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A survey of the literature on methods of making forage inventories was made by the writer. The methods were studied and grouped into ecological research, large-scale inventory, and utilization determination methods. This paper brings together, for the first time, under one heading, the methods used in studying and inventorying range forage.

Under ecological research methods are included nine methods of studying the structure and composition of vegetation and the effect of environmental factors upon it. Methods of studying vegetation are many, varying according to the demands of the individual making the study and the requirements of the study being made.

Large-scale methods are used primarily to determine the grazing capacity of range lands. Six methods of inventorying forage on an extensive scale are discussed. In all cases the inventory is carried on by estimating rather than measuring the amount, kind, and location of forage. The first attempt at estimating grazing capacity by a systematic inventory was made in Arizona in 1911. The reconnaissance method was used. Since that time the method has undergone considerable change. However, some of the basic principles established at that time are still in use today, notwithstanding the method employed.

Utilization determination methods are used as a follow-up check on the grazing capacity figures arrived at by large scale methods. Nine methods of determining the amount of forage taken by livestock are discussed in this paper.

It is apparent from the findings of this paper that range forage inventories must be made on an extensive scale which accordingly necessitates the use of estimation; actual measurement being practically impossible.

There is evidence of strong movement developing to express productivity of a forage-producing range unit in terms of volume of forage produced instead of by "forage acres". Standing, Pickford, and Pechanec have pioneered in this viewpoint, substantiating their beliefs with research data and experience.

The efficiency and effectiveness of inventorying vegetative cover for any purpose whatsoever depends largely upon the use of standardized methods which will undergo statistical analysis.

A
SURVEY AND ANALYSIS
OF THE
RANGE FORAGE INVENTORY METHODS

by

JOHN CHOHLIS

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INTRODUCTION

The definition of a forage inventory is a method of systematically observing and recording data on vegetative cover and the environmental factors affecting it for the purpose of determining the maximum number of grazing animals the vegetation is capable of supporting on a sustained yield basis.

The range livestock industry, operating as it does over 728 million acres of land, is an immense business. These 728 million acres, 99 per cent of which are available to livestock, constitute 40 per cent of the total land area of the continental United States.

The vegetation growing on this vast acreage of land produces forage for livestock. As a consequence, forage may well be considered as the "backbone" of this immense industry. Were there no vegetation growing on the land there would likewise be no livestock industry.

Every major industry finds that its final product is affected to a great degree by the quantity, quality, and availability of the raw material from which is manufactured the final product. The livestock produced on an area of land is markedly affected by the quantity, quality, and availability of the forage produced on the land.

Every major industry must take stock of its raw material. Inventories are made listing the amount, kind, and location of their raw materials. Some ranching units operated by adjusting their livestock numbers in a very general way to the amount of raw material their lands were capable of producing. Vegetation and the accompanying forage which is produced on the land is governed in a large measure by the climatic conditions obtaining on the area, and climate is unstable; any fluctuation of the climate is evidenced by a consequent fluctuation of the forage yield on the area.

In order that the livestock industry operate on a true business basis and in order to stabilize the industry, it is of vital importance that inventories of forage resources be made. A forage inventory is performed for the purpose of obtaining data as to the number of grazing animals an area of range land is capable of supporting. It serves also as a guide for future inventories and reports, and it furnishes a measure by which the progress in experimental work can be measured. The results obtained on an efficient forage inventory could be considered the hub around which revolve the operations and policies of a range livestock business. It is the basis upon which the plan of range land management is formulated.

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OBJECT

An attempt has been made to bring together, in one paper, as much material as possible pertaining to the methods of making forage inventories on range land. The methods in actual detail are many and in this paper they are grouped under general headings. If any important detailed variation occurs in any method it is discussed in the body of the paper.

In addition to presenting a summation of the literature on the subject, it was deemed advisable to go into some detail regarding the various methods. This paper can then be used as a future supplementary source of information for the course in Range Survey Methods given at Oregon State College.

SCOPE

In the survey of the literature a great amount of tabular and statistical information was encountered. This was a direct result of investigators putting methods to actual field tests for the purpose of determining their worth under varying field conditions. It is not within the scope of this paper to present this information as such, but whenever pertinent conclusions could be made from statistical data offered they were included under the proper heading.

Although the management plan forms an integral part of a forage inventory, since the data are gathered for the purpose of formulating a plan of management consistent with the sustained yield of forage on an area, it was thought that this phase of the subject merited a special study in itself. It is not discussed in any detail in this paper.

INVENTORY METHODS

Forage inventory methods may be subdivided into two main groups: (1) Those designed to study the effect of environmental factors upon the structure and composition of the vegetation or, ecological research methods; and (2) those designed to obtain grazing capacity figures. Of a necessity these methods are used to inventory large areas of vegetation and will be grouped under the heading of large-scale inventory methods.

ECOLOGICAL RESEARCH METHODS

Structure and development of vegetation and the effect of environmental factors should be studied as thoroughly and carefully as are individual species. Vegetation readily responds to changes in the environment. If the habitat becomes wetter or drier, better or more poorly lighted, etc., certain species and perhaps whole groups of plants show radical change in their composition. Changes in vegetation occur also when it is repeatedly grazed, burned, or cut, as in lumbering. In response to the stimuli of a modified environment, the entire composition and structure of the vegetation may change.

In order to properly manage the forage resources so vital to the range livestock industry, it is imperative to know whether or not the most valuable forage species are able to reproduce and retain their position under the degree of grazing imposed upon them or whether they are being replaced by less valuable species. To be sure, this may be partially determined by superficial examination but usually not until the range has been depleted to such an extent that there is a decline in the amount, quality, and availability of forage.(30)

In reseeding overgrazed range or pasture land, it is important to know exactly how the herbaceous vegetation is developing or to determine the cause of its failure. Therefore, exact methods of tracing these developments must be used. The rate of increase or decrease in the number of poisonous plants on a range or the rapidity of distribution of introduced weeds in a pasture can be accurately determined only by careful study.

As was brought out beforehand, these methods are designed for the purpose of studying the effect of environmental factors upon the structure and composition of the vegetation. The methods are intensive in that they are usually used on a relatively small area, their operation being too time-consuming and laborious to permit their use over extensive areas.

They may be considered as forage inventory methods in that they indicate changes in the character of the vegetation from season to season or year to year. It must be understood that a plant community is a dynamic unit and in order to better understand changes that take place and the cause of these changes it is advisable to enter into considerable detail in studying the community and the individuals. Study areas are representative of the unit as a whole and are selected deliberately and carefully.

Point Method

The point method of pasture analysis described by Levy (22) makes possible the recognition of pasture association types. The fundamental principle upon which the method is based is the mathematical concept of the homogeneity of a unit area as represented by a pin point. The method consists in recording all vegetation hit by the needle point as the point is projected from above. If a sufficient number of pin points are taken, an elaborate picture may be obtained of a pasture.

The apparatus used is a frame, mounted on pointed legs to facilitate insertion into the soil, with a row of steel pins 2 inches apart held so that they slide up and down in a set course.

RESULTS OBTAINABLE.

1. Percentage ground covered by each species: Obtained by recording in each downward projection all species and expressing these in terms of percentage for every 100 points

examined.

2. Percentage cover each species is contributing to the total area: Obtained by use of the following formula:

Number of times species hit per 100 points examined multiplied by (100 - percentage of bare ground)

3. Relative frequency of each species in pasture sward: Obtained by examining vegetation story by story and recording every hit as the needle descends, irrespective of species.

4. Percentage each species is contributing to the pasture: Obtained by computing the percentage composition of the pasture based on the number of hits of each species in relation to the total number of hits of vegetation.

Levy (22) states that the point method can be used as a basis of an inquiry into the economics of the seed mixtures sown. It must be performed, however, in regard to soil type, strains of species sown, season, etc. The following conditions can be studied by the use of the point method:

1. The change in pasture condition may be accurately followed and mapped.

2. The effect of management and forage utilization upon ecological vegetative changes may be followed.

3. The soundness or otherwise of an experimental technique and results may be obtained.

Quadrat Method

THE QUADRAT. The quadrat, as the name indicates, is a square area of varying size marked off for the purpose of detailed study. It is one of the many unit areas which jointly constitute the whole. Just as a knowledge of plant structure may be gained by examining in detail representative portions of the plant, so too, by study of numerous quadrats a knowledge of the structure of vegetation may be obtained. Although a quadrat includes only a small area of vegetation, it reveals the exact structure of this small part. It is impossible, and in fact unnecessary, to study the whole area of vegetation with the same thoroughness. A number of quadrats, located with care in places that appear different upon observation, will reveal the entire range of structure. The quadrat like any other method must be used with discrimination.(48)

KINDS OF QUADRATS. Quadrats vary in both size and use. The size varies from a square meter, which is used in grassland or most other herbaceous vegetation, to a square decimeter in studying soil-forming lichens. A square inch area marked off separately is convenient in studying the development of seedlings.

Quadrats are also subdivided with respect to their use. They may be either permanent or temporary. The permanent or the temporary quadrats may be used under any quadrating method, depending on the need of the study. A denuded quadrat is a permanent one from which the vegetation has been removed in order that the manner in which the plants reenter may be followed. Frequently, the denudation is only partial, certain species only being removed or the above ground parts of all species at various intervals, by grazing, clipping, etc.

The purpose of the quadrat and the nature of the vegetation are major factors in determining the method to employ. If the purpose of the quadrat is to determine the proportion of different species constituting the vegetation, the temporary quadrats may be established. If the purpose of the quadrat is to determine changes in the vegetation from year to year, various kinds of permanent quadrats may be used.

MARKING OUT QUADRATS. Cloth or steel tapes or strips of hardwood or strap iron slightly more than a meter in length and a centimeter wide are used in marking out quadrats. These are furnished with small holes or eyelets a decimeter apart and the ten intervals between the holes are numbered from left to right. Care is taken to make the quadrat square.

METHODS OF QUADRATING. The methods of quadrating are subdivided according to the method used in securing the data and the character of the data secured. Quadrats are located in most cases on areas that represent the average of the conditions to be studied and which will produce results that have an important bearing upon the problem in hand. They may, however, be randomized and replicated depending upon the nature of the problem and the method used.

Charting Method. The charting method of quadrating may be considered as a graphic census of the vegetation. Two methods are used in charting quadrats both of which are satisfactory in regard to accuracy. The main difference between them lies in the speed with which they are performed.

(Pantograph Chart Method). The pantograph chart method described by Hill (14) requires the use of a pantograph which consists of a low stand, and set of pantograph arms, set in such a manner that the clumps of vegetation are traced on a quadrat sheet reduced to one fifth. This method requires two operators but only one need be acquainted with the vegetation.

(Strap Chart Method). The strap method of charting is performed by dividing the quadrats into decimeter strips by means of straps and subdividing the strips into decimeter squares. The vegetation is then sketched on the quadrat sheet reduced to one fifth.(10)

Hanson (10) is of the opinion that the pantograph chart method of quadrating is equal, or superior, to the strap method in accuracy. This statement, however, is disputible because there is much mechanical error involved in the operation of the pantograph.

Common rules observed in mapping quadrats are as follows:(23)

1. The area drawn on the map should represent the basal area of the plant at the ground level. With such plants as Antennaria and Phlox it may be advisable to sketch the outline of the plants. Other prostrate plants such as Leontodon are best represented as dots or by drawing the circumference of the root crown. The basal area of grasses and the taller weeds should always be used.

2. Outline the circumference of all plants having a basal area of one-half square centimeter or more.

3. All plants having a basal area of less than one-half square centimeter are shown as dots.

4. Annuals are not charted as they will be gone by the next year. They should be listed in a space provided on the quadrat sheet.

5. When a shrub forms a "second story" in the vegetation, its boundary should be sketched with a dotted line.

6. Each plant is labeled with a symbol inside or if too small at the right hand side on the quadrat sheet.

7. If a clump is within and partly outside a quadrat, draw its entire boundary to facilitate future comparison on permanent quadrats.

8. If the center of a clump is dead it is shown by hatch lines.

9. The quadrat sheet should be inked as soon as possible to insure permanency.

(<u>Compilation and Analysis of Data</u>). The area of each clump is determined by an average of repeated planimetering. It may also be determined by counting the squares. Totals for each species should be computed for each decimeter strip in the strap method. Totals should be carried by the number of dots, number of clumps, and total area for each species.

