and examination, to use in a planned survey of soil algae in central Oklahoma. Three collecting procedures—surface, auger, and solid core—were compared and found to be similar in results. The flora was similar in composition throughout the plow layer, although usually more luxuriant near the surface. Two unplowed grassland plots in different locations and a cultivated plot adjoining one of them contained an essentially identical flora. The flora did not change in composition from late March to late May. Enrichment of soil cultures with mineral solution or organic solution speeded development but did not otherwise affect the common flora. Illumination by either white or daylight fluorescent tubes (about 50-200 candlepower) yielded the same result in growth.

References

Booth, W. E. 1941. Algae as pioneers in plant succession and their importance in erosion control. Ecology **22**: 38-46.

Feher, D. 1936. Über die Algenflora des Waldbodens. Silva **24**: 101-104.

Fletcher, J. E. and Martin, W. P. 1948. Some effects of algae and molds in the rain-crust of desert soils. Ecology **29**: 95-100.

Grintzesco, Jean. 1929. Contribution a l'etude de la microflore des sols de Roumanie. XIVeme Congr. Internat. Agric. Bucarest Actes **4**: 565-568.

Hoagland, D. R. and Arnon, D. I. 1938. The water-culture method of growing plants without soil. Univ. of Cal. Col. of Agr. Expt. Stat. Cir. **347**: 1-39.

James, E. J. 1935. An investigation of the algal growth in some naturally occurring soils. Beih. Bot. Centralbl. Abt. A. **53**(3): 519-553.

Kelting, R. W. 1951. Vegetation and soil conditions of prairie and pasture plots in central Oklahoma. Unpublished Ph.D. thesis, University of Oklahoma.

Lowe, C. W. and Moyse, A. V. 1934. An investigation of some Manitoba soils for the presence of soil algae. Trans. Roy. Soc. Canada, Sec. 5. **28**: 119-152.

Lund, J. W. G. 1945. Observations on soil algae I: The ecology, size and taxonomy of British soil diatoms. Part I. New Phytologist **44**: 196-219.

———. 1947. Observations on soil algae II: Notes on groups other than diatoms. New Phytologist **46**: 35-60.

McElroy, Celia Anne. 1953. A comparison of the soil fungi of a virgin prairie and an abandoned field. Unpublished Master's thesis, University of Oklahoma.

Mitra, A. K. 1951. The algal flora of certain Indian soils. Indian Jour. Agr. Sci. **21**: 357-373.

Moore, G. T. and Carter, Nellie. 1926. Further studies on the subterranean algal flora of the Missouri Botanical Garden. Ann. Missouri Bot. Gard. **13**: 101-140.

Peterson, J. B. 1935. Studies on the biology and taxonomy of soil algae. Dansk Botanisk Arkiv. **8**: 1-180.

Rice, E. L. and Penfound, W. T. 1954. Plant succession and yield of living plant material in a plowed prairie in Central Oklahoma. Ecology **35**: 176-180.

Smith, F. B. 1944. Occurrence and distribution of algae in soils. Proceedings of the Florida Academy of Sciences **7**: 44-49.

Tchan, Y. T. and Whitehouse, Jill A. 1953. Study of soil algae, II. The variation of algal population in sandy soils. Proc. Linn. Soc. N. S. Wales **78**(¾): 160-170.

Warcup, J. H. 1950. The soil plate method for isolation of fungi from soil. Nature **166**: 117-118.

THE MEASUREMENT AND VALUE OF PLANT HEIGHT IN THE STUDY OF HERBACEOUS VEGETATION[1]

Harold F. Heady
School of Forestry, University of California, Berkeley

During the course of studies on the structure and changes in the California annual grass type, differences in plant height appeared in various treatments and years. Accurate, objective measurements of height were needed. A search in the literature failed to reveal clearcut information on procedures of sampling for height, on how to measure heights of plants of different growth forms, and in fact, the concept of plant height itself seemed confused. This paper explores the concept of height, mentions some of the difficulties in the accurate measurement of height, discusses the usefulness of height measurements, and describes a new method whereby the point-plot system may be employed to obtain an objective sample of height of plant materials. The term "plant materials" is significant and will be explained later.

