Methods of Determining Utilization of Range Forage

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ACCORDING to the Society of American Foresters (1944) "utilization" is the degree to which animals have removed the current growth of herbage and is expressed in percentage of the growth within reach of livestock. The units of measurement, as percentage of weight or height, are not mentioned. The concept may be applied to a single plant or species, to a group of plants or species, or to the whole of a range area. This article is primarily concerned with the measurement of utilization. However, a few comments on the interpretation and standards of proper use are given. Sustained production of forage plants is dependent for the most part on a moderate degree of cropping and trampling each year. Measurement, interpretation, and control of the use of forage plants is one of the most important phases of range management.

No doubt utilization has been estimated by stock raisers since man began controlling livestock. The oldtime western stockman judged how near his feed was fully used or how many more days of grazing he could get from a particular pasture. These estimates were merely ocular and were influenced greatly by the man's judgment and experience. No doubt many of the estimates were accurate. However, lack of knowledge of how much grazing a range could withstand was a contributing factor to widespread range depletion.

Probably the first organized attempt to control utilization was by U. S. Forest Service officials. They believed that 15 to 20 percent of the volume of herbage should remain if the forage production was to be maintained. In 1926, Sampson and Malmsten made the statement: "It is generally conceded that if from 10 to 25 percent of the herbage of the more important palatable species remains in the fall, proper utilization has been affected." Others applied the same percentages on a strictly height basis. Several authors in recent years (Lommasson and Jensen, 1938; Crafts, 1938; Parker and Glendening, 1942; Costello and Turner, 1944) have shown that most of the volume of grass herbage is produced in the lower few inches of the plants and that grazing to a certain percentage of the height may result in either under, proper, or over utilization depending upon the climate, site, or plant species. Some held the belief that 20 percent of the seed stalks should remain ungrazed on short-grass ranges (Costello and Turner, 1944) and 25 per cent on southwestern ranges (Parker and Glendening, 1942a). The U. S. Forest Service in its revised codes in 1936 required that 10 to 25 percent of the palatable vegetation be left at the end of the grazing season and approximately 25 percent of the seed heads be allowed to reach maturity. A few range men thought that height and volume were analogous and that it made little difference whether the percentages referred to height or weight. This idea has proven fallacious.

At first the differences between percentages of utilization and 100 were called palatability ratings. When attempts were made to standardize the percentages on a height, weight, or some other basis,

such terms as proper use, resistance level, and use factor came into use. No attempt is made here to clarify that terminology.

Methods Based on Estimates

General reconnaissance

In the general reconnaissance method the inspector looks over a range area in more or less detail and makes an estimate of utilization. This may be one estimate which covers the entire area or it may be an average of estimates on small areas or by individual species. However, no plots are taken nor are individual plants measured. The estimates may be of the percentage of height or volume removed or both or it may be in general terms such as light, moderate, or heavy utilization. The accuracy of the estimates depends largely upon the experience and judgment of the inspector. It has been shown (Smith, 1944) that estimates of density vary between individuals and for one individual between days and within the same day. Presumably estimates of use would vary in somewhat the same manner.

Several variations or refinements of the reconnaissance method have been devised. For example, Pechanec and Pickford (1937) describe a weight estimate method to determine range production in which they were able to appraise very closely the actual mean herbage weights of the important species and to calculate stocking rates by this method more closely than with other methods. Presumably then the estimation of weight remaining after grazing could be accomplished with similar accuracy.

Ocular estimate by plot

The ocular estimate by plot method is a refinement of the general reconnaissance method and was developed on the U. S. Sheep Experiment Station in 1933. According to Pechanec and Pickford (1937a): "It differs from the general reconnaissance method in that each estimate is made on a plot of such limited area that the entire plot is clearly visible from one point, and percentage utilization is the average of estimates from a series of plots selected at random. As with the general reconnaissance method, percentage utilization of height, volume, or weight is estimated. By confining observations to smaller areas, adequately replicated, rather consistent results between individual workers have been obtained." In addition to the replication obtained when small plots are used, Stapledon (1931) has shown experimentally that small plots concentrate your efforts on small areas and thus make your estimates more intensive.

