THE QUADRAT METHOD AS APPLIED TO INVESTIGATIONS IN FORESTRY.*

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It is the aim of phytogeographers as well as descriptive and ecomonic ecologists, I believe, to determine as definitely as possible the relationship existing between plant associations or other vegetative units and their environment. The role which the quadrat method of study plays in the incidence of the environmental factors and the corresponding adjustment of the vegetation, while indirectly determined, is of high significance under varied field conditions. Its importance may probably best be appreciated by first pointing out the complications involved in the study of the direct influence of the physical factors upon vegetation.

Relation of Habitat Factors to Vegetation.

The habitat of a plant is admittedly a rather indefinite thing so far as concerns the factors which have to do with the limitations and causations of life processes. While the structural ecologist has shown fairly conclusively that a given plant association has well defined geographical limits, which, in turn, are represented by rather distinct complexes of environmental conditions, he has not, as yet, determined which factor or set of factors are most influential in affecting association limitations or physiological functions. Before this can be done, as pointed out by Livingston,** the potent factors making up a given environment (the controlling factors would not be the same in the case of all habitats) must be recognized; and once they are known, the part they play in affecting readjustment of the internal and external structure of the plant, and thus in affecting distribution, must be determined.

Obviously for purposes of study, the complexes of the environmental factors must be reduced to their simplest form, a matter which may be accomplished by maintaining constant all

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**Livingston, B. E. and G. J., Bot. Gaz. 56: 349-375, 1913.

but the factor investigated, and the effectiveness of each determined. This being done, their influence must be integrated; and further, since under natural conditions climatic factors vary widely both in intensity and in duration, facts of the highest importance to life processes yet often overlooked by junior investigators, such variations must be taken strictly into account. For example, a temperature of three or four degrees below freezing lasting for only an hour or so is not necessarily detrimental to the plant, whereas, if the same low temperature maintains for several hours part or all of the superficial plant tissues may be killed. On the other hand, freezing temperatures of relatively short duration coupled with *high winds* may be fully as harmful as noticably longer periods of similar minimum temperatures.

From the foregoing it is apparent that the direct determination of the response of vegetation to the controlling factors is a problem of such detailed and far-reaching potentialities as to involve not only infinitely more time than most field botanists can devote to the problem but of necessity elaborate and costly laboratory and field equipment. Further, a problem of this character is hardly to be solved by a single investigator. It is a study in which the plant ecologist, the physiologist, the morphologist, the taxonomist, the physicist and the chemist might well cooperate.

The quadrat method of noting the correspondence between habitat factors and vegetation while somewhat superficial, but nevertheless reliable, may be used by any investigator. This method of study, while tedious because of the necessary detail involved, presents ocularly the integrated relationship existing between the factors of the habitat and the vegetation. While this correspondence may be more or less apparent to the *experienced* physiologist and ecologist absolute invasional and successional figures so essential to purely scientific studies and to the practical management of lands are not available without a detailed "pictorial" account of the vegetative structure and compositional changes. The readiest methods available by means of which to obtain these data are briefly stated.

Application and Establishment of Permanent Sample Plots.

The use of experimental plots, as applied in forestry investigations, consists, in general, more of applying quadrat methods of noting relative vegetative progression than of establishing definite square units of vegetation. While the square unit (the quadrat if that cognomen is desired) is sometimes used, experience has taught the forester that the square unit of definite dimensions is not generally adapted to conditions under which he is working due to superficial obstacles as well as for other reasons. The shape and size of the vegetative plot may be square, rectangular or even irregular, this being almost wholly determined by the nature of the investigation, character of the vegetation, the surface, whether regular or irregular, and the detail necessary in obtaining results. As a concrete example,—a permanent woodlot sample plot may consist of several acres of land, the topographic features and striking vegetative characters of which may be recorded in a more or less general way. Within the major plot detailed sample sub-plots of varying size, from two or three feet or a meter square (quadrat) to a rectangular or irregular area many times the size of the meter quadrat, may be established in various places. The main plot may be blocked off into convenient segments for general study and the sub-plots within the former similarly segregated to suit the detailed conditions of the investigations.

Kinds and Use of Different Plots.

Use is commonly made of what ecologists generally recognize as (1) the chart plot, which, as the reader will recall, derives its name from the fact that the species making up the vegetative cover within the boundary of the square or rectangle are located *in situ;* (2) the list quadrat in which the abundance and composition of the vegetative cover within the limits of the plot are recorded or listed usually regardless of location and relationship; (3) the depopulated plot in which the vegetation is removed in varying degrees to total denudation. "Cleared," "thinned," and other names are given to sample plots according to the method of removal used, but these terms are embodied in the designation of "depopulated" plots.

