight removed of all important grass and grass-like plants on sheep range.

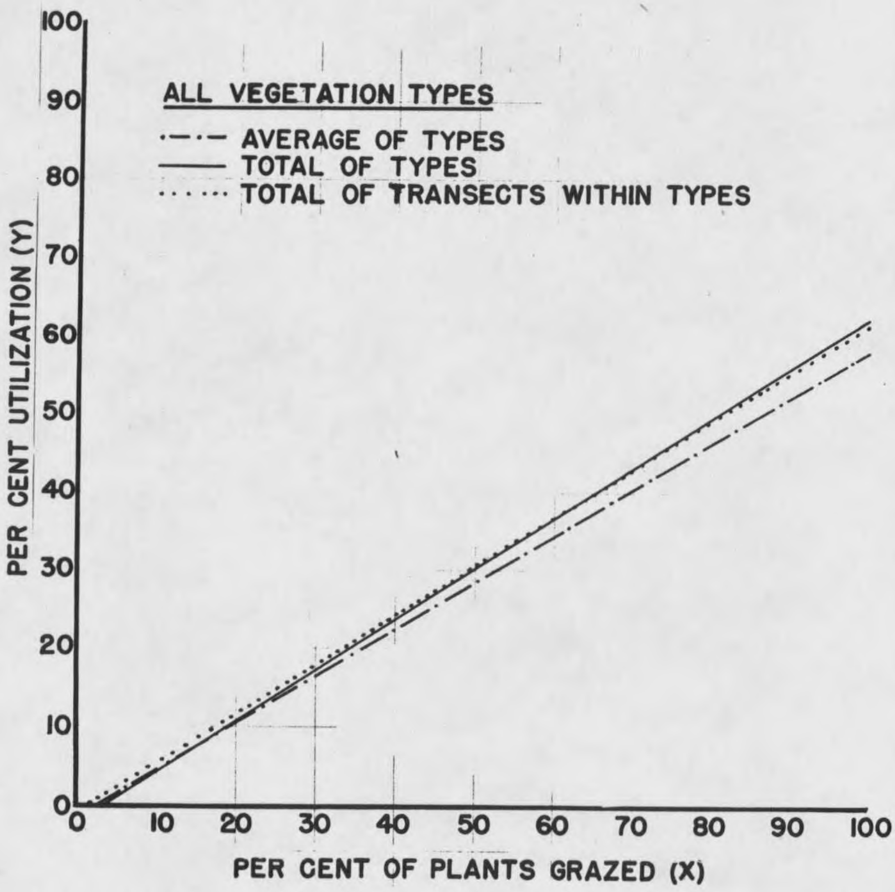

Figure 30. Relationships between per cent of plants grazed and per cent of weight removed of all important grass and grass-like plants on sheep range.

in making such a decision, if the pattern is very irregular.

Graphs for the six most important plant species found in the study area are presented in the form required by the "per cent of plants grazed method" of utilization determination (Figures 31 through 36). These graphs are based upon the regression equations found in Tables XXI through XXIII. No definite conclusions, in regard to accuracy of utilization determinations by these various methods of data summation, could be drawn from these graphs. Because of the fewer pairs of values developed by the "type only" method of summation, this method may be the least accurate. On the other hand, it may be possible that the larger number of values included in the fewer number of averages may offset this apparent lack of accuracy. Hence, what may be lacking in number of values may be made up in the representativeness likely to occur as a result of this averaging. Thus, this method may be quite accurate. With this method the numbers of paired values are limited by the number of vegetation types when the utilization values are computed for each plant species. When computing utilization values for vegetation types by this method, the number of paired values are limited by the number of plant species present.

All of the graphs developed from these analyses need to be tested for several years on the same study area in order to determine the relative accuracy of these various methods of data summation, as well as the over-all accuracy of the method. One of these methods of data summation may be the most accurate for one plant species, and utilization on another plant species may be more accurately determined by using an-

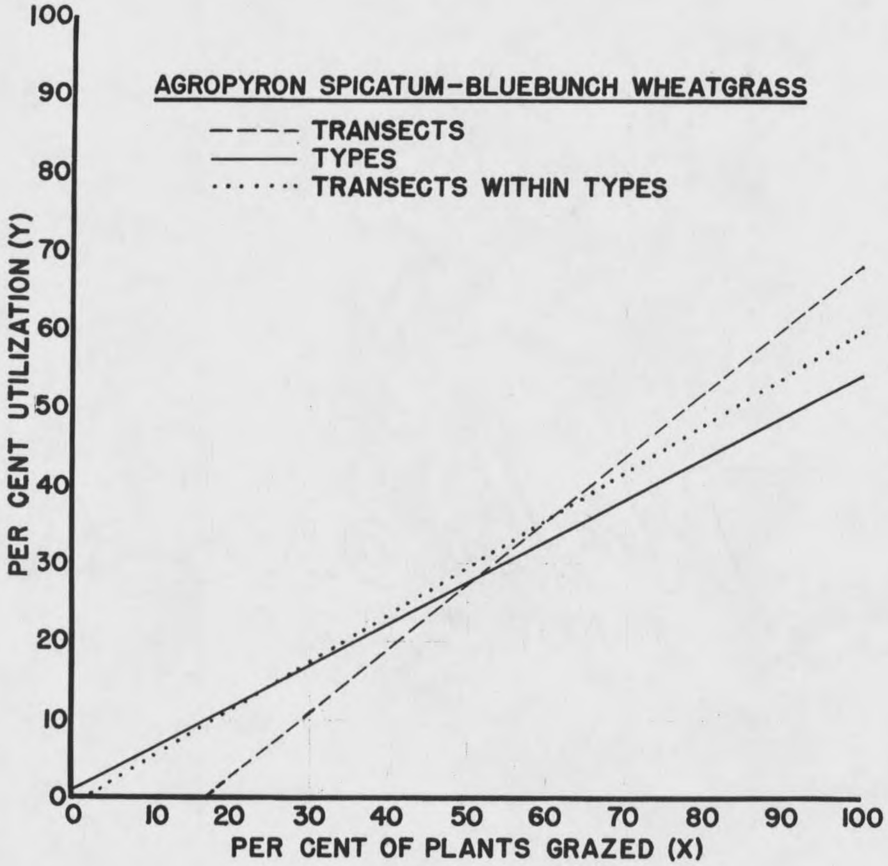

Figure 31. Relationships between per cent of plants grazed and per cent of weight removed of bluebunch wheatgrass (*Agropyron spicatum*) on sheep range.

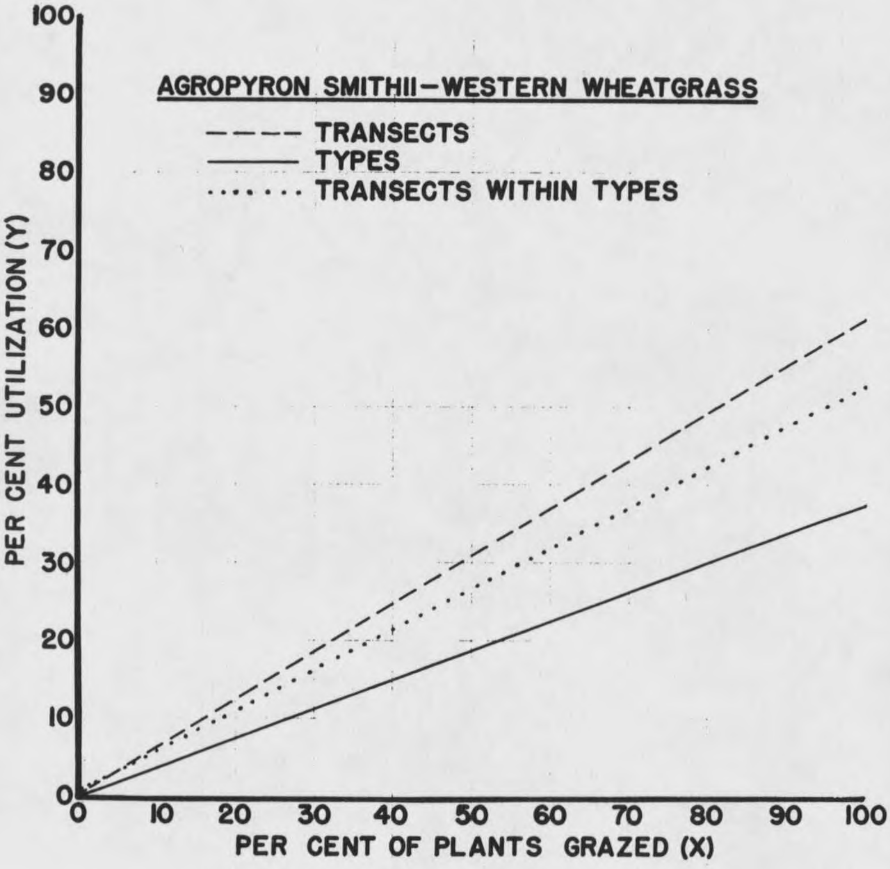

Figure 32. Relationships between per cent of plants grazed and per cent of weight removed of western wheatgrass (Agropyron smithii) on sheep range.