Definition

Webster defines height as "the distance to which anything rises above that on which it stands; the measure upward from a surface, as the floor or the ground, of a man or an animal." Three points are clear in the definition. There is only one height of an individual. It is maximum; therefore, "height" and "maximum height" are synonymous. The second point is that "rises above" and "meas-

[1] The data in this paper were collected as a part of Project 1501 in the California Agricultural Experiment Station.

ure upward" denote perpendicular distance. Natural position is implied. The height of a man is the distance from the floor on which he stands to the top of his head—not to the tip of his finger when his arm is extended above his head. When these concepts are applied to an individual plant the definition becomes: The height of a plant is the perpendicular distance from the soil at its base to the highest point reached with all parts in their natural position.

The terms "average height" and "maximum average height" must be used carefully. Individuals of a plant species differ in height, so average height of a species denotes a mean of single measurements taken on several plants. In this sense the word "maximum" is excess wordage and average height is the proper term. On the other hand, when several average heights are being considered, the greatest of them is maximum average height. The least of them would be the minimum average height. Together they constitute the range of means; just as maximum and minimum heights must be reserved for the tallest and shortest individuals of an array from which a single mean is calculated.

The concept of height has not always been used in the precise manner of Webster's definition in the reports of research on vegetation. First, plant heights are difficult to determine. Second, viewpoints differ as to which plants should be measured to characterize the height of vegetation. Third, the principal value of height is to symbolize such qualities as vigor, stage of growth, site classification, and range readiness. Measurements other than "maximum" height may serve these purposes as well or better than those taken according to Webster's definition.

Difficulties in Measuring Height

Many factors impede the measurement of height in the precise manner specified by Webster's definition. The highest point may be difficult to find when plants are trailing or drooping, when the top is the tip of an awn, and when several parts are nearly the same height. If the highest part is not perpendicular from the base of the plant, an offset measurement is needed. In that case, configuration and slope of the ground surface hinder the taking of an accurate measurement. The base level must be defined arbitrarily for pedestaled plants. Wind and temporary wilting change the position of plants and they may be weighted down with a load of rainwater, dew or snow. Lastly, individual plants in such life-forms as rhizomatous grasses and rosettes are often inseparable from a patch of many plants. What appears to be a single bunchgrass may actually be several plants.

Perhaps these difficulties are indicated by the fact that seldom have procedures of measuring height been described in publication. For example, the statement, "Average height of leaf growth was measured to the nearest 0.5 cm.," does not tell whether the leaves were measured in natural position or straightened to their full length. Does the average, calculated to the nearest 0.5 cm., indicate that the actual measurements were taken to 0.5 cm.? How many measurements were taken to compute the average? In another case, the statement, "Height measurements were taken"; and the table heading, "Height of . . . ," do not tell whether leaves or stems were measured; yet separate grass plants, some with culms and some without, were shown in a photograph. Neither do these statements tell how many measurements were made and whether the data in the table are averages or single measurements. If heights are important enough to present in publication, the procedure for obtaining them should be described.

Concepts of Height

Most people have a general idea of the height of familiar things. That concept is close to Webster's definition when it is applied to individuals. When the items are in groups, as expressed by the words lawn, forest, and vegetation, the concept of group height varies widely.

Seventeen people including research workers, secretaries, students, and a janitor were shown Figure 1 and asked: What is the height of this example of vegetation? Their answers varied from 5 to 12 inches, and were based on various interpretations of the question. One used Webster's definition to express the height of vegetation as the height of its highest part, 12 inches. All the others reasoned that since vegetation is composed of individuals the height of vegetation should be an average. But here their viewpoints differed widely as to what should be included in the average.

The mean height of the dominant plants was considered by some, and their estimates averaged 10.3 inches. The average height of the 4 tallest plants in Figure 1 is 10.6 inches. This viewpoint may be the basis for the statement found in several papers to the effect that "Average heights of leaves and seedstalks were determined by measuring the 5 tallest in each plot." Others who examined Figure 1 included the dominants and subdominants in their estimates and one person mentioned the height of all plants.