The forester makes use of the three kinds of plots above mentioned in varying applied ways; but since the types of vegetation and scope of investigations are greatly varied, having to do with herbaceous as well as with shrubby and arborescent vegetation, his methods are probably more specialized, intensive as well as extensive, than are those of the ecologist interested primarily in ascertaining the relative rank of the plants in making up his species or generic list of gregarious, sub-gregarious and other density vegetative relationships. Since field studies of this kind are still in a formative state, a brief discussion of the way in which chart, list and depopulated plots are applied and what results may be obtained may be of value to other workers.

Chart Plots:—When this plot is used, as it often is on areas where herbaceous or arborescent reproduction is being studied, either all vegetation within the sample is charted or account is taken only of the species under specific study in the investigation at hand. The amount of work involved in charting all of the vegetation within a given unit is generally, of course, many times greater than when only one or more predominant or commercially valuable species are recorded. Mapping of all the vegetation within the plot, therefore, is avoided where practicable. When a single important species in an association is charted it is possible to establish a comparatively large plot, as will be shown in actual practice later, since the work involved in recording is curtailed by avoiding the mapping of all species. By the extension of the plot more data may be obtained relative to the behavior of a few species than where more detailed and smaller plots are established.

In order to determine to what extent a species succeeds in competing with its neighbors, the associated species are merely listed and notes taken with great care to show the density of stand and association with secondary vegetation in various parts of the plot. Such records, among other things, usually throw light on the success or failure of the seed reaching the mineral soil and the role of plant competition in the establishment of reproduction. The majority of these sample plots, as previously stated, generally take the shape of quadrangles rather than of quadrats, though, indeed, the latter are sometimes used.

List Plots:—This form of plot is used by most investigators merely to determine the composition and density of species within a plant unit. A record of such general character, however, affords little or no data of value upon which to base a rational and judicious plan for forest or range management, and its use in successional and distributional studies is often overestimated.

A method of mapping which affords the desired detail and at the same time lessens the work necessarily involved in making regular "location" chart plots is that of combining the chart and list plot. In the establishment of such a combined sample plot the exact number of individual specimens is obtained per hundredth unit of the plot, the scale used in plotting practically all vegetative units, and the data are obtained precisely as described in the case of the chart quadrat, a matter which will be discussed later, except that the total number of each species occurring within the unit is given in figures in that unit quite regardless of exact location. For example, if there are 14 specimens of *Poa scabrella*, 7 of *Stipa occidentalis* and 30 of *Polygonum douglasii* within one-hundredth unit of the plot, the vegetation would be listed as p-14, s-7, po-30, one under the other, respectively, within the unit or division in which these plants occur. (See Plot No. 26.) From such detail it is possible to ascertain at any future time the changes in the vegetative personnel, the density, as well as other facts within any hundredth unit of the plot or in the plot as a whole.

Depopulated Plots:—Vegetative depopulation is of much value in the study of numerous plant activities which might figure in the ultimate management of one or several species. Often the results from artificial depopulation apply more or less directly to field conditions in so far as they throw light on the ultimate management of cut-over and slightly depleted and denuded lands. Radical changes in the personnel of a type, for example, commonly take place as a result of the application of one of the thinning or clear cutting methods, through logging, or as a result of forest fires. Likewise the herbaceous vegetation is readily affected by mismanagement in the handling of range stock. As a result of overgrazing, even if only for a short time, the vegetative "personnel" may be temporarily diminished, both in number of species and in density; or because of destructive trailing of stock causing a change in the edaphic conditions due to rearrangement in the physical structure of the soil, conditions may favor the invasion and succession of quite different species from those which originally predominated.