Ocular estimate by average of plants

This method is a refinement, by Pechanec and Pickford (1937), of the ocular estimate by plot method. The percentage removal of weight is estimated for each plant within the plot and the average of the estimates is taken as percentage utilization for the plot. After comparison with the volume-by-weight, stem count, and ocular-estimate-by-plot methods, Pechanec and Pickford (1937a) prefer this method because of its relative freedom from personal error and its high correlation with volume of forage removed. The method is sufficiently rapid so that numerous replications can be made. It was designed for plants with a bunch growth-habit.

Primary forage plant

The primary forage plant method was described by Deming (1939) and has been tested by several federal agencies. It is based on the principle of recording at the close of the grazing season specific

information about each of the main forage plants which carry the principal load of grazing on a range area. Briefly described are other factors which influence use, such as composition of the vegetation, abundance and vigor of plants, mortality of reproduction, poisonous plants, soil erosion conditions, topography, water, rodent infestation, fires, and season of use. After considering all factors, an area is then assigned to one of nine described classes of degree of use, as follows:

1. Unused.
2. Slight. Casual grazing only.
3. Light. Best plants "topped."
4. Moderate. Choice plants fully used; poor plants unused.
5. Proper. Primary forage plants correctly used; grazing as uniform over most of area as natural features will allow.
6. Close. Some repetition of grazing; slight use of low value plants.
7. Severe. Hedged or mown appearance; choice and good forage plants injuriously used; low value plants carrying much of grazing load.
8. Extreme. "Stripped" appearance with close use of low value plants.
9. Destructive. Range appears "grubbed;" some death loss of primary forage plants; active soil movement; low value plants closely and universally used.

A sufficient number of observations are made within an administrative unit to afford a picture of what is happening to the whole area under existing conditions of use. To give an opportunity for subsequent examinations for comparative purposes, the location of each observation station is described and plotted on a map. These map locations also show diagrammatically the approximate portions of the unit subjected to different degrees of grazing use, which gives a key to where corrective management adjustments are necessary.

Lantow (1939) suggested that utilization be estimated separately for several species and also be based upon all the noticeable features of management and use. These figures were then multiplied by the percentage composition of each species in the stand and the products totaled. The percentage composition was also multiplied by the palatability, or the percent of the species that will be eaten under proper range management, and the products totaled. The two sums were then divided to obtain the percent utilization of the forage available under proper use.

Utilization by comparison of range with standard photographs

Hormay and Fausett (1942) described a method of judging range utilization of annual-type ranges in California which is based on standard photographs. In this method the object is to match the range against a set of photographs to determine degree of use. Other points considered in making a decision include litter, stubble height, use of poor species, visibility of rocks, hoofprints, squirrel mounds, bare soil, and erosion.

Methods Based on Measurements

Weight measurements

Beruldsen and Morgan (1934) in Australia used a method of determining percentage utilization which necessitates two clippings of the forage. Briefly the authors clipped 25 and 35 well-distributed random samples before grazing and after grazing, respectively. Grazing was done by sufficient numbers of sheep on small pastures so that only one day elapsed between the clippings. Growth of the pasture plants, therefore, was not a factor. Presumably the difference in air-dry weight between the two clippings, or the percentage of volume reduction, was the percentage of forage utilized by the animals. Further, the clippings were

separated by species so that preferential differences between the species were also determined. If enclosures are used, clippings on the grazed and ungrazed plots may be made after grazing. When grazing continues over a period of several days or more, the procedure must include enclosures because growth of the forage plants become a factor.