A convenient way of recording these data is provided on special forms. Totals may be transferred to another form, or may also be compiled under the summary of quadrat data.

The total area is equal to the total area of the clumps plus one-fourth the number of dots. Per cent of class area is determined by dividing the total area of species by the total class area (i.e., grasses, "weeds", or browse).

This chart quadrat method is accurate and provides unlimited data, including a permanent record of the exact location and the size and shape of the basal cross section of every perennial plant within a definite area. It is a useful method for tracing the history of individual plants, development of erosion gullies, or other disturbances, and their effects upon the structure and composition of the vegetation. It is, however, a time-consuming method and very laborious.

<u>Count List Quadrat</u>. This method, used by Hanson (10) in a comparison in methods of quadrating, consists in counting the number of stalks or plants of each species. The total number of stalks or plants in the quadrat and the ratio between species can then be rapidly determined. The resultant data indicate the composition of the vegetation.

In grazing studies, count-list quadrats are often permanently located in pastures and also areas protected from grazing. Usually a record is kept from year to year of only the more important species. In North Dakota (32) it has been shown that while certain of the best grasses almost entirely disappeared under close grazing, weedy herbs, such as certain sages, which were not eaten at all or only when the other vegetation is very sparse, were greatly increased. At the end of 5 years, they were five times as abundant as in ungrazed or normally grazed areas where they were held in check by the grasses. Not only had they increased in number but also in size and they soon became so abundant that the value of the pasture was greatly reduced.

This method, although rapid in manipulation, does not show the quantity of vegetation on the ground in terms of density or volume. Another point against using this method to any great extent is that it is not applicable to grasses or turf-forming plants.

<u>Frequency Method</u>. This method was developed out of Raunkiaer's frequency studies relating to the abundance and distribution of different species in plant communities.(17) Ranunkiaer based his studies on small quadrats or circles of 0.1, 0.5, or 1.0 square centimeters taking 25, 50, or 100 quadrats at random in the stand or vegetative community investigated.(2)

Determinations of frequency are made with fewer (10 to 20) and larger (1 to 4 square meters) quadrats. The test areas as in the determination of density are arranged in a definite order or are distributed at random in a uniform community. The results may be expressed in a diagram, distributed in 5- or 10- frequency classes.

With increasing size of the test areas, the highest frequency classes enlarge, while the lowest decrease. Frequency diagrams are comparable, therefore, only when they are made from test areas of equal size.

Frequency index, a value derived from the use of this method, is the number of quadrats on which a certain species is found. For example, if a three-awn grass occurs on 10 of 25 quadrats, its frequency index is 10 and its frequence percentage is $\frac{10}{25} = 40$ per cent. Another species occurring on 20 of 25 quadrats would have a frequency index of 20 and a frequence percentage of 80.

Raunkiaer then arranged all species into five classes according to their frequence percentage and called these classes A, B, C, D, and E. The frequence apportioned to each of these classes were 1-20, 21-40, 41-60, 61-80, 81-100 per cent respectively.

The dominant species of a stable association usually fall into class E. Most of the secondary species are found in class A, which contains the majority of the species composing a stabilized community.

This method was used on two pastures of about 5,000 feet elevation near Ft. Collins, Colorado, on mixed tall and short grass vegetation.(12) One pasture was under deferred-rotation system of management and the other was used season-long. Observations showed there was more western wheatgrass (Agropyron smithii) on the deferred-rotation pasture but the effect of the grazing systems on the other species was less easily discernible. Studies were performed on adjacent portions of the pastures having similar topography and soil. It was found that continuous grazing killed out winter fat (Eurotia lanata) which had a frequency of 56 per cent in the deferred-rotation pasture but did not occur in the continuously grazed one. In both pastures studied the largest number of species fall into class A. As stated by Kenoyer (17) this is typical in quadrat studies of this kind.

In this study it was found that the frequency ratio in deferred-rotation area was 62, 14, 7, 7, 10 and in the season long area 59, 13, 13, 11, 4. The first ratio is nearer than the latter to the more normal ratio of distribution as developed by Raunkiaer. The variation in the two is due to the decrease in palatable plants that are not resistant to continuous grazing and to the increase in unpalatable invaders or palatable species highly resistant to grazing in the continuously grazed pasture.

The application of this law to grazing studies demonstrates the relation of most of the species constituting the vegetation. For the region studied, the method revealed that overgrazing by cattle is indicated by the disappearance or diminution in numbers of winter fat (*Eurotia lanata*), green wormwood (*Artemesia dracunculoides*) and by the appearance or increase in numbers of snakeweed (*Guiterrizia longifolia*), three-awn grass (*Aristida longiseta*), grama grass (*Bouteloua gracilis*), mountain sage (*Artemesia frigida*) and evolvulus (*Evolvulus pilosus*).

Other species such as *Agropyron smithii* and *Malvastrum coccineum* etc., may be about equal in frequency under various systems of grazing because they are dominant members of the association, and if highly palatable, resistant to close grazing.

This method may be of value in connection with other methods in studying the effects of various systems of grazing on vegetation and as an indicator of the significance of each species.

Frequency-Abundance. A variation of Raunkiaer's frequency method was used by Hanson (12) in a study of the methods of botanical analysis. Quadrats 1.0 meter square are established an equal number of paces apart along two lines running parallel, the lines being well separated. For each quadrat an estimate is made of the abundance of each species according to the scale:

S = 1 to 4, stalks or small plants per quadrat; I = 5 to 14; F = 15 to 29; A = 30 to 99; and VA = 100 and over.

Frequency is expressed in percentage, calculated by dividing the number of quadrats in which the species is found by the total number of quadrats that are examined. Average abundance is calculated for each species by adding the abundance values and dividing by the number of quadrats in which the species are present. A valuable index number of the abundance of each species on the area as a whole can be secured by multiplying the frequency by the average abundance. The maximum possible range for any species present is from 100 to 0.03. It is usually impossible for any species except the chief dominants to reach figures above 50 or 60. The higher the index value, the more important is the species in the community.

About 30 to 50 quadrats per 5 acres are recommended to obtain the proper relationship between species. (8)

Density List. The density-list method of quadrating consists in estimating the density of the plant cover (approximately basal cover). By means of cross straps the quadrat is divided into 25 subdivisions. First the density of each small square is determined and then the percentage of each species in the square is listed. Totals and averages are then secured. (10)

Area List. The area-list method of quadrating is similar to the density-list method except that the basal areas occupied by each species in each small square are measured by means of a ruler or listing square. These areas are expressed in square centimeters instead of in percentage as is done in the density-list method. The number of stalks or clumps may also be given. Totals and percentages of each species in the quadrat may then be computed. (10)

The method is based on the determination by actual measurement of the area of each perennial plant within the quadrat. Measurement is made with an especially marked scale, developed by Pearse (24), or by means of a listing square. The foliage of each plant is brought together by hand and compressed enough to prevent the sight of the ground through the plant from above. The area of the clump is then read directly on the special scale, which is laid across or inserted through the compressed plant.

Perennial plants, the centers of which have died, are given two measurements. In addition to the measured area of the entire clump, the area of the dead portion will be measured in the same manner and subtracted from the total area.

Seedlings are not measured, but counted. The examiner will estimate the average figure for the area of seedlings before leaving the plot. Annual species will not be measured individually, but total area of ground covered by species will be estimated with the aid of the scale, and this figure is recorded.

In this method the compilation of data is simple, rapid, and not readily subject to major errors. The area of each species is determined by totaling the area made up of each size class recorded. This is then converted into species density by expressing it as a decimal fraction of the total area of the plot. Total density is the sum of individual species densitites.

Pearse (24) reports the method as being very satisfactory after five seasons of use on the Boise River Watershed. About 1½ hours are spent on each plot, yet, as a whole, it is faster than other methods. It is more accurate than any except the chart-quadrat method when applied to clump-forming species.

This method, for obvious reasons, may not be as applicable to vegetation growing in dense stands or, on the other hand, vegetation composed largely of single stalked species.

It may, however, be adjusted to suit different conditions.

List Weight. The list weight method consists merely of securing the dry weight (oven-dried at 100° C - 110° C) of each species clipped at a certain height. This height varies according to the standards of the users. It is considered standard when vegetation is clipped between 1-2 inches above ground. After this oven-dried weight for each species has been recorded the total weight and the percentage by weight of each species in the quadrat is then computed.

Using the list weight method, an attempt was made to work out an expression representing the average carrying capacity of the Santa Rita Range Reserve in Arizona.(49) Four kinds of records were obtained, as follows:

1. Collection of all vegetation from quadrats was made for nine years in representative parts of the reserve and from weights of the dry material that was collected, the total production in terms of pounds per forage acre was calculated. This figure was 1160 pounds per acre although stock (in their opinion) get less than this.

2. Hay cutting records were kept for five years. The average amount of hay cut was 640 pounds per acre. They figured that the average production of hay was 70 per cent of the productivity shown by the quadrat collections, made on and beside the areas cut. They concluded then

that stocking on the basis of an estimated production of more than one half the total productivity as obtained from the quadrat measurements would be unwise, since such a policy would tend to lower the carrying capacity below the maintenance capacity for the area carrying stock.

3. Using the quadrat measurements they obtained the approximate productivity of the various forage plant associations of the reserve. From these figures and the areas of each association a weighted average expression representing the average productivity of the whole reserve was derived. The figure derived was 110 pounds per acre, assuming that it was the average for total productivity and 50 percent of that as maintenance capacity of that area. Then if the average animal ate the equivalent of 30 pounds of dry feed per day it would take 10 acres of land to furnish that amount at full productivity and 20 acres of land at maintenance capacity. Therefore, the average value for carrying capacity would equal 20 acres per head per year or 32 head per section for the reserve.

ANALYSIS OF METHODS OF QUADRATING. Charting appears to be the best way of quadrating large and well-defined mats or clumps, and count-listing the best for few or single-stalked plants. Small or poorly defined clumps or mats may perhaps best be measured by means of some instrument as the listing square or special rule to overcome errors due to the operation of the pantograph or planimeter.

Where several growth forms are present in a quadrat the use of one unit of measure such as basal area will not give a correct expression of the relationship between the species. For example one stalk of yarrow (Achillea millefolium) or pinegrass (Calamagrostis rubescens) occupying a basal area of about 0.1 square centimeter, may make greater demands upon the soil and have more effect upon the community than an area of 1.0 square centimeters of mat or clump formers as Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum). (10)

While it is convenient to summarize quadrat data to some standard unit, such as area occupied, it is doubtful whether this can be done and at the same time present a true relationship between species.

If one method must be used it appears that the list-weight method would provide a better comparison, otherwise a combination of the count and area-list methods should be used for single or few-stalked species and some area method for mats and clumps. No effort should be made to reduce the data to some common denominator.

The density-list method is usually not as desirable as the area-list method because it requires only estimates and because the calculations in working up the data are more complicated.

There is more error in the pantograph than in the area-list method on small areas. Error is incurred when tracing the outline of the plants with the pointer, when setting up the pantograph in the field, in reducing small areas to 1/25 of their field size, and in operating the planimeter. In the area-list method the areas are measured directly.

The time required for the different methods is important, especially when a large number of quadrats are to be studied during the growing season. The field work by the area-list method requires 1/5 to 1/2 as much time as the pantograph-chart method. The former does not require the use of a planimeter so final calculations can be made in 1/5 of the time necessary for the other method.(10)

Hanson (10) found that whenever two or more methods were used in a single quadrat the total areas as well as the ratio between the species in the total area were different in each method. Pantograph measurements of the areas occupied by plants at different levels (as basal area and at a height of one inch) were not comparable.

He concluded that the growth form of plants being studied and the purpose of the quadrats, are the important factors in determining the method of quadrating to use. Herbaceous plants in a certain community may vary widely in growth form. Orchard grass (Dactylis glomerata) forming large clumps, meadow fescue (Festuca elatior) forming small clumps, Kentucky bluegrass (Poa pratensis) forming sod, and smooth bromegrass (Bromus inermis) forming sod, may all be found on one area.