These conditions of natural and utilitarian depopulation often furnish data of direct value in connection with field investigations. In the case of trees which reproduce vegetatively from coppice and by root suckers, for example, cleared and thinned lands are an asset to the determination of the best time of season and methods of commercial thinning and clear cutting. Likewise denuded herbaceous lands have given valuable general ideas of vegetative changes and of methods of management of such lands. To obtain data of such detail as to form a reliable basis for management and to show, for example, not only the life history performances of individual species but something as to their seed viability as well, carefully selected and established plots are invaluable. The value of field germination tests is not fully appreciated by many workers. Under artificial (incubatorial) conditions, for example, the seed of some species is known to germinate very poorly and in the case of some species practically not at all. For normal germination, on the contrary, there seems to be certain inherent tendencies requiring the conditions of temperature and other factors of the habitat to act on the seed during the period between its maturity up to and including the vernal and possibly other germination periods. By doing the seed testing under denuded conditions in the natural habitat, where the germination per cent will be virtually the same as in the case of the seed naturally disseminated over the area, germination potentialities of the season's seed crop scattered over the habitat are pretty definitely known. Thus the denuded plot has a value in germination work as well as in the study of invasion and succession.

While, as stated, conditions of depopulation and denudation brought about as a result of utilization, as well as from fires or other causes, when suitably located and physiographically desirable are often directly useful in general investigative work, experience has shown that it is often advantageous artificially to thin, clear cut, and denude. When artificially depopulated, the personnel of the plot may be definitely known and timber areas of the desired age of stand and herbaceous association of a particular composition may be selected. A former record of the personnel is often of great importance in the interpretation of results, especially if the vegetation stand is noted or mapped more or less in detail prior to depopulating. From such records it is often possible to explain the reversion to a type, the stages of temporary vegetation which characteristically forerun the permanent type or the immediate return to the permanent type, the reasons for which are often not clear without historic data.

From the viewpoint of light, the size of the cleared plot within a timbered area has an important bearing upon results. In order to avoid flecking from surrounding trees, for example, from one-half to one acre of square area is usually sufficiently large, provided the detailed vegetative plots upon which results are to be based are located near the center.

Establishment of Plots.

The charting, when on a minute and detailed scale, is done much as described by Clements in the case of the permanent quadrat.[a] In some investigations, as in the case of timbered

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a Research methods, pp. 172-186, Clements, F. E., 1905.

plots where dominance or suppressed condition of the tree, its height, diameter, health and other factors should be known, it is not practical, of course, merely to locate the specimens on the chart by recording the initial letter of the generic name. In such instance, the species is labeled with a numbered tag and the number listed on the map and in a notebook where full data may be recorded.[b] Herbaceous plants too are often individually numbered in the event that full notes are desired. Lath pegs, painted or unpainted, bearing stenciled numbers have proven satisfactory.

Plot Guide Straps:—In accurate germination as well as charting work it is practically essential to have the best possible straps or plot guides placed along and across the area selected. For example, prior to planting seed in the natural habitat for a germination test, as already mentioned, an area large enough to place meter guide straps is denuded of vegetation. When the straps are in position a seed is planted at each decimeter point, in case a test of 100 seeds is to be made, or if a 200 seed sample is desired the planting is done at intervals of every five centimeters along the strap throughout the meter unit. The straps are subsequently replaced to facilitate the location of the seedlings and sterile seed and the germination record obtained in terms of percentage.

Since satisfactory plot guide straps are not obtainable on the market, some guides have recently been devised which appear to be highly utilitarian and permit of greater accuracy than those generally used. A description and figure showing their exact construction is here presented. While the sketch is designed on the basis of a meter unit, any length desired may be made according to the description given.

Each set (Fig. 1) consists of four boundary straps as shown by A, and two division straps as shown by B. The Boundary straps have a width of 13 mm., a total length of 1.113 meters, and a thickness of approximately one mm.* Each boundary strap is divided and perforated as follows: The first perforation

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b In case of trees, aluminum tags of circular shape and usually not to exceed an inch in diameter bearing the number of the specimen has given satisfaction. Such tags are obtainable on the market and can be purchased bearing figures ranging numerically from 1 to any practical denomination. The iron finishing nail and the copper nail have both been successfully used to fasten the tags. The iron nail may be relied upon in semi-arid regions for a period of approximately five years. In the event that the experiment is to be continued for a longer time, the copper nail should be used in so much as the initial cost will offset by the added work in replacing the iron nails from time to time.

*In case that straps of much greater length are desired to those used for meter plot mapping, they should, of course, be made correspondingly wider and of heavier material.

comes at a point 5 cm. from the end of the strap, as shown in the sketch, the diameter being 5 mm.—large enough to allow the insertion of a surveying pin. The space occupied by the overlapping within the meter unit of the boundary straps when all perforations are made at dm. intervals, space heretofore practically disregarded in mapping, is here taken care of by having the distance between the center of the first and second perforations one dm. in length plus one-half the width of the boundary strap which would overlap on the meter unit. Thus the distance between the first and second perforations is 1.065 dm. At each succeeding dm. there is a similar perforation marking off a total of exactly 10 dm. within the mapping unit. For convenience in mapping, the space midway between each dm. division is numbered, the numbers running numerically from one to ten.