The lowest figure given, 5 inches, was more with

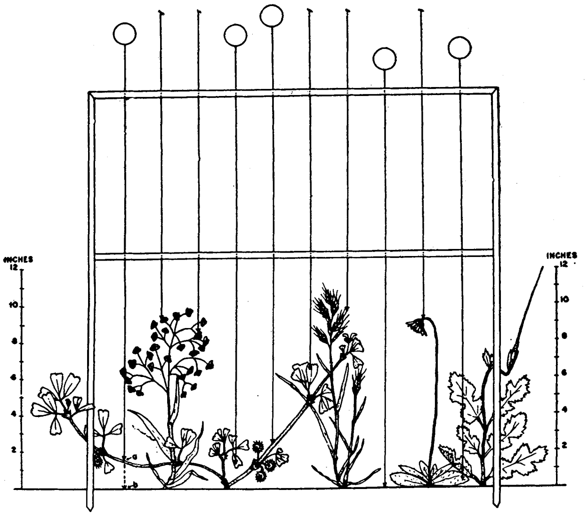

FIG. 1. This frame with 10 pins illustrates diagrammatically the point-plot method of sampling vegetation in the Califorina annual type. Data from the example are given in Table I and an explanation is in the text. Plants illustrated from left to right at the soil surface are *Briza minor, Medicago hispida, Bromus mollis, Hypochoeris glabra,* and *Erodium botrys.* The scale along each side gives the reader an opportunity to compare his own estimate of height with those mentioned.

regard to the thickness or volume of plant material than to the actual height of individuals. In field application, it is the height of that point where one can see horizontally through the vegetation for a reasonable but unstated distance. Put another way, it is the average height of a large proportion of all the plant parts.

A related concept mentioned by some people in the discussion of Figure 1 was concerned with the length of stems and leaves. None confused this idea with height, but there is room for confusion of length and height in statements like: "The heights of grass leaves were measured after they were raised to their maximum length." Length measurements of plants seem more likely to be referred to as height than vice versa. Length of some plants is undoubtedly easier to determine accurately than height, and for purposes of measuring rate of growth and vigor length may be the best measure. However, if length is measured, it should not be called height even if it was measured as a perpendicular distance from the ground.

The varied interpretations resulted because the observers unconsciously gave different answers to three questions: What is the usefulness of height measurement? What constitutes the vegetation? How should height be measured? The different answers were indicative of the diverse training, interests, and approach among the group. To standardize the answer to any one of the questions is undesirable because that would tend to stereotype answers to the others. This is based on the premise that each objective has a best-method and each method is best suited to one or more objectives. There is little justification for saying that one method is better than another; except when stipulations of objectives and population are also given.

Each of us builds on what others do; part of our research job is to make that building as feasible as possible for the next person. Rather than standardize methodology, a better approach is to answer completely the three questions whenever experimental results are presented. These answers would be along the lines of: (1) clearcut statements of objectives, (2) definition of the population being considered, and (3) accurate descriptions of the methods employed. If this were done, few questions would arise as to the nature of the data.

METHODS OF MEASURING HEIGHT

Height measurements have been taken in three different ways, although not without variation in the procedures with respect to type of equipment and accuracy of determination. Fortunately only one kind of measuring unit is employed—distance.

Frequently ocular estimates of height are made. They are difficult to define because the observer often tries to average in his "mind's-eye" the heights of several plants of a species or even of a plant community. Sometimes intentionally, he omits the exceptionally tall or short individuals from the estimate. The results may be sufficiently accurate for the purpose intended, especially if the observer is experienced and has trained himself with actual measurements. The procedures followed need to be accurately described so that another person may duplicate the study and make accurate comparison between his work and that already pubilshed. Ocular estimates are difficult to duplicate in the exact manner of another person.

A second procedure is to place a ruler alongside the plant to be measured and to read the height of the plant in its natural position. The factors that cause inaccuracies have been mentioned.

The third procedure is to straighten the plant to its fullest length and to measure that length with a ruler alongside. This measure eliminates the idea of natural position and should be described as length even though it may be height in some cases.

USEFULNESS OF HEIGHT MEASUREMENTS

Height of plants has been used by many investigators with numerous objectives in their studies. Nearly all have used height as a basis for interpretation of characteristics such as growth, vigor, competition, etc. A few have given height data for its descriptive value and without reference to comparisons of treatments and conditions.

Growth: The rate of growth and the annual cycle of growth is well illustrated by McCarty, 1938; and McCarty and Price, 1942, who measured height at 5-day intervals and used the data to plot the annual growth cycle and to describe the relationship between growth and the chemical composition of plants. The differences in growth of plants in response to differences in weather have been shown by Sampson, 1918; Hanson, et al., 1931; Nelson, 1934; Lister and Schumacher, 1937; Tisdale, 1947; and Arnold, 1955. Growth of plants in pots of several kinds of soil was given on a basis of height by Joy, et al., 1954.