If the vegetation consists chiefly of large and well-defined mats or bunches, 200 to 400 square centimeters or more in area, then a combination of the pantograph chart and count-list method is very desirable. If the vegetation consists chiefly of smaller areas or a mixture of small clumps or mats and single or few-stalked species then the area-list method, combined with the count-list method appears desirable. If the vegetation consists of single or few-stalked species then the count-list method is best. The area-list method combined with the count-list method has been found to be most satisfactory in a mixed prairie type of vegetation and in irrigated pastures after the first year. Area measurements are not comparable with numbers of individual stalks.

Comparison of List Weight, Frequency, and Point Methods. Hanson (8) made a comparison of the list weight, frequency, and point methods by arranging species in the vegetation he studied in five groups. (See TABLE I)

Percentages secured by the frequency-abundance method in most cases are nearer the list-weight figures than are the point method figures.

For determining as quantitatively as possible the effects of different grazing practices upon the vegetation, a few well-located permanent quadrats for studying specific problems should be supplemented by a sufficient number of

COMPARISON OF METHODS SHOWING THE PERCENTAGE OF VEGETATION OR PASTURAGE CONTRIBUTED BY EACH GROUP ON NORTH DAKOTA PLATEAUS
(After Hanson)

Groups	List Wt. Method 96 Sample Areas		Frequency-Abundance Method 30 Quadrats		Point Method 2,400 Points
	Grams	Percent	FxA Index No.	Percent	Percent
Bouteloua gracilis and Carex spp.	568.2	49.9	195.8	55.4	65.3
Agropyron smithii	322.6	28.3	627.0	17.8	15.0
Stipa comata	110.9	9.7	45.0	12.7	12.0
Miscellaneous grass	28.3	2.5	.9	.2	2.3
Forbs	109.9	9.6	48.9	13.9	5.4
TOTALS	1,139.9	100.0	353.0	100.0	100.0

sample areas located at random.

The conclusions of Hanson's (8) study are applicable to the mixed prairie vegetation consisting of the dominants *Boutelous gracilis*, *Agropyron smithii*, *Carex filifolia*, *Carex stenophylla*, and *Stipa comata*.

Transect Method

It is frequently desirable to know just how vegetation changes with changing environment, such as is caused by slope exposure, or other irregularities in topography or soil, or to determine how one community of plants gives way to another. This may be ascertained by a transect, which is a continuous narrow strip that gives a cross section of the vegetation. Transects are indispensible in studying zones and transitions of all kinds. They are always made at right angles to the zones or transitions. (48)

LINE TRANSECT. The simplest form of transect and one that is most easily charted is the line transect. It is employed when only the more striking differences in structure are sought. It is made by running a tape, along a selected line. The position of the individual plants touching the tape on one or both sides is recorded on a line on the chart drawn to scale. As in the quadrat chart, the scale employed varies with the type of vegetation, but it should always be large enough to prevent crowding. (48)

BELT TRANSECT. The belt transect is a strip of vegetation of uniform width and of considerable length. The width is determined largely by the character of the vegetation, just enough being included to reveal its true structure. In herbaceous vegetation, the usual width is one decimeter, but it varies from 1 to 10 meters in woodland. The belt transect shows a definite range of vegetation and by making it permanent and recharting at suitable intervals, changes in the vegetation along the line of the transect may be readily detected and measured. (48)

Isolation transects are regularly used in grazing experiments. These consist of two strips, each 300 feet long and 20 feet wide with a protected strip between as a control. One is grazed, the other ungrazed. At the end of each year one 20-foot square unit of ungrazed area is opened and one of the grazed units closed. Thus, after a few years, a history of the development of vegetation as affected by one, two, three or more years of grazing may be seen as well as its development after one or more years under protection. (48)

LARGE SCALE METHODS

There is an ever-present need for the fullest and most accurate up-to-date practical information in connection with the use and administration of the range and related resources for such purposes as livestock production, watershed protection, game conservation, recreation, and other legitimate demand. As the demands for various uses increase, conflicts develop, the settlement of which requires accurate information regarding all the factors involved. It is for the purpose of obtaining these basic facts, analyzing the various problems and from them developing a comprehensive plan for managing the resource, that large-scale forage inventories are conducted. These inventory methods involve every phase of invoicing forage resources, studying and analyzing problems, working out solutions, and providing for the application of suitable plans.(46)

It can be seen that in order to fulfill the requirements called for above, the whole area being inventoried must be invoiced as a unit instead of by means of representative areas as is done in the use of ecological research methods. Methods must be used that are not laborious and time-consuming and they must be of such nature that the training of the individuals who are to use them is not difficult.

In these methods actual inventories are made of the forage resources of the unit being studied, while the ecological research methods are used primarily for studying effects of environmental factors, especially grazing, upon the composition and structure of the vegetation.

Fundamental Principles Involved

In using these large-scale methods of inventorying range resources, certain fundamental principles and terms assume an integral part in the application and use of the method either in the field while making observations and recording the data or in the office upon compilation of the data secured. One or more of these principles may be found in an inventory method. In the more general methods all or a great majority of them will be included in the inventory method.

For the sake of clarity, it is well to enumerate, define, and discuss these basic principles at the beginning of this discussion on large-scale methods in order to give the reader a better understanding of the discussion included under the various methods.

FUNDAMENTAL FORMULA. The fundamental formula of a forage inventory, used in computing the grazing capacity of an area, is as follows:(30)

$$\frac{\text{Density x Palatability x Surface Acres x Utilization Cut}}{\text{Forage Acre Requirement}} = \text{Grazing Capacity}$$

DENSITY. The most common definition of this term is that density may be considered as the per cent of bare ground covered by plants individually or collectively. The method of arriving at this percentage figure differs with different methods, these differences being taken up with the discussion of the various methods.(30)

In the methods more commonly used for making forage inventories on range lands, density is of paramount importance for it is the "main spoke" of the inventory. The greater the amount of bare area covered by forage, the greater the density and consequently the greater the carrying capacity of the area of land being inventoried.

Undoubtedly the factor of density is one of the most important factors affecting the carrying capacity of any area of range land producing forage but this factor alone should not be placed in the "main role." The main burden of the inventory should not be born by density as the one single factor governing the grazing capacity of an area. To cite an example, two areas may have similar densities, yet differ very materially in the number of animals to which they can safely furnish forage and still maintain their productivity. To put it more clearly two haystacks side by side may cover exactly the same area of ground yet if one is higher than the other there will be more feed available for grazing animals in that stack than in the lower one.

It can be seen, therefore, that density alone, without consideration of volume, is not a true "measuring stick" by which the carrying capacity, or the amount of feed furnished to grazing animals can be measured. However, under the prevailing circumstances, it has been the most practical indication of the amount of forage furnished by range vegetation.

<u>PALATABILITY</u>. Palatability, as used in forage inventories, is the per cent of the total current year's growth, within reach of stock, to which a species is grazed when a range unit is properly utilized under the best practical range management.(46)

Palatability ratings are accordingly assigned to species and tables listing the species and their corresponding ratings are assembled. These tables are made separately for regions, National Forests, districts, or localized areas.

In the main, palatability tables are computed for domestic livestock although a few have been compiled for game animals subsisting by grazing on forage. The class of stock, composition of the vegetation, and the proper time of using the range as a whole must be considered when rating the palatability of individual species.(46)

There are many objections against the use of the basic principles of palatability and incorporating them for computing grazing capacity of range lands. The basis for some of these objections are as follows:

1. Palatability varies according to the origin of the livestock grazing on the area. Livestock for instance that have been grown in Montana and brought to Oregon do not utilize the forage on Oregon range lands in the same manner or to the same extent as livestock that have been grown in Oregon. This is because the Montana livestock have been grown on an area in which the species composing the vegetation show marked differences as compared to those of Oregon.

2. Palatability varies with the change in season. Livestock utilize certain species to a greater extent during certain seasons of the year than at others.

3. Palatability of individual species varies according to the habitat in which they are growing. For example, livestock men have observed that bluebunch wheatgrass (*Agropyron spicatum*) is utilized to a lesser extent by livestock when growing on a hillside than when growing on a bottomland site.

To date, however, no satisfactory applicable substitute for this basic principle has been set forth and consequently it has been retained for want of a better principle that would be applicable to forage inventories on a large-scale basis.

FORAGE FACTOR. The forage factor is the figure obtained by multiplying the density by the palatability.(46)

FORAGE ACRE. A forage acre is theoretically an acre of ground completely covered with palatable forage. Actually it is a figure obtained by multiplying the forage factor by the number of surface acres supporting vegetation of that particular forage type or unit.(46)

This also is a disputed feature of the large scale inventory methods of computing grazing capacity. In the practical application of the forage acre, a forage acre of one type of range does not necessarily have the same feed value as does a forage acre of a different forage type. Forage inventories would be more directly applicable if forage acres of different forage types were of equal value. The use of the term "forage acre" is merely to designate the grazing value of a given type of vegetative cover.(30)

FORAGE ACRE REQUIREMENT. The forage acre requirement is the number of forage acres required to maintain a grazing animal for a definite period of time; this is expressed in terms of forage acres required per day, week, month, or year according to the standards adopted. Determination of the forage acre requirement base, by means of which the forage-acre data are converted to terms of grazing capacity, is as important as any phase of the forage inventory work.

Ordinarily the most satisfactory method of determining this base is to select for forage-acre-requirement studies those units that have every appearance of having been properly used for a period of years and that have been inventoried in the course of the season's work. These areas should be as representative of large portions of the range as it is possible to find. Figures for controlled ranges, whenever obtainable, should be used. At the close of the season, the examiner studies the utilization and condition of these ranges and obtains the most accurate and detailed information possible on the rate of stocking and seasonal use that has obtained on such areas for the past several years. Supplied with this information he is able to determine, as soon as compilation of the current inventory data is complete, the number of forage acres per animal unit that have been used in the past. If this determination is followed with slight adjustments to correlate actual use with previously determined range conditions on the selected areas, the figure obtained should yield a satisfactory base from which to determine approximate grazing capacity. If actual use on the basis of the grazing capacity as determined by the inventory indicates that the forage acre requirement determined is uniformly high or low, it should be adjusted to permit increased or reduced stocking. (46)

Herein lies another weakness in the basic foundation of large-scale forage inventory; for the standards by which proper utilization of the forage cover is judged are not wholly accepted nor easily established. It is judged wholly by experience and personal opinion and because of this lack of uniformity it cannot be considered as an absolute or accurate figure, for it is not based on any mechanical measurement.

Forage acre requirements, when applied to data secured on a forage inventory, differ markedly according to the forage inventory method used. For example, when computing grazing capacity in the reconnaissance method the figure .8 is used as the forage acre requirement of one cow for one month, while in the point-observation-plot method the requirement for one cow for one month is .25 forage acres.

GRAZING CAPACITY. Grazing capacity is considered as the maximum number of grazing animals an area of vegetation will support on a sustained yield basis. Grazing capacity, as used in forage inventories, may be computed by dividing the forage acres present on a range unit by the forage acre requirement of the grazing animals utilizing the unit.(46)

<u>FORAGE TYPE</u>. A forage or grazing type as used in forage inventories, consists of an area on which the forage cover may be composed of one class of vegetation. Types are classified according to aspect. For example, if the vegetation is composed predominantly of grass species with scattering timber, it is considered as a grass type. (46)

<u>CLASSIFICATION OF FORAGE TYPES</u>. (Type Designations). Types are indicated by a type number followed by standard symbols which indicate the dominant species. Types containing a timber overstory carry the principal timber species symbol after the type numbers. The governing rule is that the number and symbols give an accurate picture of the principal species.

The conspicuous or most important species or genus symbol is shown first, followed by minor species. Ordinarily, unless exceptional conditions prevail not more than three symbols are shown in a designation. If less than three species are prominent the number of symbols are reduced accordingly.

(Symbols). Symbol lists for trees, shrubs, and herbaceous vegetation are devised and standardized for regions; these are incorporated into the palatability tables. Symbols for all common and widely distributed genera and species are standardized for the entire range area.

The governing principle is a three letter symbol--all capitals for the genus symbol and one capital and two lower-case letters for the species. The genus symbol, except for trees, consists of the first three letters of the genus name. In case of conflict the least common genus carries the second or third letter changed to remove the conflict. For example, there would be a conflict between the symbols of the genera *Agrostis* and *Agropyron*. Accordingly, the symbol for *Agropyron* would be AGR and for *Agrostis*, AGO.