The method possesses two very desirable features—simplicity and reduction of personal error. However, the necessity of a fenced area or a mature vegetation prohibits its use on most range land except for experimental studies. The heterogeneity of range vegetation and the variations in use would necessitate a large number of plots to attain sufficient accuracy for changing management. The method has little promise on the millions of acres of range land but is well adapted to a short grazing period on small pastures.

Cassady (1941) suggests a modification of the weight method for determining utilization on sheep range. A predetermined number of units (one twig, one stem, one leaf, or some other distinctive plant part) is collected and weighed immediately before and another group immediately after grazing. The difference in weights is used to determine percentage utilization. The units collected must be by randomized technique and the weighings should not be more than a few hours apart; otherwise differences in moisture content and growth will cause errors in determinations. From tests not described, the author claims accuracy without undue expense. There was close agreement between results for two years, but differences between the actual utilization and the proper use factors were great for many species.

When the soil moisture and grass species are such that growth continues over several weeks and the grasses respond well after close cutting, forage production and forage utilization may be determined by 2-week periods by a method suggested by a Joint Committee of the Am. Soc. of Agronomy, Am. Dairy Sc. Association, and the Am. Soc. of Animal Production (1943). In this method a series of 2 one-meter square enclosure cages are placed at random in each pasture. A third square meter, unprotected, plot is located within 10 feet of the enclosures, that had as near as possible the same density and growth of vegetation as that in the enclosure. These plots are clipped at 2-week intervals and moved to new locations. The total of the calculated differences of the dry weight of forage produced on these paired plots should closely approximate the quantity of herbage eaten by the grazing animals. Similar methods have given good results in pasture studies in the midwest (Fuelleman and Burlison, 1939; Van Doren, *et al.*, 1940; and Gard, *et al.*, 1943). Klingman, Miles, and Mott (1943) show statistically that the caged units should be located at random but the unprotected plot should be selected for its likeness to the first to give the most accurate results.

The following is a summary of treatment for each set of 3 one-meter square plots:

Treatment	Beginning of period	During period	End of period
A	Clipped	Protected	Clipped
B	None	Protected	Clipped
C	None	None	Clipped

It was found by Nevens (1945) that the production for each period and for the season were more accurately determined with treatment "A" than by any other combination of plots. Treatment "B" alone gives the total forage available during the period; "C" the amount left after grazing; and the difference between "B" and "C" is the amount consumed.

Height measurements

According to Pechanec and Pickford (1937a) the height measurement method is based on the premise that percentage utilization of grass is equal to the reduction in average leaf height as a result of grazing. Enclosures are necessary if grazing occurs for any considerable length of time during the period of rapid growth of the grasses. When grazing is completed, the difference in average leaf heights of the grazed and ungrazed areas is considered the removed portion and is used to calculate percentage utilization. If the grasses are mature or growth is negligible, differences in leaf height before and after grazing or of grazed and ungrazed plants may be used for the calculation of percentage utilization. Due regard must be given the different degrees of use of different species and the percentage composition of various species in the stand. Collecting the data may involve the use of either plots or transects. Two variations of the height measurement method based on stubble height follow:

Canfield (1944) measured stubble heights and diameters along a 50- or 100-foot line transect and then arranged the data according to species and stubble height classes. The measurements along the line were converted to percentages so that the final summary sheet shows the part of the stand contributed by each species, the proportion of each species in each stubble height class, and weighted mean-use by stubble height classes. The costs and results from this method were not greatly different from other methods of intensive utilization surveys. It is hardly applicable to other than experimental areas.

Canfield (1944a) described a method developed at the Southwestern Forest and Range Experiment Station which is based on the premise that the percentage of the grass stand grazed closer than a two-inch stubble height is proportional to the percentage grazed to a height above two inches and to the ungrazed portion. The percentage grazed to two inches or less may be estimated or counted depending upon the desired accuracy and experience of the inspector. After this percentage is determined the other two percentages are read from a graph. The authors claim accuracy to within 10 per cent even by untrained personnel, and that it is a speedy one-man method. A chart or graph must be constructed for each area or new grass type. Details were given for the construction of the graph in an earlier publication (Canfield, 1942).