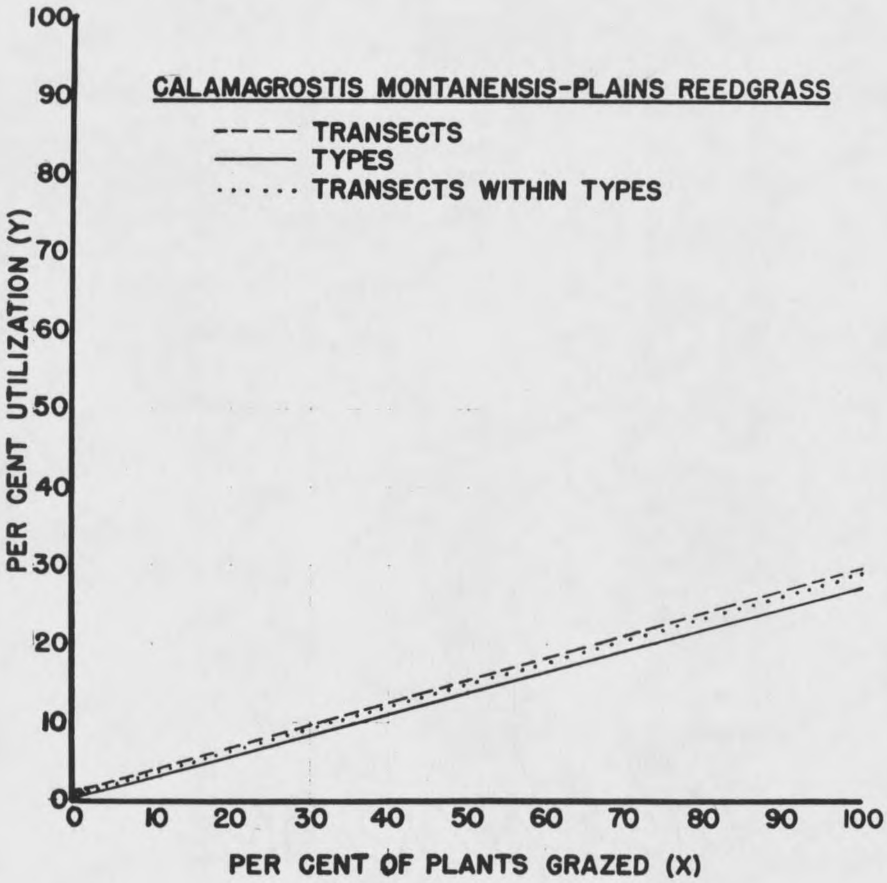

Figure 33. Relationships between per cent of plants grazed and per cent of weight removed of plains reedgrass (Calamagrostis montanensis) on sheep range.

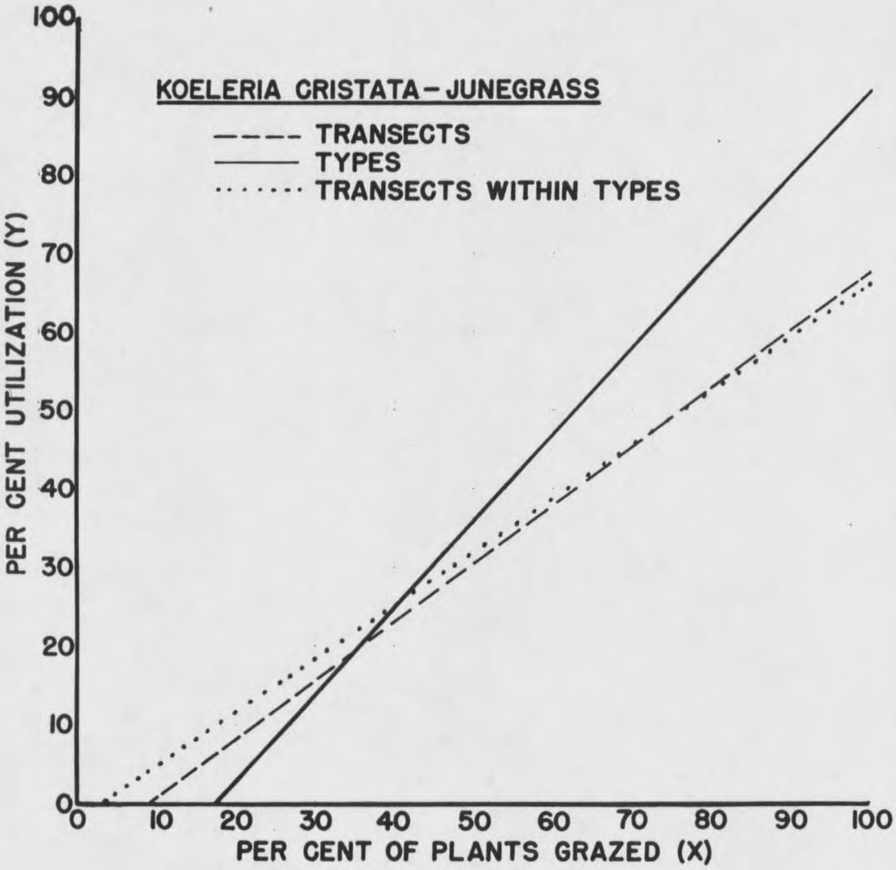

Figure 34. Relationships between per cent of plants grazed and per cent of weight removed of junegrass (Koeleria cristata) on sheep range.