Species symbols consist of the first letter of the Latin generic name, followed by the first two letters of the specific name. In case of conflicts, the same rule applies as above. For example, the symbol for *Artemesia tridentata* and for *Artemesia tripartita* would, according to the rule, be Atr. Since *Artemesia tridentata* is more abundant than *Artemesia tripartita*, the symbol for the former species would be Atr and for the symbol for the latter would be Art. Where the species determination is unimportant and where species cannot be readily identified the genus symbol is used. When there is a difference in forage value or general characteristics between species in the same genus, the species symbol is used.

(Type Descriptions). Type No. 1 -- Grassland

Includes grassland other than meadow, such as grama-buffalo grass, bunch grass, wheatgrass, sedge, alpine grassland, and bluestem.

Type No. 2 -- Meadows

Two classes of meadows are recognized: wet meadows and dry meadows.

Wet meadows -- These are characterized principally by sedges and remain wet or moist throughout the summer.

Dry meadows -- These are characterized by grasses rather than sedges, occurring as moist meadowlike areas in open timber or intermittent meadows.

Type No. 3 -- Perennial forbs (Weeds)

Includes areas where perennial weeds predominate over other classes of vegetation.

Type No. 4 -- Sagebrush

Includes lands where sagebrush or species of similar appearance predominate.

Type No. 5 -- Browse-Shrub

Includes range where browse, except sagebrush or its sub-types, gives the main aspect to the type or is the predominating vegetation.

Type No. 6 -- Conifer

Includes range in coniferous timber supporting grasses, weeds, either singly or in combination, except as provided in Type 7 and 9.

Type No. 7 -- Waste

Includes areas of dense timber and brush which have no value for grazing.

Type 8 -- Barren

Includes areas in which there is naturally no vegetation.

Type 9 -- Pinon-Juniper

Includes areas in which pinon, juniper, pinon-juniper, and digger pine predominate.

Type 10 -- Broad Leaf Trees

Includes range supporting deciduous timber. The principle sub-types which are encountered are: aspen, cottonwood, oak, birch, alder, ash-elm, etc. when they occur in tree form.

Type 11 -- Creosote

Includes areas where creosote bush (*Covillea*) constitutes the predominant vegetation.

Type 12 -- Mesquite

Includes areas where mesquite (*Prosopis*) predominate.

Type 13 -- Saltbush

Species of saltbush (*Atriplex*) constitute the predominant vegetation in this type.

Type 14 -- Greasewood

Species of greaswood (Sarcobatus) constitute the precominant vegetation in this type.

Type 15 -- Winterfat

Includes areas in which winterfat (*Eurotia lanata*) gives a characteristic aspect.

Type 16 -- Desert Shrub

Includes a general type which is made up of desert shrubs aside from those separated into individual types and which constitute the predominant vegetation or give the characteristic aspect.

Type 17 -- Half Shrub

Includes areas where half shrubs such as *Aplopappus*, *Gutierrezia*, *Artemisia frigida*, *Eriogonum wrightii*, etc., constitute the predominant vegetation.

Type 18 -- Annuals

Includes areas in which annual weeds or annual grasses constitute the dominant vegetation.

- - - - -

Plant species are innumerable as likewise are the various combinations they form to make up the vegetation. It is not possible therefore, to include all of these combinations under a type and for this reason subtypes are recognized.

The above classification was worked out by governmental agencies using forage inventories and agreed upon by them in a conference held in Ogden, Utah of leading grazing experts in 1937. (46)

COMPOSITION. Type composition estimates are based on the relative density abundance of each available species composing the vegetation. (46)

Actual Usage Method

There is a great degree of similarity between this method and the procedure of computing forage acre requirement discussed previously. This method is one that has been used by the practical stockman since the beginning of the range industry. It does not entail measuring forage by any mechanical means but is, rather, based upon observation and personal experience. For example, if, at the end of a grazing season, a ranch operator found the land used by his stock was in good condition and had not been excessively utilized and yet no feed was wasted, he could then assume that the grazing capacity of the area, for that year at least, was identical to the number of stock utilizing it. If this procedure were followed for a number of years and the yearly grazing capacity figures for the area were averaged, the fluctuations in forage production due to climatic conditions would be eliminated.

Although this method may seem simple upon superficial examination, the ability to recognize when an area has been properly utilized comes only with training and experience. It requires an intelligent power of observation and a fundamental or inherent knowledge of the growth requirements of vegetation, as well as a knowledge of the requirements of the animals grazing the area.

CORRELATION BETWEEN ANNUAL PRECIPITATION AND ACTUAL USAGE. Smith (35), by combining climatological and actual usage data, showed that there is a definite correlation between annual precipitation and the number of livestock grazed per square mile. In the Great Plains states the relationship between the annual precipitation and the number of head of livestock that can be grazed per square mile can be fairly well established, the population number decreasing with fair uniformity from east to west with the decreasing annual rainfall. The number grazed in Oklahoma and Texas is close to 50 per square mile when the rainfall is between 25 to 35 inches and about 40 where the rainfall is from 15 to 25 inches.

In the Great Plains states north of Oklahoma where feed is necessary during the winter time and where the rate of evaporation is less in the summer months, the grazing rate averages close to 20 head per square mile where the rainfall is between 10 to 15 inches, nearly 40 where it is from 15 to 20 inches and nearly 80 where it is 20 to 25 inches. The ratio rises at a faster rate with heavier rainfall.

In all of the Rocky Mountain region it becomes more difficult to establish a ratio between the annual precipitation and the rate of grazing because of the seasonal distribution of precipitation, temperature variations, the topography, soil, evaporation, snow cover, nature of vegetation and differences in the length of the grazing season. In the central and upper Rockies the grazing rate is slightly greater with small rainfall than farther east because of the shorter grazing season, but less than in the Great Plains with heavier precipitation because of the relative shortage of grazing areas in the higher mountains where the greatest precipitation occurs.

The relation between precipitation and grazing capacity of ranges can be seen in Tables II, III, IV, and V.

TABLE II

ARIZONA, NEW MEXICO, TEXAS AND OKLAHOMA WHERE GRAZING IS MOSTLY ALL YEAR.
(After Smith)

Annual Precipitation	Cattle Per Square Mile
0 - 5 inches	0
5 - 10 inches	9
10 - 15 inches	15
15 - 20 inches	24
20 - 25 inches	32

TABLE III

IN GREAT PLAINS STATES NORTH OF OKLAHOMA WHERE THERE ARE USUALLY PERIODS OF CONSIDERABLE LENGTH IN WINTERTIME WHEN GRAZING IS NOT POSSIBLE.
(After Smith)

Annual Precipitation	Cattle Per Square Mile
10 - 15 inches	19
15 - 20 inches	38
20 - 25 inches	76
25 - 30 inches	265
30 - 40 inches	409

TABLE IV

IN CENTRAL AND UPPER ROCKY MOUNTAIN AND PACIFIC STATES MOSTLY SUMMER RANGES, THE PERIOD OF GRAZING VARYING FROM 3 to 7 MONTHS DEPENDING ON LOCATION.
(After Smith)

Annual Precipitation	Cattle Per Square Mile
5 - 10 inches	20
10 - 15 inches	28
15 - 20 inches	47
20 - 25 inches	63
25 - 30 inches	97

Greater grazing capacity with the lighter rainfall in the first part of TABLE IV as compared with TABLE III is undoubtedly explained by the shorter grazing period in the Rocky Mountain region. On the other hand, the smaller capacity with the heavier rainfalls in the last part of TABLE IV as compared with TABLE III seems to be because the degree of heaviest rainfall in the Rocky Mountain states are at the highest elevations where the country is very rough and the available grazing areas small as compared with the Great Plains territory.

In the following table all of the data from the Great Plains westward are averaged together after correcting for the period of grazing. If the grazing period is 6 months the grazing capacity as reported is divided by 2.

TABLE V

RELATION BETWEEN THE ANNUAL PRECIPITATION AND THE GRAZING CAPACITY OF RANGES FROM THE GREAT PLAINS WESTWARD (NOT INCLUDING CALIFORNIA)
(After Smith)

Annual Precipitation	Cattle Per Square Mile
0 - 5 inches	0
5 - 10 inches	8
10 - 15 inches	14
15 - 20 inches	20
20 - 25 inches	43
25 - 30 inches	66
over 30 inches	138

While this table may represent the theoretical grazing capacity of ranges, it is not so reliable as the preceding tables which show averages for the actual grazing that is taking place under different rainfall amounts and for such periods as the season will allow.

Inventory

These methods, from the standpoint of usage by governmental agencies administering grazing lands, are the most important methods used in arriving at grazing capacity figures.

Two of them, the reconnaissance and point-observation-plot methods, are the ones most used by range examiners; the volume-palatability, weight estimate, and density-weight methods still being in the experimental stage. Field men who possess a fundamental knowledge of vegetation can be easily trained to use the methods, although the factor of personal error is great in any of the methods used.

Because of the relatively low value of range lands used for grazing as compared with other lands producing agricultural crops, it is not feasible to spend any great sum of money in order to inventory the forage resources of an area of range land. Therefore, the cost of using the method must not be excessive.

Because of the shortness of the growing season it is necessary to inventory in as short a time as possible large acreages of land. Therefore, the method must not be time-consuming and laborious.

In these large-scale methods the procedure followed in securing data is, for all practical purposes, the same; the differences lying in the interpretation of fundamental principles embodied in the method and consequent recording and summarization of the data.

Reconnaissance Method

The reconnaissance method of forage inventory, from the standpoint of priority, represents the first attempt made at inventorying the forage resources for the purpose of obtaining the grazing capacity on an area of range land. Broadly speaking, the reconnaissance method may be intensive or extensive. The observations may be recorded in various ways, the aim being to obtain and compile an inventory of the forage resources as affected by topographic features, climatic conditions, need for watershed protection, amount, kind and availability of forage, watering facilities, etc. In addition, the completed reconnaissance classifies the lands into forage types and shows the forage value of each type.

The reason for the widespread acceptance of the reconnaissance method by governmental agencies is that the areas of grazing land over which they have jurisdiction are so great, and the surface and vegetative types so varied that it is impossible for any single individual to form any mental picture in sufficient detail of any single administrative unit as a whole, to properly administer the forage resources on the area.

The first reconnaissance of range forage was made in 1911 on the Coconino National Forest in northern Arizona. The original reconnaissance plans were developed and the first party was organized by Jardine. (30) The methods of securing, recording, and summarizing the data have passed through a period of evolutionary development, although the method and plans set forth by Jardine form the basis of the reconnaissance method and other methods as they stand today.

In the interest of the sustained yield of forage and the maintenance and improvement of the range unit, the major questions which the reconnaissance and other methods aim to clarify are: (45)

1. Adaptability of the range unit to the class of stock grazed.

2. Number and distribution of stock grazed.

3. The opening date and the length of the grazing season.

The deciding factors in determining the adaptability of the range unit to the different classes of stock as set forth by the U. S. Forest Service (45) are as follows:

1. Abundance and condition of timber reproduction.

2. Watershed protection.

3. Topography and climate.

4. Quantity, quality, and availability of the forage.

5. Watering facilities.

6. Accessibility of the unit to the different classes of grazing animals.

The number and distribution of grazing animals are based on the following: (45)

1. Quantity, quality, of the vegetation and its availability and palatability to the different classes of grazing animals.

2. Climatic conditions.

3. Obstacles to the proper distribution of the stock, as, for instance, barriers and streams.

4. Water facilities.

5. Need for protection of any problem areas.

The opening date and length of the grazing season will be largely determined by the following:

1. Climate and elevation, especially as related to the acreage and the productivity of the spring, summer, and winter range.

2. Need for rejuvenation and maintenance of the more valuable forage cover.

3. Permanency and abundance of the watering facilities and type of forage.

A complete forage inventory by the use of the reconnaissance method is made up of many different parts.

PREPARATION BEFORE FIELD WORK. A topographic map, including all the more important features pertinent to the management of the forage producing areas, such as the location of drainage and all stock watering places, ridges, elevations, (usually by 100-foot contour intervals), as well as all the more important cultural features, should be used when available. One inch maps are suitable where forage types are broadly distributed. Two to four inch maps are preferable where the ground is broken or the type pattern of forage types intricate. (46)

FIELD METHODS. Vegetation is classified according to forage types. Typing and note taking in the field is ordinarily done by each man individually. The unit used for correlation of notes and type descriptions differs with agencies doing the work. It may be a legal subdivision, ownership unit, allotment, or other type of describable area.