Vigor: Many studies where height has been used have attempted an estimation of vigor in one way or another. These usually are concerned with the relative response of plants to different experimental treatments. The treatments may be reseeded species under grazed and ungrazed conditions (Hull, 1944); pastures grazed by different systems of management (Hanson, et al., 1931 and Sarvis, 1923); burned and unburned conditions (Hervey, 1949); various frequencies and intensities of clipping forage plants (Sampson and Malmsten, 1926; Holscher, 1945; Whitman and Helgeson, 1946; and Weaver and Darland, 1947).

Competition: Height of plants was used as one of several criteria to determine the degree of competition between 17 seeded species and *Artemisia tridentata* (Robertson, 1947).

Adaptability: Comparisons of height attained by different species on the same habitat and within one species on different sites has been used widely in the study of adaptability of forage species to new areas (Hull, 1954; and Potter, 1955).

Resistance to grazing: Branson (1953) presented data which showed that the height to which growing points in grasses was elevated above the ground was related to resistance to grazing. Much of the work listed under vigor also has application in studying the differential response of species to grazing.

Range readiness: Height of important forage plants is the best indicator of the time when ranges are ready for grazing (Costello and Price, 1939; and Craddock and Forsling, 1938). Studies of the effects of various frequencies and intensities of clipping forage plants have practical application in the determination of the date of range readiness.

Forage utilization: This subject has received considerable attention and several methods are available for measuring degree of forage use by livestock. Comparisons of height between grazed and ungrazed plants is an important feature in most of these methods (Heady, 1949).

Range condition and trend: For several years height of plants has been used in the evaluation of trend of range condition. Short-run changes due to yearly differences in weather are indicated by heights of leaves and stems. Parker (1953) has given a procedure whereby height changes due to grazing treatment may be separated from those due to weather. These are indicative of short-time trends in range condition and even though a large amount of personal judgment is required the concept is a useful one.

Site classification: In forest management a timber site may be defined by the timber growing capacity. Growth is indicated by height for age of the dominant trees and this is the primary basis for timber site classes (Dunning, 1942). Tree height is measured by means of an Abney level and tape.

Yield: Often there is a close correlation of the height of plants and the dry weight or bulk. Klages (1942) found the correlation coefficient to be greater than 0.9 on numerous occasions. This allows successive approximations of weight of the same plant.

The concept of height is embodied in several terms in plant ecology although actual data for height of plants or plant communities is seldom given. A few of them are dominants and subdominants, layer societies, life-forms, and seasonal aspects. Actual data on height would add to the descriptive value of these and other terms.

The Point-plot Method of Determining Height

The point system was found to be an accurate and objective procedure for determining percentage botanical composition in the California annual-type. Briefly, the method of determining height was simply to ascertain the height of the first hit above the soil surface. This distance was measured along the pin. When the point first touched a plant (point a in Figure 1) as it was gently pushed through the vegetation, the location on the pin where it was protruding from the upper cross piece of the frame (point A) was held by the thumbnail. After the point had touched soil (point b) the distance A-B, between thumbnail and frame, was measured with a steel tape. This distance was equal to the distance between the hit and the soil surface, a-b.

The data constitute a sample of the heights of every bit of plant material the size of the pin point. The pins are maintained at needle sharpness so the heights for all practical purposes are of infinitely small spots on the plants. The spots vary in location from 0.1 inch above the ground, the minimum recorded, to the very top of some plants. For want of a better term, the data are referred to as "heights of plant material."

The data are indicative of the height of mass within an individual plant or a species. Likewise, the concept may be applied to the whole vegetation by summarizing without regard to species. The method furnishes data for determining the relative vertical position of species in a stand. In short, it gives a vertical dimension to the concept of foliage cover.

There are several advantages to the method. It is objective in that the observer exercises little choice in what is measured and how. The sample may be random or systematic according to the desires of the investigator. Many readings can be made cheaply and easily. The sampling for height can be done in conjunction with the sampling for other types of information obtained from the points. For example, the same set of pins may be used to determine foliage cover, cover repetition, percentage botanical composition, mulch cover on the soil, and height. Sampling can be done by one man although two will relieve the tediousness of the job. In terms of output, two men, each working separately, will gather more data than two men working together.