Strap B, i. e. the division strap, is 9 mm. wide and 1.033 meters long. The length within the mapping unit is the same as that of the boundary straps which provide for a full square meter within the unit. As a convenience in segregating the vegetation on the proper side of the guide, the division strap in cross section assumes the shape of a semicircle, except for that portion whose surface is in contact with or extending beyond the boundary strap. This portion is flattened in order that the strap may be held quite securely. The upper or flattened surface is divided, numbered, and perforated as follows: 10 mm. from either end there is a perforation of 5 mm. in diameter leaving 1.013 meters between these two perforations. Each dm. division within the plotting surface is plainly marked off by grooves. Between the perforation and first groove at either end there is a distance of 1.065 dm., which space is the same as the corresponding interval of the boundary straps. Midway between each is a number, the latter running numerically from one to ten corresponding to the numbers along strap A. All straps are made of flexible, noncorrosive, nonreflecting steel or other stable material which is practically free from contraction and expansion.*

As stated, there is an extension of 5cm. from the last perforation to the end of each boundary strap. This projection makes possible the placing of the corner stake at exactly the proper angle and in the correct position with the intersection and extension of the straps as a guide, a matter which greatly facilitates the placing of the guide tapes for accurate future map-

*Linen or cloth tape provided with eyelets, as well as the leather straps with perforated holes, are usually used but only with fair success. These materials contract and expand notably so the straps at one mapping are liable to be of quite different length than at another. The metallic straps are, therefore, much to be preferred.

ping of the plot. In the establishment of permanent sample plots everything should, of course, be made as permanent as possible and certainly its location should be definitely established. Obviously there is nothing permanent about wooden stakes such as are often used. The writer has failed to locate small inconspicuous sample plots because of the disappearance of wooden boundary stakes due to their consumption by forest fires, or to their ruthless removal by disinterested persons who possibly made use of them on the evening camp fire. A carefully established plot is an investment of financial consideration, and more important still, an investment of scientific and practical value not to be estimated in money value. The location should, therefore, be permanent.

Figure 2 shows a recent device for the permanent staking of the smaller plots whose relocation is often difficult. From this figure it will be noted that metallic pegs are driven at the outer interception of the guide straps which determine the corner locations. These pegs are about 12 inches in length and 1 inch in diameter. They are driven securely into the ground, leaving only about 2 inches to protrude. The end of the protruding portion is blunt so that grazing animals will not be injured should these pegs be trampled upon. Further, in order to facilitate ready location of the plot, larger wooden stakes are driven very close to the metallic peg, so the latter is pretty well protected against dislocation by grazing animals.

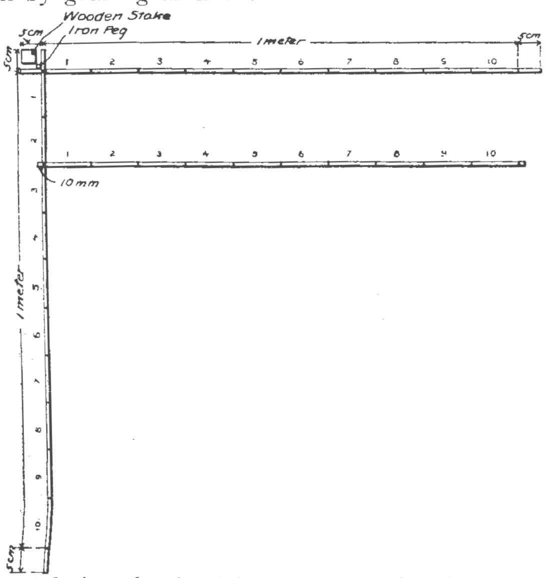


Fig. 2.—Horizontal view showing intersection of guide straps and location of iron peg and wooden stake.

Some Results Obtained Through Application of the Quadrat Method.

There is probably no more convincing means of emphasizing the value of the quadrat method than to give briefly the story revealed by sample plots on various vegetative types established as already described. Obviously space will not permit of detailed discussion of the findings in any one type, as it is desired to direct attention more to methods of research applicable to arborescent as well as herbaceous species rather than to give results *in toto* in the case of any one project.