TYPING AND MAPPING THE FIELD. The intensity of forage type examination varies considerably. The minimum requirement is that the examiner observe enough of each type to obtain a reliable estimate of its density and composition and to determine the various conditions that would affect the practical use of the type. Previously compiled type maps from aerial photographs are sometimes used and where this is the case, work is planned so that the examiner passes through the largest portion of each type without backtracking or recrossing the general line of travel.

In the "strip" system the examiner traverses the area in a systematic manner by compass and pacing from established points, with checks being made on as many additional points as possible. On sections survey by the General Land Office, section and quarter corners are used as control points and section lines and centers of sections are followed. The areas are covered on a basis equivalent to passing twice through each section and mapping at least 20 chains on each side of the line traversed. Variations are added according to the uniformity of the forage type.

Whatever method of traversing the area is used forage types (see definition) are shown on the field map.

SOIL EROSION. Because of the depletion of native vegetation, accelerated erosion has attained such an importance on range lands that it is necessary to take it into account when making a forage inventory.

FIELD NOTES. Each forage type and sub-type is written up on forms provided especially for the purpose. Data which cannot be shown on the map such as elevation, topography, drainage, character of the watering places, proper seasonal use, proper distribution and handling of the stock, recommended changes in the salting plan, notes on rodents, poisonous plants, insects, game, and predatory animals, and the need for range improvements are also included in the field notes.

DENSITY AND COMPOSITION. The complete ground cover showing forage species, the percentage of surface supporting vegetation, the density of the ground cover, the percentage of "weeds", grasses, and shrubs is obtained by the examiner using the reconnaissance method. This information may be recorded either by classes or individual species of the total ground cover and the palatability of the cover as a whole or by vegetation classes or individual species.

DENSITY. In estimating density by the reconnaissance method, the spread of the vegetation above the ground is considered. The density of more or less upright weeds is based on the amount of ground that appears covered when the vegetation is viewed from directly above. In estimating the density of spreading weeds, or browse, or open clumps of grass this forage is compressed or raised at an angle so that all the normal interstices between the leaves are completely filled without compressing or unduly crowding the vegetation. All density of browse should be determined by the portion of the ground covered by that part of the browse that is accessible to stock. In the case of the interior of dense clumps, the interior may be excluded from the estimate. Any oak or other brush that forms an upper story beyond the reach of stock does not enter into the density estimate. Where a double story of available vegetation exists, such as browse over grass, the density of each story is judged separately. Both stories are included in the density estimates.

In passing through a type, the examiner mentally calculates and carries with him a moving average of plant density and composition.

<u>COMPOSITION</u>. In the reconnaissance method, write-ups of forage types are not recorded until a representative sample of the area has been traversed and, in addition, the write-up should be completed on the representative sample. Type composition is itemized on special forms and is expressed in terms of percentage. (See sample form 1

in appendix.) The sum of the percentage ratings for individual species should always total 100 per cent.* (See sample computation below.)

COMPUTATION. After the composition rating for each individual species is recorded, that rating is multiplied by the accepted palatability rating for the species. The sum of all the individual products yields the weighted or total average palatability of the type. This last figure is multiplied by the estimated density of the type. The forage factor is carried onto the camp map for type "jibing" purposes and otherwise used in compilation of the data. The forage acres (see formula) in each type and each unit are then calculated and tabulated.

Following is a sample computation:

	Principle Species	Percent Palatability		Percent Cover	Palatability	
Weeds:	nil					
Grasses:	Bouteloua eriopoda	80	x	30	0.240	
	Sporobolus flexuosus	70	x	5	0.035	
	Aristida divaricata	50	x	10	0.050	
	Total			45*	0.325	-- 0.325
Shrubs:	Yucca elata	10	x	20	0.020	
	Gutierrezia juncea	0	x	30	0.000	
	Prosopis glandulosa	10	x	3	0.003	
	Ephedra trifurca	0	x	2	0.000	
	Total			55*	0.023	-- 0.023
	Total average type palatability					0.348

Average type density 0.17 x average type palatability 0.348 = Forage acre factor 0.059. Figure taken for Forage acre requirement of cow is .8 forage acres per month.

.8 / 0.059 = in the example above 13 acres per cow month or 156 acres per cow per year.

In cases where detailed figures have not been worked out and where elaborate typing and mapping is not a prime requisite a more extensive method is used which takes into consideration grasses, browse, and "weeds" with just the average palatability for each of them.

	Percent Palatability		Percent Cover		Palatability Factor
Grasses	50	x	40	=	0.200
Weeds	30	x	35	=	0.105
Browse	25	x	25	=	0.062
					0.367

Total average type palatability = 0.367

ANALYSIS OF RECONNAISSANCE METHOD. The low expense of the reconnaissance is in great part due to the rapidity with which the work can be performed as compared with the ecological research methods. For this reason many objections are raised to the effect that certain features are overlooked which are pertinent to the development of a detailed management plan. Furthermore, the exact character and density of the forage type varies according to the time of season the examination is made.

The amount of personal error entering into the use of this method is great. In writing up the type and in choosing the representative unit on which to do it one examiner's choice may vary considerably from that of another, hence, varying the final result considerably.

This method, although the first actual forage inventory method developed, is still widely used by the United States Forest Service, Division of Grazing, and other agencies having an interest in range lands. It is interesting to note that it has its widest use in regions where there is a very marked predominance of grazing lands under the jurisdiction of the United States Forest Service. At best the method gives only a good indication of the forage resources and cannot in any way be considered as an exact measure of the grazing capacity of any range unit.

Point-Observation-Plot (Square-Foot Density) Method

In order to offset the inaccuracy of the reconnaissance method and the time-consuming nature of the ecological research methods, Stewart and Hutchings (41) devised a method of estimating vegetation by the large plot method. It differs from the reconnaissance method in the manner of estimating density and of obtaining vegetative composition and density on forage types of varying acreage. The procedure for computing grazing capacity, following the determination of the forage factor, is identical for the two methods.

This method is founded on the technique used by plant breeders to obtain reliable preliminary field tests of large numbers of strains. Plots are selected on a randomized, replicated system. The method has been modified to include many phases of the timber survey and refinements of the reconnaissance method.

As the name indicates, the method utilizes a series of replicated plots. The chart-quadrat furnishes these data but as was pointed out, the method is too time-consuming to be used on a large scale. The meter quadrat sometimes used in the area-list method is often too small to contain the 20 to 50 or more individual plants of major species which must be included to overcome the differences of individual plants. In both the quadrat and the reconnaissance methods, studies are made on areas that are estimated as being representative of the whole unit being examined or inventoried. On the other hand, this method provides for randomization and replication, insures a closer scrutiny of the plant cover than is the case in the reconnaissance method, a greater ease and reduction of error in compilation, and an immense saving of time as compared with the plot system in the ecological research methods.

THE PLOT. The size of the plot commonly used in this method is usually 100 square feet in area, although 200 square-foot plots have been used on sparse desert vegetation. The size may vary within reasonable limits but 100 square-foot plots have proved more satisfactory.

For convenience and speed, the circular plot has many advantages. Any method of describing a circle with a radius of 5.64 feet may be used to mark out the boundary of the plot.

THE ESTIMATE. Vegetation may be grouped into classes and data kept accordingly. Grouping may be done to whatever degree of refinement is desired; i.e., there may be as few or as many groups, according to the information desired and as the time available may warrant. For example, vegetation may be grouped into "weeds", grasses, and browse or it may be grouped by individual species or it may be restricted to the most dominant species.

With these groups in mind, estimates are made as to how much current growth of a given vegetation group equals one square foot of plant cover. The number of square feet of plant cover of that species or plant group are then counted and this number recorded on an especially prepared form. Estimates for other species or plant groups are then made and recorded.

The $\frac{1}{2}$ square foot may be the smallest fractional area of plant cover needed on an extensive survey, in which case the limits are $\frac{1}{4}$ square foot above and below each figure to be recorded. The limits, however, vary according to the needs of the survey and the agency using it.

PLOT SYSTEM AND REPLICATION. When the data are taken on one plot, estimates are then made on other plots located in a predetermined direction and distance-interval. Whether the interval is 100 feet, 0.1 mile, or 0.5 mile, depends on the intensity of the inventory, inasmuch as the method is adjustable to any intensity desired.

Two systems are used in laying out the position of plots. One is for obtaining a comparison of forage on various range units. More important, however, is the one in which a network of plots are set up over a given range to obtain a forage inventory, or to determine the volume of plant cover on a pasture or watershed and consequent grazing capacity.

COMPILING THE DATA. Since the original data are taken in square feet in plots of 100 square feet in an area, they read in percentages directly without calculation or adjustment. One simple mathematical addition and the pointing off of a decimal place keep the mean figures used much nearer to the observed data than is possible with the intricately "calculated" figures derived by the use of other methods. This use actually-obtained figures is a scientific advantage not to be overlooked. For example within a plot containing 100 square feet, a certain species of grass may completely cover 35 of the 100 square feet, or, in other words within that plot the grass species makes up 35 per cent of the total vegetative density.

In determining the forage factor, the following order of computation is observed: (See Form 2 in appendix)

1. Species densities are added for each plot and the total estimated density is recorded in the space provided on the field sheet.

2. Densities for individual species are added horizontally across the form for all plots within the forage type and the sums recorded in the total density column.

3. Total densities of species are added and this sum should equal the total of the plot densities.

4. Each total species density is divided by the number of plots in the type and the quotients recorded in the average density column.

5. The average density of each species is multiplied by its percentage palatability.

6. The products thus obtained are added to obtain the forage factor. This is expressed as forage acres per 100 surface acres and two decimal places are pointed off to the left to secure values expressed in terms of one surface acre.

ADVANTAGES OF THE METHOD. The advantages of this method of inventorying forage resources as set forth by Stewart and Hutchings (41) are as follows:

1. It has proved superior to the chart method and to the large estimate method.

2. It provides for a randomization and replication of plots which make it a sound method both biologically and statistically.

3. It is easy to learn and operate. Its time-saving qualities so greatly reduce the labor cost of providing replication and randomization that these two essential requirements of a good inventory can be fully met.

4. Forage inventories on both range and farm pastures can be made by the use of this method.

5. Surface soil erosion conditions can also be readily studied by using this method.

6. This method makes possible a statistical analysis of the data by probable errors, by analysis of variance, or by the correlation method.

DISADVANTAGES OF THE METHOD. The disadvantages of inventorying range forage by the use of this method are as follows:

1. This method does not take into account the volume of forage produced but is concerned only with the density.

2. There is error present when density estimates are made by this method which, as shown by Pickford and Reid (28) lies not so much in and between individuals as with the varying relationships between the density and the weight of different species. Since the relationship between the density and the herbage weight is not constant the error lies in the basic concept of the method and cannot easily be eliminated.

The work of Pickford and Reid (28) confirms that of Standing (36) who came to the conclusion that different species produce different amounts of herbage per unit area and that computed forage acres based on an inventory of plant cover density are greatly influenced by the species making up the cover.

3. The results obtained when an examiner samples the vegetative density for the purpose of securing the relative grazing capacity of a unit the large scale inventories are subject to utilization studies for the necessary adjustments. (28)

4. The number of plots necessary to accurately sample an area are too many to be economically feasible so that this method also gives only an indication instead of an exact figure. (28)

The number of plots necessary to sample an area or vegetative type depends upon the variation (standard deviation) within the type rather than the size of the type. On a 317 acre unit (where the variation is as much as is likely to be found on any western range area) Pickford and Reid (28) found that 562 plots would be required to estimate the forage factor within a 10 per cent sampling error (5 per cent limit), and to decrease this error to 5 per cent would have required 2,266 plots. However, if grazing capacity estimates are to be made on a larger area with conditions similar to those on the unit examined, it would be practical to do intensive sampling as the number of plots required for a 10 per cent error would be 56 per section according to Pickford and Reid.

The intensity of sampling by this method, therefore, varies according to the following: (28)

1. The desired accuracy of the sampling.

2. Size of the unit upon which the grazing capacity estimate is being made.

3. The existence of well-defined forage types.

4. The size and homogeneity of the type being sampled.

5. The number of forage types on the area.

<u>APPLICATION OF METHOD TO FORAGE INVENTORIES</u>. Aside from the basic weakness in the use of the forage-acre factor for grazing capacity determinations, error will arise from inadequacy of sampling and drawing type boundaries.