For purposes of illustration; the set of 10 pins in Figure 1 is summarized in Table I. The foliage cover is 90 percent. *Medicago hispida* contributed most to the percentage botanical composition and at the same time was lower in height of materials than the other species. The two grasses were tallest but low in composition. The average height of plant material in the whole vegetation was 5.2 inches. The fifth species, *Erodium botrys* would undoubtedly have been included if the sample had been larger.

Data previously published indicate that height of plant materials and forage production in the California annual type were closely correlated with amount and position of mulch (Heady, 1956). Heights were taken with the point-plot method.

Many individuals, tall and short, of many species compose vegetation in the California annual type. These data (Table I) illustrate a procedure whereby a relative measure of their height may be obtained. If height in this sense is usful for individual species it can also be an important characteristic of the whole vegetation. The remainder of this paper is given to three examples of the use of this method in field scale studies.

TABLE I. Percentage botanical composition and average height of plant materials in inches for the example shown in Figure 1

Species	Number of hits	Composition in percent	Avg. Height in inches
Briza minor	2	22.2	8.9
Bromus mollis	1	11.1	7.7
Hypochoeris glabra	2	22.2	4.9
Medicago hispida	4	44.5	3.0
For all vegetation	9	100.0	5.2

The work was done in the annual-type vegetation on the Hopland Field Station in Mendocino County, California. The natural vegetation is seldom more than knee high and many plants of many species are present. There may be as many as a dozen mature plants per square inch with several species represented. Most of the leaves are small but there are infinite numbers of them. The method of measuring height described has not been attempted on other vegetational types but it should be effective wherever the point system is practical.

Comparisons Between Areas

Several experimental pastures about 40 acres in size have been established on the Hopland Field Station to test grazing practices. The initial inventory which in part consisted of sampling for percentage botanical composition and height of plants showed all the pastures to be similar. Data from two pastures are given in Table II.

TABLE II. Average height of plant materials in inches and percentage botanical composition on two similar pastures as determined by the point system

	PASTURE 1		PASTURE 2	
	Average ht., inches	Composition in percent	Average ht., inches	Composition in percent
Bromus rigidus	5.3	6.5	6.0	6.4
Aira caryophyllea	4.8	26.7	4.6	20.9
Daucus pusillus	4.8	7.9	4.3	3.0
Bromus mollis	4.7	22.5	5.0	21.8
Erodium botrys	3.3	15.0	3.1	16.2
Trifolium microdon	3.0	2.4	4.0	5.1
Trifolium microcephalum	2.6	5.6	2.5	2.5
Festuca dertonensis	2.4	2.4	3.4	8.5
All others	3.9	11.0	4.4	15.6
Average heights	4.3	....	4.3	....

Variation occurred between pastures but it was not significant for the major species either with respect to composition or height. The average height of vegetation was essentially the same in all the pastures. In addition, the percent of ground surface covered by plants was 44.2 in Pasture 1 and 48.7 in Pasture 2. Not only do these data characterize the degree of similarity of the pastures but they will serve as the reference points to evaluate vegetational changes as the grazing trial develops.

In addition to the use of height to assess differences in areas at one time and over time mentioned previously, the height relationship among species within a study area is obtained. Within the two pastures (Table II), *Bromus rigidus* is the tallest species, except for *Avena barbata* which is included in the group "all others." These two species give the vegetation a characteristic appearance because their height makes them the most conspicuous. In terms of botanical composition, *Aira caryophyllea, Bromus mollis,* and *Erodium botrys* were clearly the most important. The question of which group is dominant is an interpretative point of little importance when the species are described by both measurements.

The fact that some species are tall, some short and others intermediate is perfectly obvious. The use of layer societies to describe the situation is a common practice. However, a glance at the average heights by species (Table II) indicates that definite layers do not exist in this example of the California annual type. Rather, there is a continuous range of heights within one area at a given time. The range of plant heights in the California annual type changes each year (Table III) and during the growing season (Table IV). This vegetation, then, lacks clear-cut vertical layers.