Conversions of stubble height to weight removed

Lommasson and Jensen (1938) were the first to correlate height removal with weight removal in range grasses. The leaves and culms of grass plants were held in place by first wrapping a string spirally around the plant from the base upward and then removing the herbage slightly above ground level. The entire plant was cut into 1-inch segments which were dried and weighed. Percentage of the total weight was calculated for each 1-inch interval of height. These authors found that each species had a more or less definite form if data were grouped according to overall 2-inch height classes of the plants. By a series of graphs and one-cycle semi-log paper the data were transformed onto sliding scales, similar to the Mannheim slide rule, whereby stubble height could be converted to percentage of weight removed. A detailed description of the method of constructing the tables, sliding scales, and the field application is given by Lommasson and Jensen (1942 and 1943) and by Campbell (1942).

Crafts (1938) initiated a study of the height-weight relationships in 11 important grasses in Arizona and New Mexico. He found, as did Lommasson and Jensen (1938), that the major portion of the weight was near the ground level. The accuracy of using height measurement to determine weights as influenced by environmental factors was not studied. However, height-weight scales were presented for blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), rothrock grama (*B. rothrockii*), Arizona fescue (*Festuca arizonica*), mountain muhly (*Muhlenbergia montana*), curly mesquite (*Hilaria belangeri*), and tobosa (*H. mutica*). The data were for 2 to 20 individual plants for one year. Individual species writeups following this method were given by Campbell and Crafts (1938) for black grama (*Bouteloua eriopoda*), by Crafts (1938b) for blue grama, and another (Crafts, 1938a) for western wheatgrass (*Agropyron smithii*). These publications also include descriptions or guides to proper use of the plants for Southwest conditions. Crafts and Wall (1938) set forth certain definitions and concepts about proper use, utilization indicators, range types, soil, class of stock, when to judge use, utilization panels, and key species that are necessary in the use of height-weight scales. Such a statement of fundamentals is necessary in the successful use of any method that is to be followed year after year with various personnel.

Lommasson and Jensen (1942) tested their method and at the same time compared results with a weight estimate method. They concluded that the "form factor" or height-weight principle was sound and that more accurate and more uniform results could be obtained by the method than by ocular estimate, provided proper instructions were given. Also 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.

Parker and Glendening (1942) suggested a modification in the field procedure of the height-weight method to make it more applicable to mixed grass stands. All the important species were used rather than one to three "key species." The percentage composition was determined by the number of plants recorded of each species in a transect of 100 observations. The percentage of proper use of the type was then calculated by using the actual use, percentage composition, and the proper use factor. The method has limitations in that the composition is based on the number of plants rather than the percentage of ground cover. This difference may be important in some types and not in others. The figures must be substantiated with observations on erosion, distribution of livestock, forage production, and other indicators of range use or misuse.

The height-weight method, including several variations, necessitates linear measurements of both stubble height and ungrazed height, averaging ungrazed height, converting stubble height of each plant to percentage utilization, and averaging utilization. Valentine (1946) has scaled the percentages of utilization on a card which is placed by the side of a plant so that the stubble height indicates the percentage of weight that has been removed. The average ungrazed height still has to be calculated but the amount of calculations is greatly reduced in that linear stubble heights are not measured. Another advantage of this refinement is that the examiner associates stubble height with utilization because he sees both on each plant at the same time.

The height-weight method is based on the premise that growth form of grasses

is sufficiently constant between years, seasons, and sites to allow the use of height-weight tables with accuracy of plus or minus 5 per cent in the utilization determination. In fact, Lommasson and Jensen (1942) found that no member of a 6-man crew varied more than plus or minus 3.5 percent in his estimate of utilization when he used the height-weight method. However, the same crew varied from a plus 8 to a minus 7 percent in ocular estimates of the utilization. The standard was an actual weight comparison of the herbage removed by artificial grazing to that remaining.