In compiling forage inventories, the usual procedure is to compute the forage acres enclosed within each type boundary. Thus the area within the type boundary is derived by planimetering and is multiplied by the forage-acre factor, giving the forage acres for the type. The sum of the forage acres on all types of the unit is used to compute the grazing capacity of the unit. On the forage type maps the capacity in animal months is entered on each type and, often, by sections. In following this standard procedure with many types the number of plots will be inadequate with a high probability of large error of sampling. This will be amplified by any error incurred by drawing type boundaries. The sum of such shaky figures would in itself be at error.

A method of compilation that will give more reliable grazing capacity figures and which will not materially increase compilation, was worked out by Pickford and Reid (28) as follows:

1. Field work is carried out in the regular way, plots being taken at equal intervals throughout the section, and at the same time drawing the type lines. Plots are classified according to types.

2. The grazing capacity of each type will be computed in the usual way, but the total forage-acre factor computed from all plots in each type will be carried forward to a subtotal for each unit and to a total for the entire area. From these subtotals and totals, average forage-acre factors for each unit and each area will be derived and used to determine their grazing capacities. By using this procedure, the most adequate sampling available would be used to determine the stocking and distribution within the allotment and would minimize the error incurred in drawing type lines. Grazing capacity by types would still be available when needed for management purposes.

The above method appears to be good from a practical and statistical standpoint when the forage type lines have been established by field mapping. However, there is no apparent advantage to be gained by the above method when forage types have been established by aerial surveys.

Volume Palatability Method

The difficulty with any forage inventory that uses the principle of density to establish estimates of grazing capacity is that, regardless of how accurately the density is measured, the results must always be reduced to an expression of range productivity in terms of forage acres. Pechanec and Pickford (26) found that *Carex filifolia* having 1.0 per cent density produced 6.7 per cent of the forage weight produced by the more robust *Agropyron dasystachium* although the density of the latter species was also 1.0 per cent.

Standing (36) pioneered in attempting to inject the weight of herbage production into grazing capacity estimates obtained by the density method. He determined the air-dry weight of herbage produced by range plants per unit area (10 square feet of ground cover) and then rated the species with reference to their comparative average weight of forage production. He then combined the volume rating with the palatability rating for each species and obtained what he termed "volume-palatability" of the range plants studied. Use of volume palatability ratings with densities obtained by either the reconnaissance or point-observation-plot methods of forage inventories resulted in a more uniform forage-acre value since weight of forage produced had been taken into consideration.

A comparison of the forage-acre factors resulting from the computations by this method and the reconnaissance method showed that certain types with browse and "weeds" predominating have forage factors considerably higher under the reconnaissance method, while selected types with grass predominating have forage-acre factors about the same under both methods. (36)

Weight Estimate Method

Pechanec and Pickford (26) object to expressing forage value in terms of forage acres because they felt it desirable and almost necessary to use the forage inventory, palatability ratings, and percentage utilization, all of which are essential measurements to be considered in a forage inventory, on the same unit. They further state that measurements of grazing use for example, when expressed in terms of utilization of a plane surface, are obscure and confusing both to the expert and to the layman.

In view of these objections to the density method, they proposed a method to measure forage production, as discussed by Davies (6) and adapted by Beruldsen and Morgan (1), Davies and Trumble (5), and Klapp (18). Various modifications of this method have been tried by other investigators. With this method, forage yield is sampled by clipping and weighing herbage from several randomized plots.

Percentage composition by weight is then estimated either from the clipped herbage or by regularly spaced repeated estimates of percentage productivity on unclipped areas. These figures applied to the yield from clipped plots, give the floristic composition of the sampled area in terms of yield. Data secured with this method have been proved accurate by Beruldsen and Morgan (1), and since an absolute check on estimates by weight analysis is possible, the method is widely used.

Pechanec and Pickford (26) present a modification of the percentage productivity method in that forage weights are obtained by estimation rather than by clipping and weighing, which would result in a greater speed and economy in taking the inventory. In tests, Pickford and Reid (28) found that, since forage yield is expressed in units of weight, the "weight estimate" method of determining forage production is more accurate and rapid, more indicative of forage yield than results of density estimates, and is subject to mechanical checking and more understandable by the expert and layman.

Further tests of the method by the Pacific Northwest Forest and Range Experiment Station (28) confirm the conclusions of Pechanec and Pickford (26), that weight of forage plants can be estimated with about the same degree of accuracy as can density.

<u>METHOD FOR FIELD USE</u>. No change is necessary in principles set forth by the point-observation-method for

use with weight estimates. Therefore, principles of plot size, location, and field plot technique need not be rediscussed. Yield and floristic composition of the total current growth, number, size, shape, location of plots depends upon the type of vegetation to be inventoried.

Equipment needed to conduct forage inventories by the weight-estimate method include a set of spring scales sensitive to the nearest 10 grams and small enough to conveniently carry in a pocket, a pair of scissors or shears with a 4- to 6-inch blade, a cloth or paper sack, and the ordinary equipment for marking out circular plots, recording data, and keeping direction.

First, an estimate of weight of one or several plants of a single species is made, attempting to define a 10-, 20-, 50-, or 100-gram unit. The herbage is counted in terms of such units. It is then clipped and weighed to determine the error of estimate. This process is repeated, adjustments being made to conform with the check weights for a particular area. One species is taken at a time.

Two difficulties encountered in the adaptability of the weight-estimate method, are, (1) the differences in herbage moisture content at different stages of growth and at the time of estimate in different years, and (2) the inaccuracies due to grazing of some of the herbage prior to the time of estimate, are overcome by the following methods: (26)

Herbage moisture content may be evaluated for all species by recording the green weight of herbage samples taken at times when daily checks are made and the weights after the samples have been oven-dried. If an oven is not available air-dry weights at the end of the season may be substituted. From these data the percentage moisture content of the herbage during the period of estimation can be calculated and the differences in estimated weights due to differences in moisture content can be adjusted between seasons, location, or year.

On grazed areas two methods may be followed in making adjustments for forage removal by grazing:

1. Estimate the herbage actually remaining on the ground and percentage utilization by weight. Adjustments in the forage inventory can then be made by the following formula:

$$\frac{\text{Weight of herbage remaining x 100}}{\text{100 - percentage utilization by weight}} = \text{Yield on the area if herbage was ungrazed.}$$

2. Where work is extensive and all possible accuracy is not desired, reconstruction of grazed portions may be made ocularly and estimates of weight made as on ungrazed areas. These figures are not subject to absolute check and are, therefore, less desirable than those obtained by the use of the first method.

<u>ANALYSIS</u>. Pickford and Reid (28) came to the following

conclusions regarding the use of the weight-estimate method over large areas:

1. The accumulation of figures ranging from five to thousands of grams per plot, introduced a bookkeeping problem beyond the limit to which a forage inventory crew should be burdened.

2. The results obtained are limited to an expression of the forage weight at the time the plot is examined.

3. Since weight of forage produced fluctuates greatly in different years as climatic conditions vary and, moreover, fluctuates importantly within a particular year as the plants grow and develop, weight estimates taken within a growing season or the average of estimates obtained for an entire growing season, may not give a true picture of the sustained productivity of the area in question.

4. The method is admirably suited to obtain yearly capacities of pastures or to study fluctuations in forage production, but for the purpose of establishing safe estimates of grazing capacity on range lands, where a million or more acres are involved, its static accuracy appears actually to be a liability.

5. It is also necessary in using the weight-estimate method to convert the green weights obtained to an air-dry basis. Because moisture content of herbage varies considerably between and within seasons, much calculation and measurement of a research character is needed to reduce

the weight estimations to an air-dry basis.

Proposed Density-Weight Method

Analyses of the data taken on the Crawfish allotment of the Whitman National Forest in 1937 by Pickford and Reid (28) revealed the possibility of calculating average weight of herbage produced from plant densities obtained by the point-observation-plot method of making forage inventories. Average density and average green weight of herbage per plot for the species worked upon, together with the correlation coefficients of density with green weight were presented in tabular form. These species made up 92 per cent of the forage on the experimental area studied.

The study revealed that there was a strong and positive linear correlation between increase in density of a particular species and increase in the weight of its herbage production. Such being the case, Pickford and Reid assumed that it should be possible to compute, by means of regression, the weight of forage production of a given species from estimates of its density. Regression coefficients and density / weight coefficients were designed for the 24 species studied. Density / weight coefficients were multiplied by the palatability ratings to express them in terms of pounds of palatable forage produced.

FIELD APPLICATION OF PROPOSED METHOD. The application of the proposed method to field conditions is as follows:

Assume that the density estimations on ten 100-square-foot plots within a 100-acre pasture have been made by the point-observation-plot method. For simplicity, say that a total of 11 square feet of Achillea lanulosa and 21 square feet of Stipa columbiana have been found. According to the table compiled by Pickford and Reid (28) one square foot of Achillea lanulosa is equivalent to 15.1 pounds. The 10 additional square feet are equivalent to 167 pounds. Similarly, the first square foot of Stipa columbiana equals 31.3 pounds and the 20 additional feet total 428 pounds. For the 10 plots therefore, there are 641.4 pounds of calculated palatable forage which, divided by the number of plots involved, gives 64.14 pounds per plot. According to the formula, pounds per plot equal pounds per acre. Therefore, palatable forage production in the 100-acre pasture is computed to be 64.14 x 100 or 6,414 pounds.

ANALYSIS. It seems unreasonable that the first square foot of Stipa columbiana should weigh 31.3 pounds and that additional feet should weigh only 21.4 pounds. Clearly, the value of additional square feet of density should be equivalent to that of the first square foot. Additional data may improve the slope of the regression lines so that this will prove actually to be the case; on this point the ultimate feasibility of the method depends. (28)

Assuming that this difficulty can be ironed out with more adequate density-weight data for each species, the value of the method as now foreseen is as follows: (28)

1. Palatable dry-weight production of forage species, with the element of climatic fluctuation largely eliminated through obtaining coefficients over a period of years, may be estimated directly from density, thus eliminating to a large extent the undesirable static quality of grazing-capacity estimates by the weight- estimate method.

2. The process of obtaining weight of herbage production is simplified by using the coefficients which are already in terms of dry forage, thus eliminating necessity of procuring shrinkage value of the forage throughout the season.

3. The converting of field data is greatly simplified by the fact that average density may be converted to pounds of dry forage per acre by one multiplication process, thus eliminating handling of the large figures that grams-per-plot estimates yield.

4. The results of the density-weight method should be more indicative of the productivity of forage types since the weight produced is not estimated directly from the forage volume of the plot but is computed from the density present at the time the plot is estimated, together with the coefficient representing average air-dry weights of the particular species. This in reality has the same

basic theory as Standing's volume-palatability method except that the results are in pounds per acre rather than in forage acres.

The values derived from the density-weight method will be subject to much the same fluctuation in terms of forage requirment that are now encountered in other inventory methods, since density is a fluctuating quantity and, as previously pointed out, forage values of one species are not the same as forage values of the same amount of another species. The results, however, should be as uniform as those obtained by the volume-palatability method and should be more usable to range administration than those obtained by the weight-estimate method. An adequate comparison with other inventory methods to check its relative accuracy and usefulness is necessary.

Comparison of Results from four Methods of Estimating Grazing Capacity

Based on 507 plots studied on the Crawfish allotment in 1937, Pickford and Reid (28) made a comparison of results from four methods of estimating grazing capacity.

Grazing capacity was computed by using the utilization study as a base. Requirement factors for estimating grazing capacity by the following inventory methods were calculated:

1. Density estimates by the point-observation-plot method.

2. Volume-palatability as applied to the point-obser-

vation-plot method.

3. Weight-estimate method.

4. Density-weight method.

Using the requirement factors so derived, the results of the four methods in the three allotment units were compared with grazing capacities derived from utilization.

It is of interest to note (TABLE VI) that the volume palatability and the density-weight estimates of grazing capacity deviated furthest from the actual capacity as computed from utilization studies.