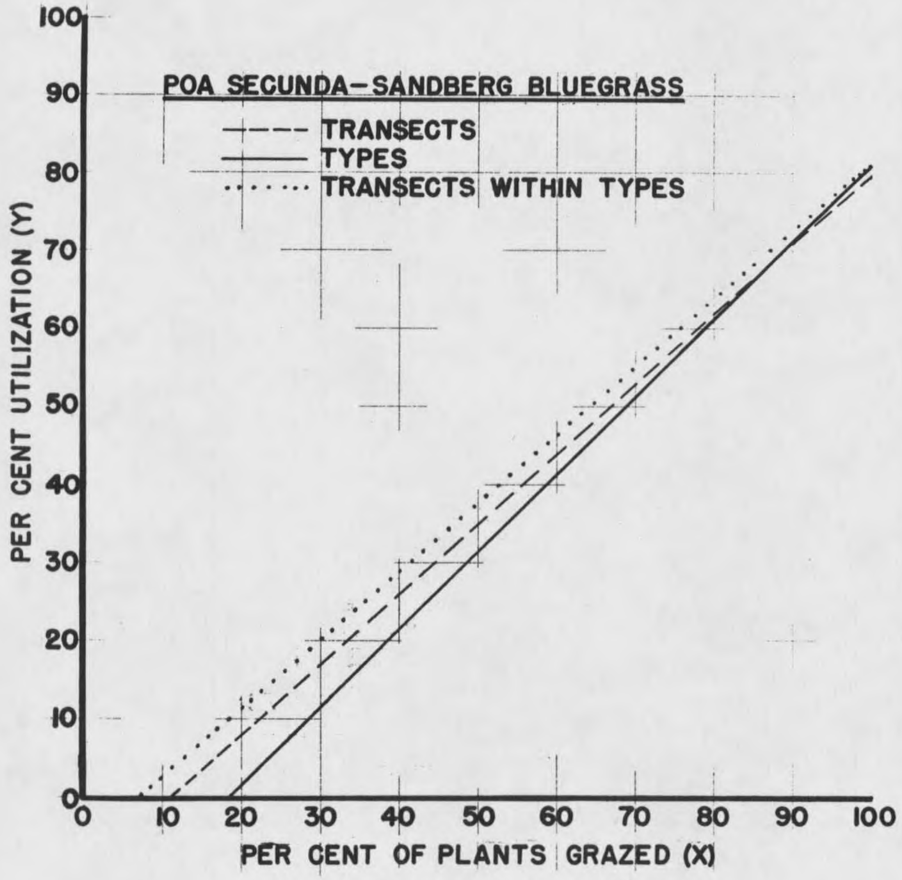

Figure 35. Relationships between per cent of plants grazed and per cent of weight removed of sandberg bluegrass (Poa secunda) on sheep range.

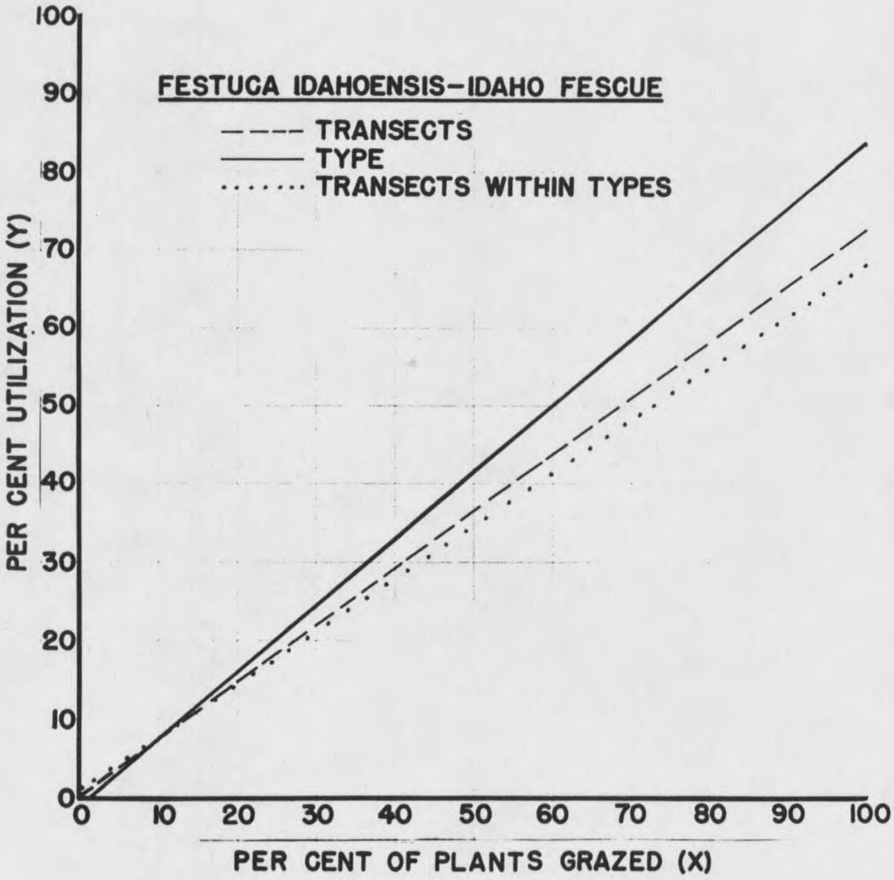

Figure 36. Relationships between per cent of plants grazed and per cent of weight removed of idaho fescue (Festuca idahoensis) on sheep range.

other method of tabulating the data.

To further test these graphs, they were applied to another range unit. During the time that the Chadbourne range, located a short distance north of Livingston, Montana, was leased by Montana State College, utilization checks of the winter use by herded sheep were made during the latter part of February of each year. Stubble height measurements and Lommasson's utilization gauge were used in determining the degree of utilization on this grazing area. These data, for the winter of 1951-52, have been tabulated for each plant species by averaging the utilization and per cent of plants grazed on each full-length transect. These transects may be a few hundred feet or several miles long. The correlation coefficients and regression equations for these data are presented in Table XXIV. The correlation coefficients are all highly significant ($P = .01$) except for plains reedgrass which was significant ($P = .05$).

These correlations are based upon Lommasson's method of utilization determination, while all of the correlations listed prior to Table XXIV have been based upon the author's height-weight table. It was felt that either method may be used as a basis for establishing a graph which can be used to determine grazing use by percentage of grazed plants. The high correlation coefficients obtained indicate that this may be true. This use of various methods was substantiated by Roach's statement (1950) to the effect that any one of the accepted systems of measuring per cent utilization can be used as a basis for preparing a graph which can be used to determine grazing use by percentage of ungrazed plants.

The regression equations in Table XXIV were used to plot graphs for

TABLE XXIV. CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS FOR PERCENTAGE USE (Y) AND PER CENT OF PLANTS GRAZED (X) FOR PLANT SPECIES TABULATED ONLY BY TRANSECT. 1/ THESE DATA WERE COLLECTED BY OTHER WORKERS ON THE CHADBOURNE LEASE LOCATED A SHORT DISTANCE NORTH OF LIVINGSTON, MONTANA. THIS EXAMINATION WAS MADE DURING LATE FEBRUARY, 1952, AND IS BASED UPON WINTER UTILIZATION.

Species	No. of Values	Correlation Coefficients	Regression Equations
Agropyron spicatum	27	0.864**	$Y = -0.8332 + 0.5388X$
Agropyron smithii	27	0.941**	$Y = -1.3277 + 0.7709X$
Calamagrostis montanensis	8	0.771*	$Y = -1.9403 + 0.5387X$
Koeleria cristata	27	0.970**	$Y = 0.5758 + 0.7841X$
Poa secunda	27	0.968**	$Y = 4.5614 + 0.8040X$
Festuca idahoensis	2	Not Analyzed 2/	Not Analyzed 2/
Stipa comata	26	0.888**	$Y = 2.1288 + 0.4246X$
Bouteloua gracilis	10	0.805**	$Y = 2.9182 + 0.3949X$
Carex eleocharis	7	Not Analyzed 2/	Not Analyzed 2/
Aristida longiseta	2	Not Analyzed 2/	Not Analyzed 2/
Carex filifolia	24	0.644**	$Y = 0.3833 + 0.3576X$
Carex spp.	2	Not Analyzed 2/	Not Analyzed 2/
Oryzopsis hymenoides	6	Not Analyzed 2/	Not Analyzed 2/
Festuca ovina	1	Not Analyzed 2/	Not Analyzed 2/
Stipa viridula	4	Not Analyzed 2/	Not Analyzed 2/
Bromus tectorum	4	Not Analyzed 2/	Not Analyzed 2/
All Species, Averaged	27	0.960**	$Y = -1.4427 + 0.6947X$
All Species, Totaled	204	0.853**	$Y = 0.1175 + 0.6404X$

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ The amount of data for this species was too limited to warrant an individual analysis but was included in the values for all species.