Reid and Pickford (1941) compared the ocular-estimate-by-plot method with the height-weight method on green fescue range in the Wallowa mountains. The first method was described by Pechanec and Pickford (1937) and the height-weight relationships were determined by using graphs by which stubble height was converted to percentage of weight removed. Both methods gave substantially the same estimate of the degree of utilization when the stubble height was quite uniform. The stubble height method gave low estimates when use was ragged or uneven. About the same number of observations or plots were required in both methods but the increased speed in the ocular method led them to recommend it as the best method available for field use.

Not all workers have found the form factor principle to be fundamentally sound. Clark (1945) in 4 years of work in the oakbrush, aspen-fir and spruce-fir zones of Utah found that composite samples of all years and all zones would in many instances show errors of 10 to 25 percent when average height-weight tables were used. The study was concerned with 10 species and the data showed variations between samples from different years, from different elevational zones, and from different sites. Each of the 10 species exhibited its own variation in growth form as a result of differences in such factors as soil, exposure, shading, moisture conditions, and temperature. Clark found that the grasses conformed more nearly to a single pattern and had greatest variability in height in favorable years, and that there was less difference in growth form between zones in one year than in one zone between years. The conclusion was reached from field trials that the ocular-estimate-by-plot method is more accurate and more suitable for estimating degree of forage utilization than the height-weight method.

Collins and Hurtt (1943) after testing the available methods for determining utilization, used a stubble height method in which the remaining height of grazed plants, a tally of grazed and ungrazed plants, and certain other information were recorded. The work was done with 3 key species on shortgrass range at Miles City, Montana. From the data, average stubble height and percentage of grazed plants were calculated. By means of height-weight curves, average stubble height was converted to percentage of use. The percentage of use multiplied by the percentage of all stems that had been grazed gave the total percent to which the species had been removed. Species like western wheatgrass may be either culmed or culmless and the ratio between the two types varied greatly from year to year. The height-weight curves were constructed each year from weight data of culmed and culmless plants in the same proportion as they occurred in the pastures. Plants with growth habits different than western wheatgrass required variations in the procedure.

A method based upon stubble height as the initial measurement is an indirect method because it is based on the un-

grazed portion rather than the grazed portion. Furthermore no direct method of measuring utilization has been devised. Collins and Hurtt (1943) state that differences in degree of use show a close relationship with calf gains under 3 different intensities of grazing. Intensive use of this method at Miles City revealed differences in utilization too slight to be noticed by ocular estimation.

Results obtained by various workers have contributed much to the knowledge of height-weight relationships. However, the results have not been consistent. Yet, this method has more promise than any developed so far because it is based on sound experimental procedure.

Stem count

Stoddard (1935) used the stem-count method in which he showed that percentage utilization was a direct function of the total number of stems grazed. The work was done with western wheatgrass. The method required a count of grazed and ungrazed stems from a randomized plot or transect procedure. It is a simple method with little error resulting from personal or procedural causes. If proper grazing is attained when 80 percent of the stems have been grazed it is a simple calculation to determine whether use has been under, proper, or over. Pechanec (1936) tested this method with thickspike wheatgrass (*Agropyron dasystachyum*) at Dubois, Idaho, and found it insufficiently accurate to merit its use. The percentage utilization by the stem-count method was found to be consistently higher than when percentage utilization was based on the volume of forage removed. The difference was due largely to the fact that all the stems grazed were not completely grazed. The error was greater with light grazing than with heavy grazing.

Special Problems with Browse and Weed Species

The problems of determining the utilization of woody species are much different than with grasses because of the growth habit of browse species. Hormay (1943) in his work with bitterbrush in California found he could get percentage utilization by (1) multiplying the area of each plant crown by the average estimated ungrazed twig growth of each plant and add the results for all plants on the plot; (2) multiplying the products of each plant in step one by the estimated percentage utilization of the twig growth of each plant and add all the results for the plants on the plot; and (3) divide the sum in step two by the sum in step one and multiply by 100 to obtain the percentage utilization.