Of the four methods, the weight-estimate method was the most accurate, with density, as estimated by the point-observation-plot methods, yielding next to the best results. It appears from these results that it is a mistake to attempt to inject weight or volume into density estimates. However, Pickford and Reid (28) state the test was made under conditions that were ideal for applying the weight-estimate method in that the inventory was immediately followed by grazing. More complete data on density / weight coefficients and on volume-palatability ratings might substantially reduce the error in these methods. From present data, it is also impossible to conclude that the density as estimated by the point-observation-plot method is more inaccurate than other methods of making forage inventories. They believe that more study of the methods is essential to rate their efficiency.

TABLE VI

COMPARISON OF GRAZING-CAPACITY ESTIMATES FROM FOUR SURVEY METHODS
(After Pickford & Reid)

Unit	Grazing Capacity From Utilization Study (Sheep Days)	Grazing-Capacity Estimates By Inventory Method (Sheep Days)				Deviation Estimated Grazing Capacity From Actual (Sheep Days)			
		Density	Volume Palatability	Weight Estimate	Density Weight	Density	Volume Palatability	Weight Estimate	Density Weight
1	3,563	2,563	2,660	2,915	2,599	-1,000	-903	-648	964
2	4,946	5,716	5,883	5,588	6,019	+ 770	+937	+642	1,073
3	3,371	3,611	3,361	3,343	3,270	+ 240	- 10	- 28	101
Tot.	11,880	11,890	11,904	11,888	11,846	2,010 1/	1,850 1/	1,318 1/	2,138 1/

1/ Disregarding Algebraic Signs

UTILIZATION DETERMINATION METHODS

The proper utilization of range forage plants is the primary problem with which the livestock operator and range examiner has to contend in using and preserving the forage and range resources.

Utilization

Utilization is expressed in per cent. When herbaceous plants have been grazed down to the ground they are considered 100 per cent utilized. An exception will be made in the case of species with tough, coarse stems, such as *Senecio serra*, *Rudbeckia*, etc. When the leaves, side branches, and ends of the main stems of such plants have been fully grazed they are considered as 100 per cent utilized. When the leaves and current season's twig growth readily accessible to stock have been taken from shrubby plants, they are considered 100 per cent utilized.

Key Areas

Key areas are used as a basis for degree of stocking, and as places on which to estimate degree of utilization, trends in plant cover, and condition of the range. The most heavily grazed areas should not always be used as key areas, since these are isolated or small areas on which stock congregate where overgrazing may logically be tolerated in order to make reasonable use of surrounding areas. Key areas may vary in size from just a few to to several hundred acres. Key areas since they are the portions of a unit upon which management is concentrated are used for the following purposes: (47)

1. Judging range conditions of the unit.
2. Judging utilization of key species.
3. Determining vegetative readiness or seed maturity.
4. Investigative studies.
5. Basing grazing capacity.

Key Species

On these key areas are "key species" upon which utilization and management may be based. If the key species maintain themselves or increase in abundance, the forage will usually be maintained in a satisfactory condition. Special checks are made to determine extent of utilization, trend of forage conditions as determined by vigor, number and use made of these particular plants.

In the southwest, for example, Campbell (3) found that black grama (Bouteloua eriopoda) cannot withstand the annual removal of stems and leaves to a height of two inches. Other studies of grazing capacity and natural revegetation indicate that proper utilization of black grama should leave a stubble of approximately 15 to 20 per cent of all the vertical stems and all the horizontal stolons, since the principle means of starting new plants is through vegetative reproduction. On more compact soils, or under higher rainfall, the plants appear able to withstand a closer degree of utilization.

These plants may vary with the class of stock grazed, but to be of most practical use key species must possess the following characteristics: (47)

1. Be above average palatability to livestock.
2. Have about the same palatability-utilization.
3. Not be "ice cream" plants.
4. Be fairly abundant on the area or potentially so.
5. Have fair ability to withstand grazing injury.
6. Be perennials.
7. Be suited to class of stock grazed.

From three to six species are ordinarily selected as key species on each key area. However, under some circumstances one species may predominate in a forage type and management may be based upon it. If a range is managed in such a way that these species are able to maintain themselves, or increase in plant cover, the other plants can safely be left to care for themselves.

Key species are used for the following purposes: (47)

1. Checking on utilization during the grazing season.
2. Determination of utilization at close of season.
3. Range study programs.
4. Determination of vegetative readiness or palatability-utilization factor tables.

7. Basis for determination of grazing capacity.

Utilization Standards

Standing (37) writes that the figure used as the correct degree of use under proper stocking is 75 or 80 per cent utilization of the more palatable plants. If overgrazing causes less palatable species to be grazed 75 or 80 per cent, the highly palatable species will be completely utilized and range depletion will ensue. This figure of 75 or 80 per cent utilization is the best figure available and has some basis in experience and experimentation. There is good evidence that the degree of utilization should be varied with localities due to changes in soil, elevation, and amount and kind of precipitation. Degree of utilization should also probably vary with individual species. Different standards are not only needed for different species and different localities, but for the same species in the same locality.

The following questions should be answered in setting up standards of utilization on any range unit: (3)

1. What are the species furnishing most of the forage at different seasons of the year?

2. What are their life histories and how do different classes of livestock relish them?

3. What is the natural succession, how is it affected by varying degrees of grazing and what stage can or should be maintained under grazing use?

4. Even when proper utilization has been determined for a species or type under one set of conditions, what adjustments are necessary when the type is deplete severely, and what precautions are necessary for extreme drought or where special land services, such as watershed protection, timber production or wildlife, are important or dominant?

5. What are the absolute or relative nutritive values or poisonous properties involved.

Range Unit Inspection

A system for recording information garnered on an inspection of a range unit has been developed by the U. S. Forest Service so that it may be incorporated directly into the management plan. It consists principally of a letter-size map and overlay of the unit on a 2-inch scale. The map shows topography, cultural features, allotment boundaries, unit distribution boundaries, present and proposed range improvements, salt grounds and other information which might influence the use of the area by livestock. If a forage inventory has been made of the area, the forage types are also shown in standard color. (47)

The overlay is of tracing paper and is new each year. On it are shown the allotment and distribution unit lines. While the inspector traverses the allotment he charts such information as his route of travel, date of trip, over-grazed areas, critical areas, unutilized areas, abused bed-grounds and number of nights use, rodent infested areas, recommended allotment and distribution boundary changes and any other information influencing the use of the area by livestock.

PROBLEMS OF DETERMINING UTILIZATION. The selection of areas and plants, the soil condition to be used, standards to be employed, method of training and the application of these principles confront the examiner in his effort to determine utilization.(47)

Lantow (20) believes the following factors as worthy of important consideration in determining the utilization on range areas:

1. The method of use on the area -- yearlong, deferred, or rotation.

2. The variation in established palatabilities. These variations may be due to the combination of species within the pasture, or to the time of use.

3. The time element; that is, the amount of the time period that has been utilized previous to the utilization inventory and the amount of the use period that remains.

4. Regrowth following the normal growing period.

5. Numbers, kinds, and classes of livestock.

6. Time of range readiness or condition.

7. Percentage of use of principle palatable species.

8. Cut in carrying capacity for protection of soil and plant vigor.

9. Seasonal adjustments in management.
10. The amount of reserve left for erosion protection.
11. Any changes in pastures, boundaries, or acreages.

Methods of Determining Utilization

On land that requires 20 to 100 acres to support an animal unit, the area that can be inspected by a single individual is very small, consequently, making it difficult to determine the actual degree of utilization from year to year. With the exception of very small study plots, degree of utilization is generally determined by judgment acquired from experience. However, when continued productivity or gradual death of good forage grass may depend upon a difference of 10 percent in foliage removal, a more accurate method of determining utilization is necessary.

Several methods of determining percentage utilization are used more or less commonly by range investigators in pasture and open range studies.

GENERAL RECONNAISSANCE METHOD. With the general reconnaissance method, the investigator inspects an area of several hundred to several thousand acres, more or less in detail, making estimates of utilization for the entire unit either for all vegetation or by individual species. These estimates are made of the percentages of total plant height or volume production removed by grazing. Because the accuracy of such estimates varies considerably according to the individual making them (even with the same individual at different times) some modifications of the general reconnaissance method have been tried. The principal modification has been a method in which the percentage of plants grazed, and percentage of grazed plants taken are estimated, the product of these two figures being regarded as percentage utilization. (27)

This method is particularly well adapted to grass species with a growth habit similar to bluebunch wheatgrass (Agropyron spicatum), slender wheatgrass (Agropyron smithii), and mountain bromegrass (Bromus polyanthus). To apply it, the stems of the grazed plant or plants to be studied are divided into "grazed classes" or groups of stems having the same stubble height, and the per cent of the total estimated for each grazed class. When this has been done the per cent utilization of each grazed class of stems is estimated and the per cent utilization of the whole weighted in the following manner: (47)

Per cent of grazed plant in each class		Per cent utilization of each grazed class		
30	x	20	=	6.00
40	x	60	=	24.00
10	x	80	=	8.00
20	x	0	=	0.00
				38.00% Utilization

MEASUREMENT METHOD. The measurement method is based on the premise that percentage utilization of grasses is equal to the reduction in average leaf height as a result of grazing. Under grazing conditions two variations of the method can be used, dependent upon the time and duration of the grazing period.

1. If grazing occurs during the period of rapid height growth of the grasses and is of such duration that growth during the intervening period is appreciable, the use of temporary enclosures is necessitated. After grazing, the difference between the average basal leaf height of grasses in several enclosures selected at random and on an equal number of grazed plots is taken to represent removal from which percentage utilization can be calculated.

2. When grazing occurs after growth has ceased or when it is negligible during the growing period, measurements taken at random either on plots or transects before and after grazing can be used to form the basis for the calculation of percentage utilization. (27)

VOLUME BY WEIGHT METHOD. The volume by weight method, used in pasture studies by Beruldsen and Morgan (1) is based on the assumption that percentage utilization of grasses is equal to the percentage reduction that occurs in volume by weight of herbage on an area, as a result of grazing. Two sets of randomized plots are required for study of utilization by this method, the one set protected from grazing and the other grazed. On the protected set, A, herbage is removed by clipping. Herbage from the other set, B, left open to grazing, is removed by clipping as soon as grazing of the area has been completed. Air-dry weights of the herbage from the two series of plots are obtained. It is assumed that the difference in productivity between the grazed and ungrazed plots is due to grazing and it is upon this basis that utilization is calculated. (27)

$$\frac{\text{Weight of forage from grazed plot x 100}}{\text{Weight of forage from ungrazed plot}} = \text{per cent utilization.}$$

To use this method successfully it is necessary that the type in which the plots are located be uniform in composition and density. It possesses, however, two very desirable features, simplicity and elimination of personal error. (27)

VOLUME BY WEIGHT OF INDIVIDUAL PLANT METHOD. This, in reality, is only a modification of the volume by weight method and is used only for the training of examiners in the majority of cases. As the name implies, it is applied to the individual plant. Ungrazed plants are selected and grazing simulated by clipping, the weight of the herbage removed being recorded. The per cent utilization is then estimated and the plant clipped to 100 per cent utilization. The herbage is weighed and the utilization calculated as follows: (47)

$$\frac{\text{Weight of herbage removed first clipping x 100}}{\text{Total weight of herbage removed}} = \text{percent utilization.}$$

STEM COUNT METHOD. Stoddart (43) advocates the use of the stem count method on ranges where Agropyron smithii is predominant. This method is based on the premise that percentage utilization varies directly with the percentage of the total number of stems that are grazed. It merely requires a count of grazed and ungrazed stems on randomized plots. From this count, degree of utilization is computed, using the proportion of grazed stems as the per cent utilized.

The per cent of total stems grazed is calculated as follows:

$$\frac{\text{Number of stems grazed x 100}}{\text{Number grazed stems + number ungrazed stems}} = \text{per cent utilization}$$

Pechanec (25) found that results from the use of the stem count method were unreliable, especially for the lower intensities of utilization. The method presupposes reasonably complete removal of the herbage from each stem grazed, which according to Pechanec, is not the case under normal grazing conditions.

This method, with three others, was tested on a thickspike wheatgrass (<u>Agropyron</u> <u>dasystachium</u>) in Idaho. The results of this test are shown in TABLE VII.