TABLE III. Average height of plant materials in inches for annual plants at the same location and dates in three years

	May 1 1953	April 29 1954	April 29 1955
Bromus rigidus	4.2	9.3	2.2
Bromus mollis	5.5	7.2	2.5
Erodium botrys	2.8	5.1	1.5
Erodium cicutarium	3.4	3.9	1.7
Briza minor	2.2	7.5	1.3
Trifolium microcephalum	2.1	5.9	0.4
Trifolium ciliolatum	1.1	3.6	1.8
All others	3.3	5.3	2.1
Average	4.2	6.5	2.0

Comparisons Between Years

The heights of plants by species was measured near the end of the growing season in the same area for three years (Table III). The differences in height due to differences in weather conditions are brought out. All the plants grew very well in 1954 when there was an even distribution of rainfall in late spring. *Bromus mollis* and *Bromus rigidus* contributed approximately 60 percent of the composition. In 1955 there was a prolonged early spring drought and total plant growth was less than in 1954. *Erodium botrys,* a low growing species, was more abundant and the grasses less abundant than in the previous year and, hence, the low average height of vegetation in 1955. The data for height by species and average height for the whole vegetation give an additional measure of the vegetation that is helpful in describing yearly changes in vegetation.

Comparisons Between Types, Seasons, and Grazing Treatments

Table IV is presented to illustrate the usefulness of height in the description of different vegetational types, of seasonal changes, and of utilization of forage by livestock. The data were obtained by sampling a pasture of approximately 200 acres in size which was grazed by sheep from March 1 to May 10, 1955. A total of 1890 points was taken on March 8, on June 7-8 in areas protected from grazing, and on June 7-8 in grazed areas. The grassland type had no trees and the open woodland had a scattered stand of oaks with an understory similar to the grassland type.

TABLE IV. Average height of plant materials in inches of annual plants in a grassland and open woodland for March 8, ungrazed, and June 7-8, grazed and ungrazed, 1955

	GRASSLAND			OPEN WOODLAND		
	March 8, 1955	June 7-8, 1955		March 8, 1955	June 7-8, 1955	
		Ungrazed	Grazed		Ungrazed	Grazed
Avena barbata	1.5	12.1	6.5	1.3	6.1	5.5
Bromus rigidus	1.2	9.4	4.6	1.3	6.9	3.6
Bromus mollis	1.2	5.6	3.1	1.2	3.8	2.9
Aira caryophyllea	0.8	5.0	2.8	0.8	4.6	2.9
Daucus pusillus	1.1	4.7	3.5	1.1	4.2	2.8
Erodium botrys	0.7	4.5	2.4	0.7	4.6	2.3
Trifolium microcephalum	1.0	3.0	1.7	...	2.2	2.2
Trifolium ciliolatum	1.0	2.0	3.2	1.4	1.9	2.2
All others	1.1	3.5	2.5	0.9	3.3	2.8
Average	1.0	4.2	2.8	1.0	3.9	2.8

The average height of plant materials was essentially the same in both vegetational types throughout the growing season and only minor differences occurred in the botanical composition. The grasses were slightly more in percentage composition in the grassland. Exceptions were *Stipa lepida* and *Cynosurus echinatus,* which were restricted to partially shaded areas. Several broad-leaved plants were more common in the shade than in the open. There were very few species that did not occur in both types.

The heights of individual species varied considerably between types. *Avena barbata,* for example, was about twice as tall in the open and *Bromus mollis* about a third taller than in the shade. *Erodium botrys* was the same height in the two types. Others such as *Navarretia, Filago, Hordeum* and *Sanicula* were taller where partially shaded.

Foliar density was approximately 55 percent in both types. The herbaceous cover in the two types was very similar. There were slight differences in percentage botanical composition and some species were different in average height between the two types.

Seed germination of most species occurs immediately following the first fall rains. Growth is slow during the winter but the species grow in height at different rates. On March 15 the 4 grasses in Table IV had attained 12 to 24 percent of their height in the grassland and 17 to 31 percent where there was a partial canopy from trees. Other species showed a similar trend of attaining a larger proportion of their growth at a given time in partial shade than in the open. The actual height of plants in the two types was low and nearly the same in March. Greater differences among the species developed as the fruiting stalks elongated in late spring.

Grazing by animals reduces the height of vegetation. In 1955 the heights of plants both inside and outside small cages were measured. The reduction in height due to the activities of animals was 33.4 percent in the grassland and 28.2 percent in the open woodland. Utilization by weight for the two types was 42.3 and 37.4 respectively. In terms of the whole pasture there was a difference of five percent in the measurement of utilization by the height method and by the weight method. Tests in previous years and at other locations showed that both procedures indicate the trends in utilization but that large differences in the actual values are likely to occur.