Forsling and Storm (1929) found that 23 percent of the oak forage and 15 percent of the inferior shrubs were utilized when the better browse forage was fully used. The work was done in a type composed of 86 percent browse, 12 percent weeds, and 2 percent grass in the Dixie National Forest of southwestern Utah. The growth of the plants was measured and the utilization was estimated carefully to the nearest percent. Observations of plant vigor and changes in species composition were recorded from plots. The point of proper utilization was not determined but the authors considered that 10 to 20 per cent of each year's growth should remain after grazing.

From a study on the Kaibab National Forest, Julander (1937) found that aspen deteriorated if deer browsed more than 75 percent of the current year's twig growth and that improvement was made if less than 70 percent were used. Similar figures for cliffrose were 80 and 75 percent. The growth and utilization

were determined from length measurements of tagged twigs.

The measurement of use of weedy species has been tried by height or weight estimates and measurements and by other methods. As yet little more can be said because variations in growth form, differences in the manner the plants are grazed, and their unimportance as a source of forage in many ranges have resulted in less attention being given their use. When the range is at maximum production and the important grasses are properly utilized, little attention need be given to the weedy species.

Discussion

Each of the methods or variations of procedure described may be adapted to certain range types or to use by men with different qualifications or to different requirements of accuracy and speed. From the standpoint of actual management of range land the methods based on estimation seem to have found the greatest favor. Even though the determinations may not be quite as accurate as those with the measurement methods, they are usually sufficiently accurate for efficient management. As indicated by Campbell (1937), the continued productivity or the gradual decline and death of perennial grasses may depend upon a difference in foliage removal of as little as 10 percent. The methods based upon ocular estimation will usually give results within this limit particularly if the men making the estimates are well trained and continually check their estimates with one or more of the measurement methods. The proper use of range land depends upon many factors other than the actual forage removed by livestock. Such items as too early use, erosion, trampling, watershed requirements, and recreational needs must be considered. The essentials of any method are that records of the forage use can be made, that these records, which can be compared, can be made year after year by different individuals, and that supplemental records show immediately trends toward range deterioration or improvement. When actual information on the numbers of livestock by ages and kinds and the dates they use the range are also recorded, usually enough information is available to furnish a sound basis for adjustments in livestock management.

The real problem is not the measurement of use, because many of the above methods will give accurate measurements, but the interpretation of those measurements (Campbell, 1943). For example, the percentage of the volume of thickspike wheatgrass that may be removed without damage to the plant may be set at 60 percent but immediately several questions arise. For example, if 60 percent of that plant is used, will other plants in the stand be correctly used? If not, what adjustments must be made? May the use over a 10-year period average 60 percent or must the use be no more than 60 percent in any year of the ten? Can more or less than 60 percent of the plant be used after seed-maturity or during the growing season? Will weight gains of the livestock continue until 60 percent of the plant is used or will they stop with a smaller percentage of use? What adjustments must be made in areas where watershed protection, timber production, wildlife, or recreation are important? Such problems arise because of the variety of the range resource with respect to plant composition, growth form, soil, production from year to year, topography, and many other factors.

Accuracy in research methods usually require that one or more of the measurement methods be used. All of the

methods reviewed have their shortcomings in that they may apply only to certain kinds of plants, or there is a direct controversy over the basic premise. Since percentage weight removal seems to be one of the best measures of forage use, and no direct measure of the forage eaten by livestock is available, the best possiblities for a research method seems to be in the conversions of stubble height to weight removed. The effects of exposure, soil, shading, moisture conditions, temperature, and other environmental factors upon the height-weight relationships need to be accurately established for each important grass species.

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