** Significant at the 1% level.
* Significant at the 5% level.

the Chadbourne range lands. Regression lines based upon the Shaw Ranch study area at White Sulphur Springs were also placed upon the same graphs for purposes of comparison. Both of these regression lines on each graph were based upon the same type of data arrangement and analysis. These graphs were not reproduced herein because of time and cost limitations. They may be readily developed from the data presented in Tables XXIII and XXIV. The bluebunch wheatgrass and "average" regression lines for the Shaw Ranch area are steeper than and cross the Chadbourne regression lines. This arrangement is reversed in western wheatgrass, plains reedgrass, and needle-and-thread. The junegrass, sandberg bluegrass, blue grama, and "total" regression lines for the Shaw Ranch are generally lower than and parallel with the regression lines for the Chadbourne Lease. This variation may be caused by (1) comparing author's height-weight table values to Lommasson gauge values, (2) different composition of vegetation, (3) different weather conditions, (4) different sheep, (5) different grazing systems or (6) any combination of these factors. The most important single cause of difference is probably the comparison of author's table and Lommasson's gauge values.

Some of the per cent of plants grazed graphs developed for the Shaw Ranch study area were applied to the per cent of plants grazed data for the Chadbourne Lease lands. This was done to test the validity of applying these graphs to another area of similar vegetation for which they were not specifically prepared. The per cent of plants grazed graphs previously illustrated were among them. The only regression lines examined were based upon the data tabulated only by transect. The per cent of use values, as determined from measured stubble heights and Lommasson's utilization gauge, were statistically compared with the per cent of use values determined from application of the per cent of grazed plants to the per cent of plants grazed graphs developed on the Shaw Ranch study area. These analyses are presented in Table XXV. These same stubble heights were used to determine per cent utilization values from the author's height-weight chart. These utilization values were then statistically compared in Table XXVI, to the same percentage use values determined previously from these graphs and used in the analyses presented in the previous table.

The correlation coefficients in these two tables are generally very high with the exception of blue grama as shown in Table XXVI. This low correlation for blue grama was due to inconcistent variations between utilization values, because of extreme variation in utilization values determined from the author's height-weight chart in relation to the per cent of plants grazed. There were no significant differences between the Lommasson gauge values and the per cent of plants grazed values (Table XXV) for bluebunch wheatgrass, western wheatgrass, plains reedgrass, needle-and-thread, blue grama, and the average of each species. The differences in junegrass and sandberg bluegrass utilization values were highly significant (P = .01). The average of each transect values were significantly different (P = .05). No significant difference was present between the use values determined from the author's height-weight table and those determined from the per cent grazed values for plains reedgrass, needle-and-thread, blue grama, and the two average groupings

TABLE XXV. STATISTICAL COMPARISON OF AVERAGE DEGREE OF UTILIZATION BY SHAW RANCH PER CENT OF PLANTS GRAZED GRAPHS (Y) WITH AVERAGE DEGREE OF UTILIZATION BY LOMMASSON'S GAUGE (X). REGRESSION EQUATIONS SHOW RELATIONSHIP BETWEEN (Y) AND (X) FOR DIFFERENT PLANT SPECIES TABULATED ONLY BY TRANSECT. 1/ STUBBLE HEIGHTS MEASURED ON CHADBOURNE LEASE, FEBRUARY, 1952.

Species	No. of Values	Correlation Coefficients	F Values 2/	Regression Equations
Agropyron spicatum	27	0.862**	3.48	$Y = 4.1615 + 0.9981X$
Agropyron smithii	27	0.941**	1.42	$Y = 2.2095 + 0.7041X$
Calamagrostis montanensis	8	0.771*	0.26	$Y = 4.0832 + 0.3179X$
Koeleria cristata	27	0.969**	55.53**	$Y = -3.1089 + 0.8636X$
Poa secunda	27	0.961**	24.83**	$Y = -5.8873 + 0.9804X$
Stipa comata	26	0.887**	0.18	$Y = 4.4551 + 0.6891X$
Bouteloua gracilis	10	0.800**	0.39	$Y = 5.8627 + 0.6637X$
Average of Each Transect	27	0.956**	5.08*	$Y = -4.2546 + 1.0556X$
Average of Each Species	16	0.923**	0.71	$Y = 3.3659 + 0.7217X$

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ F values for testing difference between Shaw Ranch per cent of plants grazed graph utilization values and percentage utilization as determined by Lommasson's gauge.

** Significant at the 1% level.
* Significant at the 5% level.

TABLE XXVI. STATISTICAL COMPARISON OF AVERAGE DEGREE OF UTILIZATION BY SHAW RANCH PER CENT OF PLANTS GRAZED GRAPHS (Y) WITH AVERAGE DEGREE OF UTILIZATION BY AUTHOR'S HEIGHT-WEIGHT TABLE (X). REGRESSION EQUATIONS SHOW RELATIONSHIP BETWEEN (Y) AND (X) FOR DIFFERENT PLANT SPECIES TABULATED ONLY BY TRANSECT. 1/ STUBBLE HEIGHTS MEASURED ON CHADBOURNE LEASE, FEBRUARY, 1952.

Species	No. of Values	Correlation Coefficients	F Values 2/	Regression Equations
Agropyron spicatum	27	0.758**	23.65**	Y = 7.4736 + 1.3924X
Agropyron smithii	27	0.964**	7.27*	Y = 1.6454 + 0.6448X
Calamagrostis montanensis	8	0.850**	0.96	Y = 3.2698 + 0.3046X
Koeleria cristata	27	0.964**	71.39**	Y = -3.4331 + 0.8149X
Poa secunda	27	0.970**	81.50**	Y = -5.6917 + 0.8981X
Stipa comata	26	0.725**	0.15	Y = 7.2532 + 0.5470X
Bouteloua gracilis	10	0.470	0.01	Y = 16.3799 + 0.2756X
Average of Each Transect	27	0.955**	3.36	Y = -4.5927 + 1.0830X
Average of Each Species	16	0.874**	1.32	Y = 4.1280 + 0.6316X

1/ The Montana State College Statistical Laboratory conducted these analyses.

2/ F values for testing difference between Shaw Ranch per cent of plants grazed graph utilization values and percentage utilization as determined by author's height-weight table.

** Significant at the 1% level.
* Significant at the 5% level.

(Table XXVI). The bluebunch wheatgrass and western wheatgrass use values were significantly different (P = .01 and P = .05 respectively). The junegrass and sandberg bluegrass values were significantly different (P = .05). (The regression equations in these two tables were not plotted.) These analyses indicate that the Shaw Ranch per cent of plants grazed graphs are more applicable to the Chadbourne Lease area when the Lommasson gauge is used as the basis of comparison, in preference to the author's chart. The Lommasson method apparently accounts for a part of the variation due to difference in site and vegetation composition. This may be due to the fact that the Lommasson values were determined from more plant samples collected from a much wider range of sites.

The differences in Chadbourne Lease mean utilization values, as determined by the three previously mentioned methods, are directly compared in Table XXVII. The utilization means of bluebunch wheatgrass, junegrass, and sandberg bluegrass vary excessively. This, together with the analyses of variance, indicates that the application of the Shaw Ranch per cent of plants grazed graphs for these three plant species to the Chadbourne Lease is not a valid procedure. The application of the western wheatgrass graph to the Chadbourne Lease may be questionable. However, the application of the graphs for the other plant species and the groupings to the Chadbourne Lease appears to be a valid procedure.

Of these utilization values those used in determining the "average of each transect" were determined by averaging, for each transect, the values for all the plants of all species occurring on the transect in question. The averages of all the transect utilization values were then

TABLE XXVII. MEAN UTILIZATION VALUES FOR PLANT SPECIES TABULATED ONLY BY TRANSECT. 1/ STUBBLE HEIGHTS WERE MEASURED ON THE CHADBOURNE LEASE DURING LATE FEBRUARY, 1952. DEGREE OF UTILIZATION WAS DETERMINED BY LOMMASSON'S GAUGE, THE AUTHOR'S HEIGHT-WEIGHT TABLE, AND THE SHAW RANCH PER CENT OF PLANTS GRAZED GRAPHS.