Management of the Aspen Type.

In various regions of the Wasatch Mountains *Populus tremuloides* occurs in practically pure stands and appears to be the permanent type species. It has a high commercial value locally, being used more or less extensively for excelsior, as box-wood and as mine props. Reproduction, the reader will recall, is accomplished almost entirely from sprouts arising from roots and coppice, much the same as in the case of species of *Juglans, Hicoria, Fagus, Castanea* and others. The methods of study employed, therefore, are more or less directly applicable to a great many species or to an admixture of species. Let us consider a few of the questions of major importance to which the management of the species in question requires an intelligent answer, and see how the quadrat method aids the investigator in his task.

The question of the best age at which a stand may be cut is, of course, of high importance in the consideration of future production. Will a stand cut at 70 years, for example, produce more sprouts than a stand cut at 110 years, and, if so, will the greater percentage of the sprouts composing the future stand originate from the root collar or from lateral roots? From which of these latter sources will there result a larger number of sprouts whose vitality will be such as to tide them over the more adverse conditions to which they will be subjected?

Another question is the determination of the best season in which to remove the parent stand. Will a stand cut in early spring produce a more prompt and perfect reproduction than one cut in midsummer or fall? In this question we encounter the problem not so much as to the origin of the greatest number of sprouts following depopulation, but the origin of the greatest number of the most vigorous ones from which the new stand is to be composed. The solving of these and similar problems has

PLATE NO. I.

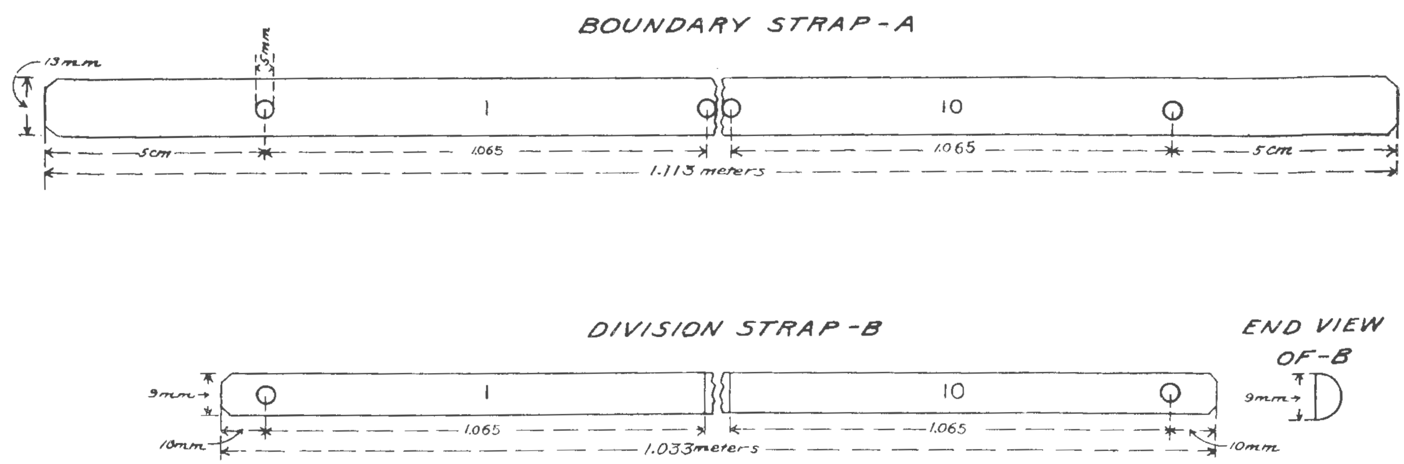


Fig. 1.—Boundary guide and division straps for use in Ecological vegetational studies.

been undertaken at the Utah Forest Experiment Station located on the Manti National Forest in the Wasatch Mountains of Central Utah.

To throw light upon the many phases of the aspen management study, several plots containing from a half acre to an acre of area have been depopulated of the species under discussion in varying degrees of intensity through the application of one of the thinning methods. Near the center of the plot where the light effects are uniform, unit sub-plots 10 feet square have been established in groups of from 2 to 15, as shown in Fig. 3. These were established immediately after depopulating or before appreciable changes in ecological and edaphic conditions had stimulated vegetative activity. The location of aspen stumps, sprouts, and in some cases other vegetation, were charted, each square foot of the 10 ft. unit being the chart sub-unit, as shown in Fig. 4.