Summary

1. The meaning of such terms as "height," "average height" and "maximum average height" is given in relation to a proposed definition of plant height: The height of a plant is the perpendicular distance from the soil at its base to the highest point reached with all parts in their natural position.

2. Different concepts of plant height and difficulties in measurement are suggested as the reasons why procedures for measuring height are seldom given in publications.

3. Stipulation of a best method to measure height can only be done after the experimental objectives and definition of the population have been provided. Clear statements of objectives, experimental material and methodology facilitate the gathering of comparable data as well as reduce questions which arise as to the nature of the data.

4. Methods of measuring height and the usefulness of height measurements are reviewed.

5. A method of measuring height of plant materials with the point-plot method is described. The data characterize the height of mass for species individually and for vegetation and provide a measure of the vertical position of a species in a stand. The point-plot method is used to determine foliage cover and the additional measurement of height with the same pins gives a vertical dimension to that cover.

6. The advantages of the point-plot method in determining height include objectiveness, ease in operation, and the addition of another measurement to those normally collected with the point system.

7. Examples of field data are given to illustrate how the method may be used to compare species and vegetation between areas, years, seasons, vegetational types, and grazing treatments.

8. Even though field application has not been attempted outside the California annual type, the method should be useful wherever the point system is applicable.

9. There is a continuous range of heights of plant materials for the many species in the California annual type rather than clear-cut layers of vegetation.

10. Height of plant materials has intrinsic value in the description of vegetation when sampled by the point-plot method.

References

Arnold, J. F. 1955. Plant life-form classification and its use in evaluating range conditions and trend. Jour. Range Management **8**: 176-181.

Branson, F. A. 1953. Two new factors affecting resistance of grasses to grazing. Jour. Range Management **6**: 165-171.

Costello, D. F. and R. Price. 1939. Weather and plant-development data as determinants of grazing periods on mountain range. U. S. Dept. Agr. Tech. Bull. **686.** 30 pp.

Craddock, G. W. and C. I. Forsling. 1938. The influence of climate and grazing on spring-fall sheep range in Southern Idaho. U. S. Dept. Agr. Tech. Bull. **600.** 42 pp.

Dunning, D. 1942. A site classification for the mixed conifer selection forests of the Sierra Nevada. Calif. Forest and Range Expt. Sta. Res. Note **28.**

Hanson, H. C., L. D. Love and M. S. Morris. 1931. Effects of different systems of grazing by cattle upon a western wheatgrass type of range. Colo. Agr. Expt. Sta. Bull. **377.** 82 pp.

Heady, H. F. 1949. Methods of determining utilization of range forage. Jour. Range Management **2**: 53-63.

———. 1956. Changes in a California annual plant community induced by manipulation of natural mulch. Ecology **37**: 798-812.

Hervey, D. F. 1949. Reaction of a California annual-plant community to fire. Jour. Range Management **2**: 116-121.

Holscher, C. E. 1945. The effects of clipping bluestem wheatgrass and blue grama at different heights and frequencies. Ecology **26**: 148-156.

Hull, A. C., Jr. 1944. The relation of grazing to establishment and vigor of crested wheatgrass. Jour. Am. Soc. Agron. **36**: 358-360.

———. 1954. Rating seeded stands on experimental range plots. Jour. Range Management **7**: 122-124.

Joy, C. R., et al. 1954. A comparison of grass growth on different horizons of three grassland soils. Jour. Range Management **7**: 212-214.

Klages, K. H. W. 1942. Ecological crop geography. The Macmillan Co. 615 pp.

Lister, P. B. and F. X. Schumacher. 1937. The influence of rainfall upon tuft area and height growth of three semi-desert range grasses in southern Arizona. Jour. Agr. Res. **54**: 109-121.

McCarty, E. C. 1938. The relation of growth to the varying carbohydrate content in mountain brome. U. S. Dept. Agr. Tech. Bull. **598**. 24 pp.

——— **and R. Price.** 1942. Growth and carbohydrate content of important mountain forage plants in central Utah as affected by clipping and grazing. U. S. Dept. Agr. Tech. Bull. **818**. 51 pp.

Nelson, E. W. 1934. The influence of precipitation and grazing upon black grama grass range. U. S. Dept. Agr. Tech. Bull. **409**. 32 pp.