Species	Mean Utilization (Lommasson)	Mean Utilization (Author)	Mean Utilization (Per Cent of Plants Grazed)
Agropyron spicatum	28.32	17.92	32.43
Agropyron smithii	11.61	13.55	10.38
Calamagrostis montanensis	9.84	12.94	7.21
Koeleria cristata	44.02	47.05	34.91
Poa secunda	60.25	65.55	53.18
Stipa comata	15.73	14.70	15.30
Bouteloua gracilis	25.63	23.55	22.87
Average of Each Transect	29.89	29.45	27.30
Average of Each Species	17.90	19.24	16.28

1/ The Montana State College Statistical Laboratory conducted these analyses.

statistically analyzed to develop values for the "average of each transect." The analyses for the "average of each species" was developed in approximately the same manner. The values for all plants of the same species on all transect lines were averaged. The averages of all the various species were then analyzed in the same manner.

The "transect only" regression line for each plant species, as prepared on the Shaw Ranch study area using the author's height-weight table, was directly compared to the "transect only" regression line for each plant species, as prepared on the Chadbourne Lease using Lommasson's utilization gauge. This comparison, using the per cent of plants grazed graphs, is based upon the conversion of 5 per cent interval readings on the per cent of plants grazed axis to per cent utilization. (None of these graphs were prepared for inclusion in this paper.) These paired utilization values were statistically analyzed in Table XXVIII. Enough numbers (20 pairs per species) are present to cause a correlation coefficient of 1.000 to be truly representative of the situation. The difference is highly significant (P = .01) for all of the plant species and groupings examined with the exception of bluebunch wheatgrass and the average of each transect. The correlation coefficients for the two graphs were highly correlated and highly significant (P = .01) for all of the plant species and groupings studied.

As previously discussed, high correlation coefficients do not necessarily mean that the values are equal or nearly equal. The rate of change may be approximately equal between two systems of utilization determination but the utilization values may be very different. This pos-

TABLE XXVIII. SHAW RANCH PER CENT OF PLANTS GRAZED GRAPH UTILIZATION VALUES (Y) 1/ COMPARED WITH CHADBOURNE LEASE PER CENT OF PLANTS GRAZED GRAPH UTILIZATION VALUES (X) 2/ BY 5 PER CENT INTERVALS. THESE VALUES TABULATED ONLY BY TRANSECT FOR EACH PLANT SPECIES. 3/ STUBBLE HEIGHTS MEASURED ON CHADBOURNE LEASE DURING LATE FEBRUARY, 1952.

Species	No. of Values	Correlation Coefficients	F Values 4/	Regression Equations
Agropyron spicatum	21	0.993**	2.70	Y = -7.7414 + 1.3953X
Agropyron smithii	21	1.000**	38.04**	Y = 1.0277 + 0.7990X
Calamagrostis montanensis	21	1.000**	34.06**	Y = 1.8608 + 0.5343X
Koeleria cristata	21	0.998**	273.07**	Y = -5.4099 + 0.9178X
Poa secunda	21	0.997**	249.13**	Y = -11.8572 + 1.0670X
Stipa comata	21	1.000**	12.29**	Y = 1.7177 + 0.8691X
Bouteloua gracilis	21	0.999**	348.48**	Y = -4.9373 + 1.0590X
Average of Each Transect	21	0.997**	0.46	Y = -6.3139 + 1.1706X
Average of Each Species	21	1.000**	269.38**	Y = -1.2071 + 0.9750X

1/ These graphs are based upon utilization determined by author's chart.
2/ These graphs are based upon utilization determined by Lommasson's gauge.
3/ The Montana State College Statistical Laboratory conducted these analyses.
4/ F values for testing difference between Shaw Ranch per cent of plants grazed graph utilization values and percentage utilization as determined by Chadbourne Lease per cent of plants grazed graphs.

** Significant at the 1% level.

sibly suggests the use of a "constant" to bring any two of the methods together in terms of actual utilization values. One difficulty with this would be the problem of deciding which method is the more accurate, thus influencing the direction of the adjustment.

SUMMARY AND CONCLUSIONS

The research work reported in this thesis was conducted to study (1) variations and adaptability of the "per cent of plants grazed method" of utilization determination as influenced by the grazing behavior of unherded sheep and (2) variations in degree of utilization as influenced by variation in height-weight relationships.

The range unit involved in this study consisted of a 366 acre area one mile long and slightly over one-half mile wide. It is located on the Shaw Ranch near White Sulphur Springs, Montana. The soils are generally gravelly or stony loams. The climate of the area is midcontinental and is characterized by moderately low rainfall. Daily showers of a localized nature are common during the late spring and early summer months. Strong winter winds are often troublesome. The vegetation present is classified as an intermingling of both the Palouse bunchgrass and the mixed prairie grasslands.

A small band of unherded ewes and lambs was allowed to graze at will on this study area from May 4 to May 8, 1954. Hay was fed to these sheep. Another small band of ewes and lambs grazed the area in a similar manner from May 12 to June 3, 1954, but no hay was fed to them. During these periods, the sheep were left alone as much as possible. The feeding of hay was detrimental to the range in the vicinity of the hay feeding because it kept the sheep from spreading out to utilize the range uniformly. The ewes and lambs that were not fed hay spread out widely in loose groups of from five to thirty ewes and their lambs and bedded on the highest portion of the area on which they were grazing when twilight approached. Factors which influenced the grazing habits of the sheep included the feeding of hay, lambing camp location, elevation, water barriers, shade, slope, vegetation roughs, and preferences for certain plant species.

The composition of the vegetation was determined by systematic sampling with a "point quadrat" frame consisting of 20 points. Paced distances along predetermined compass lines were used in this systematic procedure and the vegetation types present were mapped. The three major kinds of grassland vegetation types present on the area are dominated respectively by bluebunch wheatgrass, idaho fescue, and kentucky bluegrass. Big sagebrush and silver sagebrush dominated the two sagebrush vegetation types. Acreages for each vegetation type are presented. The per cent composition and per cent basal densities of the various plant species present are presented in table form and briefly discussed. Bluebunch wheatgrass and junegrass make up the largest percentage of the vegetation available to livestock. Silver sagebrush was the most important shrub present. The high basal density of the club moss made it an important factor in soil stabilization. This and all the other data dealing with vegetation measurements in this thesis have been statistically analyzed.

Stubble heights were systematically measured, according to the method suggested by Lommasson and Jensen, in order to establish a basis for determining degree of utilization. A composite plant for each plant species was developed through determination of the height-weight distribution by sectioning and weighing of a representative sample of each grass and grass-like plant species utilized by the sheep. Graphs depicting the relationship of stubble height to per cent utilization are presented for each of these composite plants. The author used these composite plants to develop a height-weight chart which was used to determine degree of utilization from measured stubble heights. These composite plants of each species are weighted for the entire study area and include the maximum heights measured.

Based upon the same measured stubble heights, utilization values were determined both by the author's table and Lommasson's gauge. These paired values are compared statistically to determine if they give approximately the same results. In no case do the means differ as much as 5 per cent between the author's height-weight table and Lommasson's gauge if the use values are shifted 0.5 inch in order to put the two methods on the same level of comparison. They are very highly correlated but some significant differences are noted for certain plant species. Without testing both methods by clipping, the author's height-weight table for utilization determination appears to be equally as accurate for the study area as the Lommasson utilization gauge. On the area for which it is prepared, this height-weight table may be slightly more accurate, but its preparation requires the expenditure of more time than is needed to use the Lommasson utilization gauge.

The degree of utilization, as taken from the author's height-weight table and the measured stubble heights, was determined for the study area. The over-all utilization for the study area was 31.39 per cent with a total of 79.5 animal unit months of grazing use. The area was stocked at the rate of 4.6 acres per animal unit month. The zones of utilization were examined visually and mapped accordingly. Most of the excessive use was on high ground, near the lambing camp, or both. The kentucky bluegrass-timothy vegetation type along the moist creek bottom was the most heavily utilized of the vegetation types while the degree of utilization on the sagebrush types was generally the least heavily utilized. Sandberg bluegrass was the most heavily utilized of the plant species, and wire rush was also used heavily. The various utilization values are given.