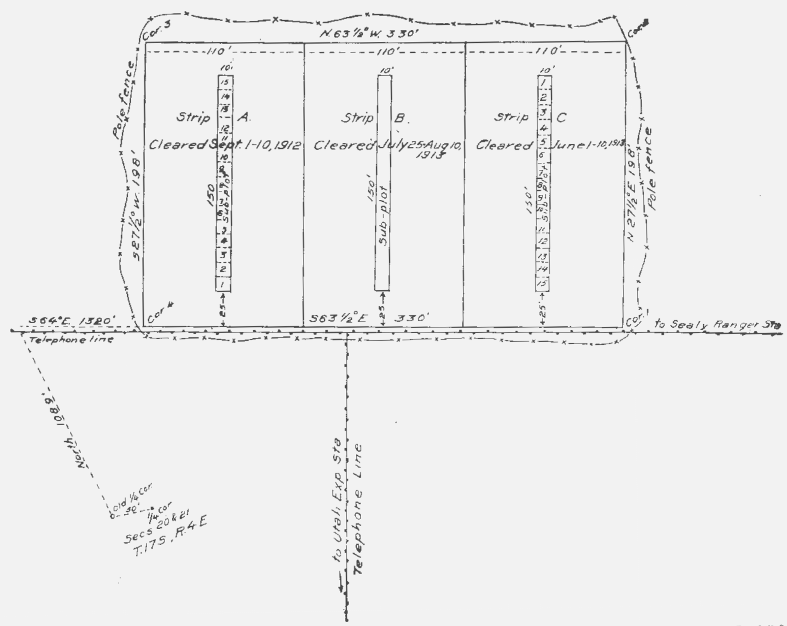


Fig. 3.—Plot No. 1.—Clear cutting at different seasons of even aged 120 year aspen stand. Scale 60 feet = 1 inch.

From chart records of the various unit sub-plots, similar to and including the one sketched, the exact number of sprouts produced under the different methods of cutting, their origin and fatality, as well as the height-growth in the first and subsequent seasons, were definitely determined. A few statements of results will illustrate the value of the quadrat method in this connection.

Following the first year of cutting it was found that all but *two* 10 ft. unit areas in sub-plot A (Fig. 3) contained new sprouts, there being 69.33 and 82.22 in June and in August respectively, in the first growing season following depopulation. Of this number 86.7 per cent and 76.2 per cent, respectively, survived through the season, though 31.6 per cent in the case of the stand in evi-

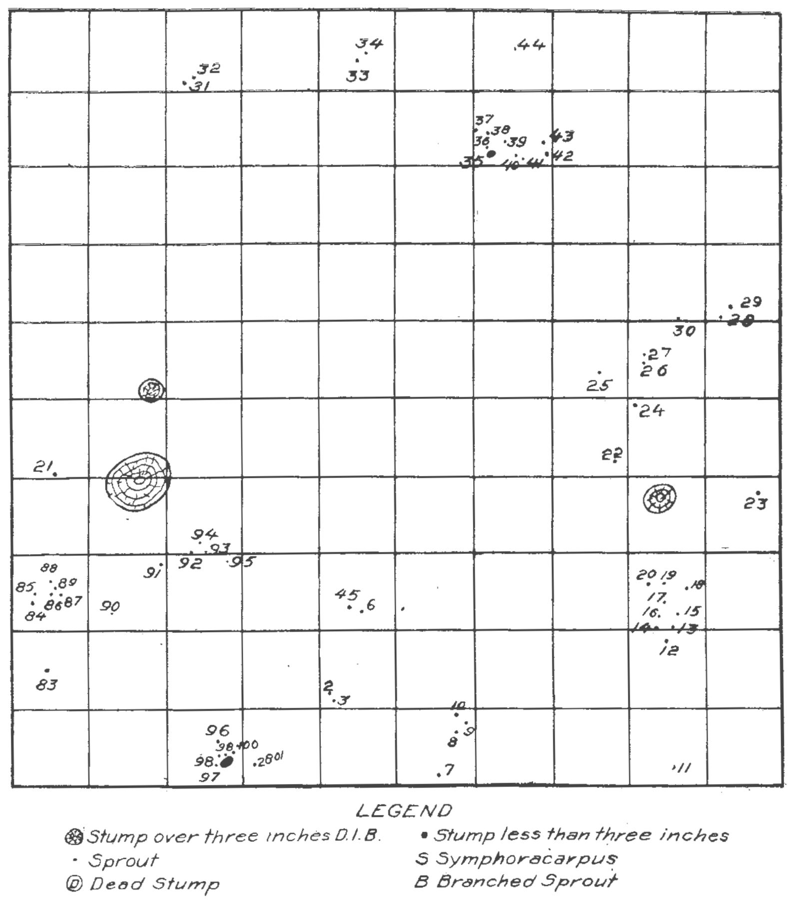


Fig. 4.—Chart showing detail involved in locating stumps and sprouts on one of the fifteen 10 ft. unit areas of sub-plot A.

dence in June was more or less seriously frostbitten—a factor which, according to later observations, appeared to increase the fatality figures.