Parker, K. W. 1953. Instructions for measurement and observation of vigor, composition and browse. U. S. Forest Service. 9 pp. (Mimeo.)

Potter, L. D. 1953. Seedling growth and soil drought resistance of Northern Great Plains legumes, alfalfa and four grasses. Jour. Range Management **6**: 399-404.

Robertson, J. H. 1947. Responses of range grasses to different intensities of competition with sagebrush (*Artemisia tridentata* Nutt.). Ecology **28**: 1-16.

Sampson, A. W. 1918. Climate and plant growth in certain vegetative associations. U. S. Dept. Agr. Bull. **700**. 72 pp.

——— **and H. E. Malmsten.** 1926. Grazing periods and forage production on the national forests. U. S. Dept. Agr. Bull. **1405**. 54 pp.

Sarvis, J. T. 1923. Effects of different systems and intensities of grazing upon the native vegetation at the Northern Great Plains Field Station. U. S. Dept. Agr. Dept. Bull. **1170**. 46 pp.

Tisdale, E. W. 1947. The grasslands of the southern interior of British Columbia. Ecology **28**: 346-382.

Weaver, J. E. and R. W. Darland. 1947. A method of measuring vigor in range grasses. Ecology **28**: 146-162.

Whitman, W. C. and E. A. Helgeson. 1946. Range vegetation studies. N. Dak Agr. Expt. Sta. Bull. 340. 43 pp.

INFLUENCE OF TEMPERATURE UPON SOIL MOISTURE CONSTANTS AND ITS POSSIBLE ECOLOGIC SIGNIFICANCE

R. DAUBENMIRE
The State College of Washington

The fact has been well established that on the basal plains surrounding the Rocky Mountains, soil drouth penetrates deeply and persists for several months each summer. With increasing elevation this aspect of drouth becomes progressively less intense, until at elevations corresponding with forests of *Picea engelmanni* and *Abies lasiocarpa*, if not before, it is far less critical as a factor determining seedling survival (Daubenmire 1943). The soil moisture gradient has been explained as the net effect of (1) an increase of precipitation with altitude, (2) decreasing intensity of factors promoting plant use of soil moisture (Sampson 1918; Whitfield, 1932), and (3) a shortening of summer.

The first of the above factors has limited significance on the westerly slope of the northern Rockies for the fact that summers are essentially rainless at all altitudes, the vertical increase in annual precipitation being primarily a result of high snowfall which comes at a time when the environmental water-balance is not critical. It is significant to note that this places no handicap on the vegetation, for the soils of subalpine regions support communities fully as mesophytic as in any other part of the Rockies even where rainfall is relatively heavy in summer. This circumstance tends to shift the explanation of continued high moisture levels to factors 2 and 3. During one summer when the moisture content of high-altitude soils was being sampled at regular intervals, it occurred to the writer that still another factor might add its weight to those mentioned, and a test of this hypothesis resulted in the studies reported below.

It was noticed that in late spring soils not much above freezing were patently moist when removed from a pit with a trowel, but after the soils were transported down to the warm regions of the basal plain and weighed in a laboratory the metal

References

Changes in a California Annual Plant Community Induced By Manipulation of Natural Mulch
Harold F. Heady
Ecology, Vol. 37, No. 4. (Oct., 1956), pp. 798-812.
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28195610%2937%3A4%3C798%3ACIACAP%3E2.0.CO%3B2-P

Responses of Range Grasses to Different Intensities of Competition with Sagebrush (Artemisia Tridentata Nutt.)
Joseph H. Robertson
Ecology, Vol. 28, No. 1. (Jan., 1947), pp. 1-16.
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28194701%2928%3A1%3C1%3ARORGTD%3E2.0.CO%3B2-M

The Grasslands of the Southern Interior of British Columbia
E. W. Tisdale
Ecology, Vol. 28, No. 4. (Oct., 1947), pp. 346-382.
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28194710%2928%3A4%3C346%3ATGOTSI%3E2.0.CO%3B2-A

A Method of Measuring Vigor of Range Grasses
J. E. Weaver; R. W. Darland
Ecology, Vol. 28, No. 2. (Apr., 1947), pp. 146-162.
Stable URL:
http://links.jstor.org/sici?sici=0012-9658%28194704%2928%3A2%3C146%3AAMOMVO%3E2.0.CO%3B2-4