The "per cent grazed method" of utilization determination was studied. Graphs are prepared for the more important species and groupings. The influence of the method of data summation is gaphically presented. Tables list the correlation coefficients and regression equations for the data collected on the Shaw Ranch at White Sulphur Springs, Montana. These analyses are also listed for the per cent utilization and per cent of plants grazed values for the winter use on the Chadbourne Lease north of Livingston, Montana. The possibility of using graphs involving the "per cent of plants grazed method" of use determination on another area of similar vegetation, for which they are not specifically prepared, was tested by using the Shaw Ranch graphs on the Chadbourne Lease utilization and per cent of plants grazed data. The method gave poor results for utilization on junegrass and sandberg bluegrass but was considered satisfactory for the other species tested. Plotted regression lines for the study area on the Shaw Ranch, based upon the author's height-weight table are compared to lines for the Chadbourne Lease based upon Lommasson's gauge. The lines are significantly different in nearly all cases.

LITERATURE CITED

Ahlgren, H. L. 1947. A comparison of methods used in evaluating the results of pasture research. Jour. Amer. Soc. Agron. 39:240-259.

Anderson, James. 1797. Essays relating to agriculture and rural affairs. (2) 486 pp. 4th Ed. London.

Arny, A. C. 1944. Alfalfa and grass determinations with the inclined point quadrat apparatus at different stages of development of the mixtures. Jour. Amer. Soc. Agron. 36:996-998.

Arny, A. C., and A. R. Schmid. 1942. A study of the inclined point quadrat method of botanical analysis of pasture mixtures. Jour. Amer. Soc. Agron. 34:238-247.

Atkeson, F. W., A. O. Shaw, and H. W. Cave. 1942. Grazing habits of dairy cattle. Jour. Dairy Sci. 25:779-784.

Bailey, R. W. 1945. Determining trend of range watershed condition essential to success in management. Jour. For. 43:733-737.

Beruldsen, E. T., and A. Morgan. 1934. Notes on botanical analysis of irrigated pasture. Imp. Bur. Plant Genetics, Herb. Pub. Ser. Bul. 14:33-43.

Bourdeau, Philippe F. 1953. A test of random versus systematic ecological sampling. Ecology. 34:499-512.

Brown, Dorothy. 1954. Methods of surveying and measuring vegetation. 223 pp. Bul. 42. 1st Ed. Bradley & Son, Ltd., The Crown Press, Reading, England.

Caird, Ralph W. 1945. Influence of site and grazing intensity on yields of grass forage in the Texas Panhandle. Jour. For. 43:45-49.

Campbell, R. S. 1937. Problems of measuring forage utilization on western ranges. Ecology. 18:528-532.

Campbell, R. S. 1942. Preparation of grass height-weight tables for use of A.A.A. in utilization gauge. U.S. Forest Service Washington Office. Unnumbered publication. 3 pp. (mimeo.).

Campbell, R. S. 1943. Ecology-progress in utilization standards for western ranges. Jour. Wash. Acad. Sci. 33:161-169.

Campbell, R. S., and Edward C. Crafts. 1938. Tentative range utilization standards--black grama (Bouteloua eriopoda). Southwestern Forest and Range Exp. Sta. Res. Note 26. 4 pp. (proc.).

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Jour. For. 39:388-394.

Canfield, R. H. 1942. A short-cut method for estimating grazing use. Southwestern Forest and Range Exp. Sta. Res. Note 99. 5 pp. (proc.).

Canfield, R. H. 1944. Measurement of grazing use by the line interception method. Jour. For. 42:192-194.

Canfield, R. H. 1944a. A short-cut method for checking degree of forage utilization. Jour. For. 42:294-295.

Canfield, R. H. Reprinted 1950. Sampling ranges by the line interception method; Plant cover-composition-density-degree of forage use. Southwestern Forest and Range Exp. Sta. Res. Report 4. 28 pp. (proc.).

Cassady, John T. 1941. A method of determining range forage utilization by sheep. Jour. For. 39:667-671.

Castle, M. E., A. S. Foot, and R. J. Halley. 1950. Some observations on the behaviour of dairy cattle with particular reference to grazing. Jour. Dairy Res. 17:215-230.

Clark, Ira. 1945. Variability in growth characteristics of forage plants on summer range in Central Utah. Jour. For. 43:273-283.

Clarke, S. E., J. A. Campbell, and J. B. Campbell. 1942. An ecological and grazing capacity study of the native grass pastures in Southern Alberta, Saskatchewan, and Manitoba. Dominion Exp. Sta. (Saskatchewan) Tech. Bul. 44. 31 pp.

Clements, Frederic E., and Victor E. Shelford. 1939. Bio-Ecology. 425 pp. 1st. Ed. John Wiley & Sons, Inc., New York, New York.

Cochran, W. G. 1946. Relative accuracy of systematic and stratified random samples for a certain class of populations. Ann. Math. Statistics. 17:164-177.

Collins, Robert W., and Leon C. Hurtt. 1943. A method for measuring utilization of bluestem wheatgrass on experimental range pastures. Ecology. 24:122-125.

Cook, Clyde J., C. Wayne Cook, and Lorin E. Harris. 1948. Utilization of Northern Utah summer range plants by sheep. Jour. For. 46:416-425.

Cook, C. Wayne, Lorin E. Harris, and L. A. Stoddart. 1948. Measuring the nutritive content of a foraging sheep's diet under range conditions. Jour. Anim. Sci. 7:170-180.

Cook, C. Wayne, and L. A. Stoddart. 1953. The quandary of utilization and preference. Jour. Range Mangt. 6:329-335.

Cory, V. L. 1927. Activities of livestock on the range. Texas Agr. Exp. Sta. Bul. 367. 47 pp.

Costello, David F., and George T. Turner. 1944. Judging condition and utilization of short-grass ranges. U.S.D.A. Farmers' Bul. 1949. 21 pp.

Coupland, Robert T. 1950. Ecology of mixed prairie in Canada. Ecol. Mono. 20:271-315.

Crafts, Edward C. 1938. Height-volume distribution in range grasses. Jour. For. 36:1182-1185.

Crafts, Edward C. 1938a. Range utilization tables and charts. Southwestern Forest and Range Exp. Sta. Unnumbered publication. 28 pp. (proc.).

Crafts, Edward C. 1938b. Tentative range utilization standards--blue grama (Bouteloua gracilis). Southwestern Forest and Range Exp. Sta. Res. Note 32. 4 pp. (proc.).

Crafts, Edward C. 1938c. Tentative range utilization standards--side-oats grama (Bouteloua curtipendula). Southwestern Forest and Range Exp. Sta. Res. Note 36. 4 pp. (proc.).

Crafts, Edward C. 1938d. Tentative range utilization standards--bluestem (Agropyron smithii). Southwestern Forest and Range Exp. Sta. Res. Note 44. 5 pp. (proc.).

Crafts, Edward C., and Lloyd A. Wall. 1938. Tentative range utilization standards. Southwestern Forest and Range Exp. Sta. Res. Note 25. 3 pp. (proc.).

Crocker, R. L., and N. S. Tiver. 1948. Survey methods in grassland ecology. Jour. Brit. Grassl. Soc. 3:1-26.

Culley, Matt J. 1937. Grazing habits of range cattle. Southwestern Forest and Range Exp. Sta. Res. Note 21. 4 pp. (proc.).

Dalke, Paul D. 1941. The use and availability of the more common winter deer browse plants in the Missouri Ozarks. Trans. N. Am. Wildl. Conf. 6:155-160.

Dasmann, William P. 1948. A critical review of range survey methods and their application to deer range management. Calif. Fish and Game. 34:189-207.

Dasmann, William P. 1951. Some deer range survey methods. Calif. Fish and Game. 37:43-52.

Daubenmire, Rexford F. 1942. An ecological study of the vegetation of southeastern Washington and adjacent Idaho. Ecol. Mono. 12:53-79.

Davies, W. 1925. The relative palatability of pasture plants. Jour. Ministry Agr., London, England. 32:106-116.