The charted units further showed that practically three-fourths (66.5 per cent and 76.7 per cent, respectively) of the stand mentioned owes its origin to lateral roots, the remainder coming from three other sources.

Two seasons of charting of the sub-plots have shown that from 63.6 per cent to 87.2 per cent of the sprouts came the first year following depopulation, and from 12.8 per cent to 36.7 per cent the second year. The fatality of these sprouts ranges from 13.37 to 18 per cent in the first season and from 17.2 to 23.87 per cent in the second season. While no exact figures are at present available as to fatality during definite growing periods, such as during the vernal, estival and autumnal seasons, it is apparent that the main loss comes from winter killing.

While the observations have not extended over a sufficiently long period to give results upon which to base conclusions, subsequent examinations of the sub-plots will doubtless disclose the complete life history of sprouts with an accuracy which will be of the highest value to management. Information should be at hand showing not only which sprouts have possessed insufficient vitality to withstand the adverse conditions of their early environment and why, but also which have succeeded in the struggle for existence and why. Thus it is seen that the quadrat method provides a means of obtaining data which is applicable to any stand whether young or old, pure or mixed, even or uneven aged regardless as to whether the system of management applies to one of clear cutting or to one of the various methods of thinning. Likewise, the method in question is quite as applicable to volumetric and general mensuration studies as to the work specifically pointed out.

Relation of Grazing to Aspen Management.

Another problem requiring quite as intelligent an answer as the foregoing, in connection with the judicious management of aspen as well as of other forest types, is the determination of the relation of grazing to the reproduction and permanent establishment of important timber species. Vast forest types support range forage of excellent quality, the annual money value of which is high owing to the large number of stock which find ample feed on the adjacent winter range and which could not be utilized without pasturing on the aspen type in the summer.

Grazing animals, especially sheep and goats, find the leaves and young tender sprouts of aspen more or less palatable at all times during the foliar period. Even coniferous reproduction, the needles of which contain considerable tannic acid, is browsed in varying degrees depending upon forage conditions and the way in which the stock is handled. The extent of injury inflicted upon reproduction by livestock is a problem of high economic importance, not from the standpoint of timber and meat production alone, but in the maintenance of the all-important vegetative watershed affecting, among other things, rate of rumoff and irrigation farming.

Careful ocular observation followed by innumerable contradictory conclusions have been ventured by silviculturists, range experts and others as to the management and proper control of grazing animals on timber-producing lands in widely diversified localities. It was soon recognized that this problem could not be solved by general ocular inspections, regardless of the experience of the observer. Therefore, it was necessary to have something tangible—to show with mathematical precision such facts as the extent to which the reproduction of timber species is injured by stock; to what extent the seedling recovers from the different injuries of varying seriousness; and the benefit, if any, from grazing in preparing the soil for the reception of the seed crop, in the prevention of destructive fires and otherwise augmenting the establishment of reproduction.

In the spring of 1912, 50 reproduction sample plots were established in typical aspen type, including as many typical ecological and physiographical conditions as were consistent with reliable results. The density, height, classification, grazing injuries and other data were recorded by means of applying the list and chart methods. Forty-two of these plots are 10x50 ft. in size, four are 3x6 ft., and the remaining four contain .4 of an acre each. The latter were depopulated (clear cut) in order to excite a maximum production of sprouts upon which observations could be made. Two of these .4 acre plots are protected from stock grazing and used purely as check plots against the other two which are subject to normal grazing. Since 1912 the number of sample plots established in connection with this study has exceeded 100. The majority of these have been examined and the injuries to reproduction due to grazing and to other causes noted.