As shown in the table the stem-count method was the only method which differed greatly from the actual percentage of volume removed. Odds are 9999 to 1 that the difference of 28.7 per cent between the means of the actual volume removed and the stem-count method is significant. Since odds of 100 to 1 are considered statistically significant,

TABLE VII

COMPARISON OF METHODS OF DETERMINING UTILIZATION
(After Pechanec)

	Volume (Check)	Stem Count	Measurement	Ocular By Individuals 1	2	3
Percentage Utilization	41.35	70.05	42.10	39.00	42.50	41.75
Difference		28.70	.75	- 2.35	1.15	.40
Odds of Significance		9999	2.00	8.68	2.00	2.00
Range in Difference		13 to 53	-27 to 16	-20 to 17	-15 to 18	-20 to 26

it is safe to assume that the large difference between the stem-count method and the actual volume removed is real and not due to chance. In comparison odds are very low (less than 10 to 1) that the differences between the means of the measurement method or the ocular estimate method and actual volume removed are significant. The data show that these two methods, as indicated, closely approximate the actual volume removed. With the stem-count method on a unit unclipped except for a few plants, the difference was only 13 per cent, whereas on another unit, lightly but uniformly clipped, the difference was as great as 53 per cent. Differences however, were consistently positive; that is, the percentage utilization derived from the stem-count method in all cases was higher than the actual volume removed. These differences are largely due to the fact that the stems grazed were not completely utilized. Because complete removal is the premise upon which the method is based its mechanics are at fault.

Ranges in differences of the measurement and ocular methods are equally as great as that of the stem-count, but since the errors are in personal estimates rather than the mechanics of the method they tend to be compensating and can be corrected.

OCULAR ESTIMATE-BY-PLOT METHOD. The ocular estimate-by-plot method, a modification of the general reconnaissance method, was developed and adapted for use on grasses at the U. S. Sheep Experiment Station in 1933. (27) It differs from the former 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.

Plots, preferably of 100 square feet, are systematically located at definite intervals along one or more transect lines completely traversing rather than attempting to pick out a transect which is thought to represent average conditions. The minimum number of plots to be used in sampling will vary with the size of the area. The following is the suggested minimum for key areas of various acreages: (47)

5 plots for areas of 20 acres or less.

8 plots for areas of 20 to 80 acres.

10 plots for areas over 80 acres.

In arriving at an average percentage utilization for each plot the following example is given:

Key Species	Per cent of Total Plant Cover		Average Per cent Utilization	
Agropyron spicatum	20	x	50	= 10.00
Festuca idahoensis	15	x	40	= 6.00
Achillea lanulosa	10	x	60	= 6.00
Chrysothamnus spp.	8	x	0	= 0.00
	53			22.00

$\frac{22.00}{53} =$ 41.50 per cent utilization for the plot. An average for the unit, both for individual species and average utilization per plot, is derived by dividing the total for all plots by the number of plots.

Pickford and Pechanec (27) found that by confining observations to smaller areas, adequately replicated, rather consistent results between individual workers have been obtained. In their opinion this method embodies four desirable features:

1. Observations are limited to a small area which makes possible more accurate decision.

2. Errors in personal judgment on individual plots frequently tend to be compensating.

3. Errors incurred when study areas are selected as being representative are eliminated.

4. Data collected can be subject to statistical analysis.

5. Data collected from these randomized samples are valuable in studying distribution on grazing areas.

OBSERVATION ON SELECTED AREAS METHOD. The method of observation on selected areas is not concerned with mechanical selection at any space interval. A careful examination is made of the key species on a number of small areas, not necessarily delimited as a plot, which are selected at various sites throughout the type. An average per cent utilization for individual key species is recorded at each selected point of observation and an average per cent utilization for the area is calculated from these values.

SINGLE PLANT OBSERVATION METHOD. In the single plant observation method, plants are estimated at specific intervals along one or more transects to completely cover a forage type. This method consists of the following procedure:

1. Selection of a transect or transects to completely cover an area in two or more places.

2. At a predetermined space interval, single plants nearest the foot marking the space interval are examined.

3. Per cent utilization is recorded for each individual plant at each station.

4. Average per cent utilization is computed for each species.

5. Per cent utilization of the area is derived by computing the arithmetic average of all species.

UNIT LEAF-COUNT METHOD. The unit-leaf count method is well adapted for "weeds", such species, for example, as *Senecio serra*, *Rudbeckia occidentalis*, etc. but it cannot be used on all broadleaf herbs. Since on most weeds all leaves are not the same size it is advisable to select a leaf of about average size to use as a unit. After selection of the leaf unit the remaining leaf units should be counted then those grazed should be counted as accurately as possible. Utilization is calculated as follows:(47)

$$\frac{\text{Leaf units taken} \times 100}{\text{Total leaf units}} = \text{per cent utilization.}$$

CHARACTERISTICS ESSENTIAL TO A DESIRABLE METHOD. Pickford and Pechanec (27) set forth the following qualifications for a satisfactory method of determining percentage utilization of grasses: (These qualifications may well be applied as a standard by which percentage utilization is determined on other classes of vegetation as well.)

1. Rapidity in conducting observations is necessary if enough replications are to be obtained to sample an area adequately where soil heterogeneity and differences in individual plant growth are augmented by irregularities in utilization. Slow laborious methods prevent this adequate replication.

2. Accuracy not only requires minimum error in the average of several determinations, but also a close correlation between individual determinations and actual

volume removal. Freedom from personal error is one of the major factors in accuracy. With studies of long duration and changing personnel, errors of individual determinations are of major importance and frequently are of such magnitude as to destroy evidence of small changes in grazing capacity.

3. Adaptability, although not a factor of material importance with grasses along, is particularly important where studies are being conducted on vegetation composed of mixed grasses, "weeds", and shrubs, and where one method must be used to obtain percentages for all groups. Methods devised for one species are not always fully desirable for others.

COMPARISON OF METHODS OF DETERMINING UTILIZATION. A study conducted by Pickford and Pechanec (27) on a sagebrush-wheatgrass range in which bluebunch wheatgrass (*Agropyron spicatum*) and threetip sagebrush (*Artemesia tripartita*) were the principal species. Bluebunch wheatgrass was used in testing the measurement, stem-count, ocular-estimate-by-plot, and ocular-estimate-by-average-of-plants methods of determining percentage utilization. They concluded from their results that:

1. The ocular-estimate-by-plot method may be very useful in range and pasture studies if a frequent check is maintained between individual estimates and with the actual percentage removal as determined with the modified volume-by-weight method.

2. The ocular-estimate-by-average-of-plants method is rapid, reduces personal error appreciably, is relatively accurate and is sensitive to fluctuations in actual utilization. From the data presented, this method is shown to be probably the most worthy of study and development.

3. The stem-count method is neither sufficiently accurate nor rapid to justify its use on bunchgrasses.

4. Owing to its lack of rapidity the measurement method is not recommended for general use. It is not of sufficient accuracy to be used as check on ocular estimates.

5. Because of the labor involved in individual determinations and the use of paired plots, the volume-by-weight method is not justifiable for use under actual range practices. The method is, however, valuable for use as a check on the accuracy of estimates by other methods.

6. From data and analyses presented they recommend that the ocular-estimate-by-plot method of determining percentage utilization, supplemented with determinations made by the modified volume-by-weight method, be considered for use in range pasture or open range studies.

SUMMARY AND CONCLUSIONS

A survey of the literature on methods of making forage inventories was made by the writer. The methods were listed under headings as ecological research methods, large-scale inventory methods, and utilization determination methods.

Ecological research methods are used primarily in studying, in detail, the composition and structure of vegetation and the effect of environmental factors, especially grazing, upon it.

Large-scale methods are used primarily to determine the maximum number of grazing animals a range unit will support on a sustained yield basis. At most, the large-scale methods furnish only an indication of the grazing capacity and should by no means be considered as exact measurement methods.

Utilization determination methods are intimately associated with the large-scale inventory methods in that they are used to check on the grazing capacity figures arrived at by these methods.

Range forage inventories must be made on an extensive scale which accordingly necessitates the use of estimation; the use of actual measurement being practically impossible, and, in fact, unnecessary. Vast acreages must be inventoried in the relatively short space of the growing season.

In the opinion and experience of the author, estimates should be based on productivity of the area in terms of volume of forage produced instead of forage acres. Since the large-scale method must, of necessity, use estimation as the basis of the forage inventory, efforts should be made to standardize the estimates so that they may be universally applicable wherever there is a need for the determination of grazing capacity. A program of training individuals who are to inventory range forage should be agreed upon and formulated by all the agencies and institutions concerned with the administration of grazing upon the forage-producing range lands of the west; namely, governmental administrative and research agencies, and schools and colleges preparing individuals as administrators of public or private grazing lands.

FORM 1

Form 764a
(Revised Mar., 1924)

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Examiner John Doe Date May 2, 1939

Sec. 24 T. 11 N R. 6 E Timber None (Composition) (Condition)

Type 5 - Ptr - Asp (Age) (Market class)

Range vegetation .45 (Density) .375 (% Pal) (Reproduction) (Density) (Age)

F. A. Factor .269 For C & H (Injury) (Cause)

PRINCIPAL SPECIES

Weeds % 25	Amt. In %	Amt. X Pal.	Grasses % Grasslike Plants % 30	Amt. In %	Amt. X Pal.	Shrubs % 45	Amt. In %	Amt. X Pal.
Ala	10	.030	Asp	20	.140	Ptr	25	.100
Bsa	10	.040	Fid	4	.024	Atr	10	.005
ERO	5	.000	Psc	6	.036	CHR	5	.000
	25	.070		30	.200	Cld	5	.000
							45	.105
Weeds	25	.070						
Grasses	30	.200						
Shrubs	45	.105						
	100	.375						

TYPE COMMENT

Poisonous plants None (Species and location)

(Abundance) (Losses)

Watering places Bear Creek (Nearest available) (Lake, spring, tank)

Permanent (Temporary or permanent) (If temporary, state usable period)

Proper grazing season Spring - Fall (Reasons)

Cattle and Horses (Class of stock best suited to range)

Utilization Overutilized (In former year) 82% (Present year in %)

Unit overstocked (Reasons for unsatisfactory conditions)

Recommendations and conclusions Place salt grounds on ridges (Bed or salt grounds)

Adjust numbers to utilize area 75% (Adjustments needed)

Troughs at springs. Drift fence (Range improvements needed)

None (Other remarks)

8—5169 [OVER]

FORM 2

Form WR-216 c
U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL ADJUSTMENT ADMINISTRATION
WESTERN DIVISION

None
(State and county code and ranch serial number)

RANGE SURVEY FIELD SHEET
(Point Observation Plot Method)

Ranching unit Squaw Butte

Examiner J. E. Doe

Type 5 - Ptr - Asp

Avg. density 20.2 Avg. % Pal.

F. A. factor .0878 For C - H (C. and H. or S. and G.)

Transect No. 2

Date May 2, 1939

Location Sect. 23, T 40 S, R50 E (Section, township, and range—aerial photo number)

Grazing capacity ______ Animal months ______ Animal units ______

Utilization cuts: Slope ____%, timber ____%, rocks ____%, lack of water ____%, erosion ____%, unstable soils ____% Total cut ______

SPECIES DENSITY

	Plot Number 1	2	3	4	5	6	7	8	9	10	Total specie density	Average density	× Palatability
Density	27.0	13.5	17.5	23.0	32.0	17.5	16.5	24.5	13.5	17.0	202.0	20.20	08.7825
Species													
Asp	7.5	3.0	6.0	3.5	10.0	6.0	1.5	4.0	3.0	5.0	49.5	4.95	3.4650
Fid	.5		3.0	2.5	4.0	3.5			1.5	3.5	18.5	1.85	1.1100
Psc	.5	1.0	.5	1.5	3.0		3.0	1.5	.5	.5	12.0	1.20	.7200
Ala	1.0	.5		1.5	2.0	1.0	2.5	3.0	.5	.5	12.5	1.25	.3750
Bsa	5.0	1.0	3.0	5.5	6.0	2.5	6.5	8.0	2.5	.5	40.5	4.05	1.6200
ERO	.5			2.0	2.0		2.0		.5	1.0	8.0	.80	.0000
Ptr	6.5	4.0	1.5	3.5	5.0	1.0		6.0	3.5	4.0	35.0	3.50	1.4000
Atr	3.5	3.0	3.0	2.0		3.5	1.0		.5	2.0	18.5	1.85	.0925
CHR	2.0	1.0	.5	1.0				2.0	1.0		7.5	.75	.0000
Total density all species											202.0		

8—11675

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