Deming, M. H. 1939. A field method for judging range utilization. U.S. D.I. Division of Graz. Unnumbered publication. 13 pp. (mimeo.).

Doran, C. W. 1943. Activities and grazing habits of sheep on summer ranges. Jour. For. 41:253-258.

Drew, William B. 1944. Studies on the use of the point quadrat method of botanical analysis of mixed pasture vegetation. Jour. Agr. Res. 69:289-297.

Ellison, Lincoln. 1942. A comparison of methods of quadratting short-grass vegetation. Jour. Agr. Res. 64:595-614.

Esplin, A. C., J. E. Greaves, and L. A. Stoddart. 1937. A study of Utah's winter range, composition of forage plants, and use of supplements. Utah Agr. Exp. Sta. Bul. 277.

Fuelleman, R. F., and W. L. Burlison. 1939. Pasture yields and consumption under grazing conditions. Jour. Amer. Soc. Agron. 31:399-412.

Gieseker, L. F., C. B. Manifold, A. T. Strahorn, and O. F. Bartholomew. 1953. Soil Survey (Reconnaissance) of Central Montana. Series 1940, No. 9, 133 pp.

Goodall, D. W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Australian Jour. Sci. Res. Series B. 5:1-41.

Green, Lisle R., Lee A. Sharp, C. Wayne Cook, and Lorin E. Harris. 1951. Utilization of winter range forage by sheep. Jour. Range Mangt. 4:233-241.

Hancock, John. 1950. Studies in monozygotic cattle twins. IV Uniformity trials: Grazing behaviour. N. Z. Jour. Sci. Tech. 32:22-59.

Hancock, John. 1950a. Grazing habits of dairy cows in New Zealand. Emp. Jour. Exp. Agr. 18:249-263.

Hancock, John. 1952. Grazing behaviour of identical twins in relation to pasture type, intake and production of dairy cattle. Proc. Sixth Int. Grassl. Cong. 2:1399-1407.

Hancock, John. 1953. Grazing behaviour of cattle. Anim. Breed. Abst. 21:1-13.

Hanson, Herbert C. 1934. A comparison of methods of botanical analysis of the native prairie in western North Dakota. Jour. Agr. Res. 49: 815-842.

Hanson, Herbert C. 1950. Vegetation and soil profiles in some solifluction and mound areas in Alaska. Ecology. 31:606-630.

Hanson, Herbert C., and Warren Whitman. 1938. Characteristics of major grassland types in western North Dakota. Ecol. Mono. 8:57-114.

Harris, Robert W. 1954. Fluctuations in forage utilization on Ponderosa pine ranges in Eastern Oregon. Jour. Range Mangt. 7:250-255.

Hasel, A. A. 1938. Sampling error in timber surveys. Jour. Agr. Res. 57:713-736.

Heady, Harold F. 1949. Methods of determining utilization of range forage. Jour. Range Mangt. 2:53-63.

Heady, Harold F. 1950. Studies on bluebunch wheatgrass in Montana and height-weight relationships of certain range grasses. Ecol. Mono. 20:55-81.

Hein, M. A. 1935. Grazing time of beef steers on permanent pasture. Jour. Amer. Soc. Agron. 27:675-679.

Hein, Mason A., and Paul R. Henson. 1942. Comparison of the effect of clipping and grazing treatments on the botanical composition of permanent pasture mixtures. Jour. Amer. Soc. Agron. 34:566-573.

Henson, Paul R., and Mason A. Hein. 1941. A botanical and yield study of pasture mixtures at Beltsville, Maryland. Jour. Amer. Soc. Agron. 33:700-708.

Holscher, Clark E., and E. J. Woolfolk. 1953. Forage utilization by cattle on Northern Great Plains ranges. U.S.D.A. Circ. 918. 27 pp.

Hormay, A. L. 1943. A method of estimating grazing use of bitterbrush. Calif. Forest and Range Exp. Sta. Res. Note 35. 4 pp. (proc.).

Hormay, A. L., and A. Fausett. 1942. Standards for judging the degree of forage utilization on California annual-type ranges. Calif. Forest and Range Exp. Sta. Tech. Note 21. 13 pp. (proc.).

Hubbard, William A. 1952. Following the animal and eye-estimation method of measuring the forage consumed by grazing animals. Proc. Sixth Int. Grassl. Cong. 2:1343-1347.

Humphrey, R. R. 1949. An analysis of forage utilization methods and a proposal for utilization surveys by range condition classes. Jour. For. 47:549-554.

Hunt, H. F., A. A. Beetle, R. L. Lang, N. W. Hilston, and P. O. Stratton. 1954. Cattle rate-of-grazing study on the Bighorn Mountains (Preliminary Report III, Project 466). Wyoming Agr. Exp. Sta. Mimeo. Circ. 36. 10 pp.

Hurd, Richard M., and Neland A. Kissinger, Jr. 1953. Estimating utilization of Idaho fescue (Festuca idahoensis) on cattle range by percent of plants grazed. Rocky Mtn. Forest and Range Exp. Sta. Paper 12. 5 pp. (proc.).

Inter-Agency Committee. 1948. Interstate winter deer range forage utilization check. Interstate Winter Deer Range Report. 25 pp. (proc.).

Jardine, J. T. 1910. The pasturage system for handling range sheep. U.S.D.A. For. Serv. Circ. 178, 40 pp.

Jardine, J. T., and Mark Anderson. 1919. Range management on the National Forests. U.S.D.A. Bul. 790, 98 pp.

Johnson, W. M. 1953. Effect of grazing intensity upon vegetation and cattle gains on Ponderosa pine-bunchgrass ranges of the Front Range of Colorado. U.S.D.A. Circ. 929, 35 pp.

Johnston, Alexander. 1954. A statistical comparison of the line interception, vertical point quadrat, and 3-step methods as used in measuring basal area of grassland vegetation in Southern Alberta. (M.S. thesis) Montana State College, 95 pp. (typewritten).

Johnstone-Wallace, D. B., and Keith Kennedy. 1944. Grazing management practices and their relationship to the behaviour and grazing habits of cattle. Jour. Agr. Sci. 34:190-197.

Joint Committee of Amer. Soc. of Agron., Amer. Dairy Sci. Assoc., and American Society of Animal Prod. 1943. Preliminary report on pasture investigations technique. Jour. Dairy Sci. 26:353-369.

Julander, O. 1937. Utilization of browse by wildlife. Trans. N. Am. Wildl. Conf. 2:276-287.

Klingman, Dayton L., S. R. Miles, and G. O. Mott. 1943. The cage method for determining consumption and yield of pasture herbage. Jour. Amer. Soc. Agron. 35:739-746.

Lantow, J. L. 1938. Range utilization surveys and procedure for follow-up. Soil Conservation Service Unnumbered publication. 8 pp. (mimeo.).

Lantow, J. L. 1939. Range utilization surveys and procedures for follow-up. Soil Conservation. 4:196-198, 204.

Leasure, J. K. 1949. Determining the species composition of swards. Agron. Jour. 41:204-206.

Levy, E. Bruce, and E. A. Madden. 1933. The point method of pasture analysis. New Zealand Jour. Agr. 46:267-279.

Lommasson, Tom, and Chandler Jensen. 1938. Grass volume tables for determining range utilization. Science. 87:444.

Lommasson, T., and Chandler Jensen. 1942. Determining the utilization of range grasses from height-weight tables. U.S. Forest Service. Unnumbered publication. 15 pp. (mimeo.).

Lommasson, T., and Chandler Jensen. 1943. Determining utilization of range grasses from height-weight tables. Jour. For. 41:589-593.

McCain, Randall. 1948. A method of measuring deer range use. Trans. N. Am. Wildl. Conf. 13:431-441.

Morgan, A., and E. T. Beruldsen. 1931. Sampling technique as applied to irrigated pasture in regard to botanical composition and carrying capacity under different grazing systems. Jour. Agr. Victoria, Australia. 29:36-45.

Morris, M. S. 1946. An ecological basis for the classification of Montana grasslands. Proc. Mont. Acad. Sci. 6:41.

Musser, H. B. 1948. Effects of soil acidity and available phosphorous on population changes in mixed kentucky bluegrass-bent turf. Jour. Amer. Soc. Agron. 40:614-620.

Nelson, Enoch W. 1930. Methods of studying shrubby plants in relation to grazing. Ecology. 11:764-769.

Nevens, W. B. 1945. A comparison of sampling procedures in making pasture yield determinations. Jour. Dairy Sci. 28:171-185.

Osborn, B. 1947. A guide to degrees of range use in southwest Texas. The Cattleman. 34:124-126.

Osborn, Ben. 1947a. Determining range utilization by frequency tallies. Jour. Soil and Water Conserv. 2:51-55.

Osborne, J. G., and Elbert H. Reid. 1952. The design, conduct, and interpretation of range grazing studies. Proc. Sixth Int. Grassl. Cong.: 7.

Ostle, Bernard. 1954. Statistics in Research: Basic Concepts and Techniques for Research Workers. 487 pp. 1st. Ed. The Iowa State College Press, Ames, Iowa.

Parker, Kenneth. 1953. Instructions for measurement and observation of vigor, composition, and browse. U.S. Forest Service. Unnumbered publication. 11 pp. (proc.).

Parker, Kenneth W., and George E. Glendening. 1942. A method for estimating grazing use in mixed grass types. Southwestern Forest and Range Exp. Res. Note 105. 5 pp. (proc.).

Parker, Kenneth W., and George E. Glendening. 1942a. General guide to satisfactory utilization of the principal southwestern range grasses. Southwestern Forest and Range Exp. Sta. Res. Note 104. 4 pp. (proc.).

Pechanec, Joseph F. 1936. Comments on the stem-count method of determining the percentage utilization of ranges. Ecology. 17:329-331.

Pechanec, Joseph F. 1941. Sampling error in range surveys of sagebrush-grass vegetation. Jour. For. 39:52-54.

Pechanec, Joseph F., and G. D. Pickford. 1937. A weight estimate method for the determination of range or pasture production. Jour. Amer. Soc. Agron. 29:894-904.

Pechanec, Joseph F., and G. D. Pickford. 1937a. A comparison of some methods used in determining percentage utilization of range grasses. Jour. Agr. Res. 54:733-765.

Pechanec, Joseph F., and George Stewart. 1940. Sagebrush-grass range sampling studies: Size and structure of sampling unit. Jour. Amer. Soc. Agron. 32:669-682.

Pechanec, Joseph F., and George Stewart. 1941. Sagebrush-grass range sampling studies: Variability of native vegetation and sampling error. Jour. Amer. Soc. Agron. 33:1057-1071.

Peterson, R. A., and E. J. Woolfolk. 1955. Behavior of Hereford cows and calves on short grass range. Jour. Range Mangt. 8:51-57.

Pickford, G. D., and Elbert H. Reid. 1942. Basis for judging subalpine grassland ranges of Oregon and Washington. U.S.D.A. Circ. 655. 38 pp.

Pickford, G. D., and E. H. Reid. 1942a. Guides to determine range condition and proper use of mountain meadows in Eastern Oregon. Pacific Northwest Forest and Range Exp. Sta. Res. Report 3. 20 pp. (proc.).

Pickford, G. D., and Elbert H. Reid. 1948. Forage utilization on summer cattle ranges in Eastern Oregon. U.S.D.A. Circ. 796. 27 pp.

Reid, Elbert H., and G. D. Pickford. 1941. A comparison of the ocular-estimate-by-plot-and the stubble-height methods of determining percentage utilization of range grasses. Jour. For. 39:935-941.

Rhoad, A. O., and R. B. Carr. 1945. Measuring productive capacity of pastures through maintenance studies with mature steers. U.S.D.A. Teach. Bul. 890. 20 pp.

Roach, Mack, E. 1950. Estimating perennial grass utilization on semi-desert cattle ranges by percentage of ungrazed plants. Jour. Range Mangt. 3:182-185.

Sampson, Arthur W. 1952. Range Management Principles and Practices. 570 pp. 1st Ed. John Wiley & Sons, Inc., New York, New York.

Sampson, Arthur W., and Harry E. Malmsten. 1926. Grazing periods and forage production on the National Forests. U.S.D.A. Dept. Bul. 1405. 55 pp.

Smith, Arthur D. 1944. A study of the reliability of range vegetation estimates. Ecology. 25:441-448.

Soil Conservation Service, Region 7, Range Division. 1944. The ocula-estimated-by-plot method of estimating utilization. Unnumbered publication. 4 pp. (mimeo.).

Sprague, V. G., and W. M. Myers. 1945. A comparative study of methods for determining yields of kentucky bluegrass and white clover when grown in association. Jour. Amer. Soc. Agron. 37:370-377.

Stapledon, R. G. 1931. The technique of grassland experiments. Rothamsted Conferences 13, The technique of field experiments:22-28.

Stapledon, R. G., T. W. Fagan, R. E. Evans, and W. E. J. Milton. 1927. The effect of methods of grazing on productivity and palatability and on the chemical and botanical composition of the herbage. Welsh Plant Breeding Station, Univ. of Wales, Aberystwyth. Series H. 5:5-41.

Stapledon, R. G., and M. G. Jones. 1927. The sheep as a grazing animal and as an instrument for estimating the productivity of pastures. Welsh Plant Breeding Station, Aberystwyth. Ser. H: 42-54.

Stoddart, L. A. 1935. Range capacity determination. Ecology. 16:531-533.

Stoddart, L. A. 1952. Problems in estimating grazing capacity of ranges. Proc. Sixth Int. Grassl. Cong.:1367-1373.

Stoddart, Laurence A., and Arthur D. Smith. 1943. Range Management. 547 pp. 1st Ed. McGraw-Hill Book Co., Inc., New York, New York.

Tayler, J. C. 1953. The grazing behaviour of bullocks under two methods of management. Brit. Jour. Anim. Behaviour 1:72-77.

Teigen, Mons L. 1949. Forage preference of range sheep. (M. S. thesis) Montana State College, 40 pp.

Tinney, Fred W., O. S. Aamodt, and Henry L. Ahlgren. 1937. Preliminary report of a study on methods used in botanical analysis of pasture swards. Jour. Amer. Soc. Agron. 29:835-840.

Tribe, D. E. 1950. The behaviour of the grazing animal: A critical review of present knowledge. Jour. Brit. Grassl. Soc. 5:209-224.

U. S. Forest Service. 1936. The use book. A manual of information about the national forests. U.S.D.A. Unnumbered. 113 pp.

U. S. Forest Service Region 4. Undated. Domestic livestock and wildlife and forage removal. Unpublished tables. 2 pp. (mimeo.).

Valentine, K. A. 1946. Determining the grazing use of grasses by scaling. Jour. For. 44:528-530.

Waite, R., W. B. MacDonald, and W. Holmes. 1951. Studies in grazing management. III. The behaviour of dairy cows grazed under the close-folding and rotational systems of management. Jour. Agr. Sci. 41:163-173.

Weaver, John E., and Frederic E. Clements. 1938. Plant Ecology. 601 pp. 2nd Ed. McGraw-Hill Book Co., Inc., New York, New York.

Weaver, J. E., and G. W. Tomanek. 1951. Ecological studies in a mid-western range: the vegetation and effects of cattle on its composition and distribution. Nebr. Conserv. Bul. 31, 82 pp.

Whitman, Warren C., and Einar D. Siggeirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology. 35:431-436.

Woolfolk, E. J. 1949. Stocking Northern Great Plains sheep range for sustained high production. U.S.D.A. Circ. 804. 39 pp.

Wright, John C., and Elnora A. Wright. 1948. Grassland types of south central Montana. Ecology. 29:449-460.

Young, Vernon A. 1945. Proper grazing use on Southern California annual range. Region 7 U.S. Soil Conservation Service Unnumbered publication. 11 pp. (proc.).