The substitution of definite results obtained through the application of the quadrat method for conclusions derived from ocular generalities, in connection with the problem in question, has resulted in the adoption of a safe and permanent grazing policy on the various types and under the different conditions. This policy will tend to put both timber and meat production on a firmer and more stable basis than formerly. Evidence of this is obvious from the fact that serious injuries to reproduction may largely be avoided through proper regulation of grazing, and as a result the annual herbage crop may be utilized to the greatest possible extent consistent with the welfare of the reproduction.

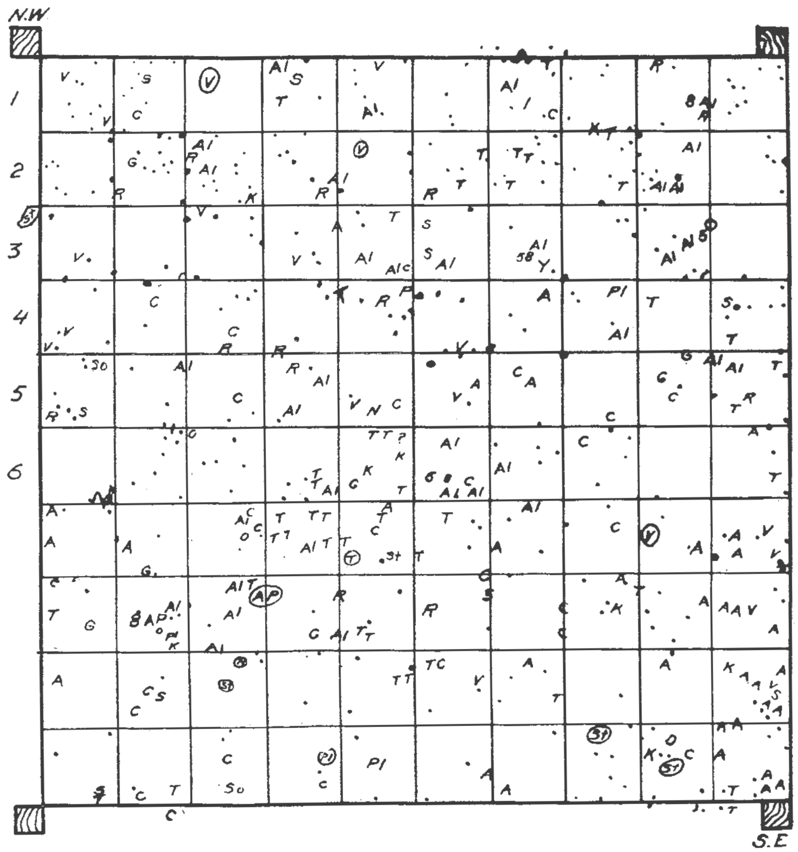
Management of the Range Lands.

In the management of the range, from the standpoint of the maintenance of the forage crop, it is desirable to note, among other things, the extent to which the most valuable forage plants are becoming established and holding their place against grazing. On certain high mountain lands on the Manti National Forest rather extensive areas in the subalpine zone, before they were under Governmental jurisdiction, suffered depletion due to range abuse. This resulted not only in the notable decrease of the annual forage crop but in serious erosion due to the elimination of the ramifying roots which bind the soil. In order [illegible] the carrying capacity of the range and at the same time [illegible] serious erosion it is essential to reestablish a p[illegible] tive cover. To accomplish this end the range is moderately grazed by cattle and sheep, which are not allowed to enter earlier than August 15 instead of early in the spring as formerly.

Naturally the time at which the herbage is grazed, coupled with the life history performances of the vegetation, would largely decide whether or not vegetation is gaining dominion over the soil under the present range practice. The life history can best be determined by the quadrat method. Accordingly, 25 sample plots of the denuded or depopulated, the chart and the list kinds, were established in 1913. These plots were designed to give (1) the general expression of seed viability by noting the identity and number of each species invading denuded plots, (2) an expression of the seed viability under conditions of natural competition as shown in the case of the chart plots, (3) the aggressiveness and superiority of species under conditions of little or no plant competition, (4) aggressiveness of species under conditions of intense competition, (5) fatality of seedlings due to grazing and to climatic conditions, and (6) rate of vegetative increment.

Charts of plots No. 18 and No. 19 are here presented, as concrete examples, to show how these units are usually mapped and to demonstrate the invasional aggressiveness which takes place under conditions of average favorability in a single year. These plots were denuded in September, 1913, and charted in August, 1914, the density and character of the vegetation at that time being shown in the figures.

The number of individuals on these plots emphasizes the fact that the investigator is able definitely to follow the structural changes only of a limited number of such units as shown. Prac-

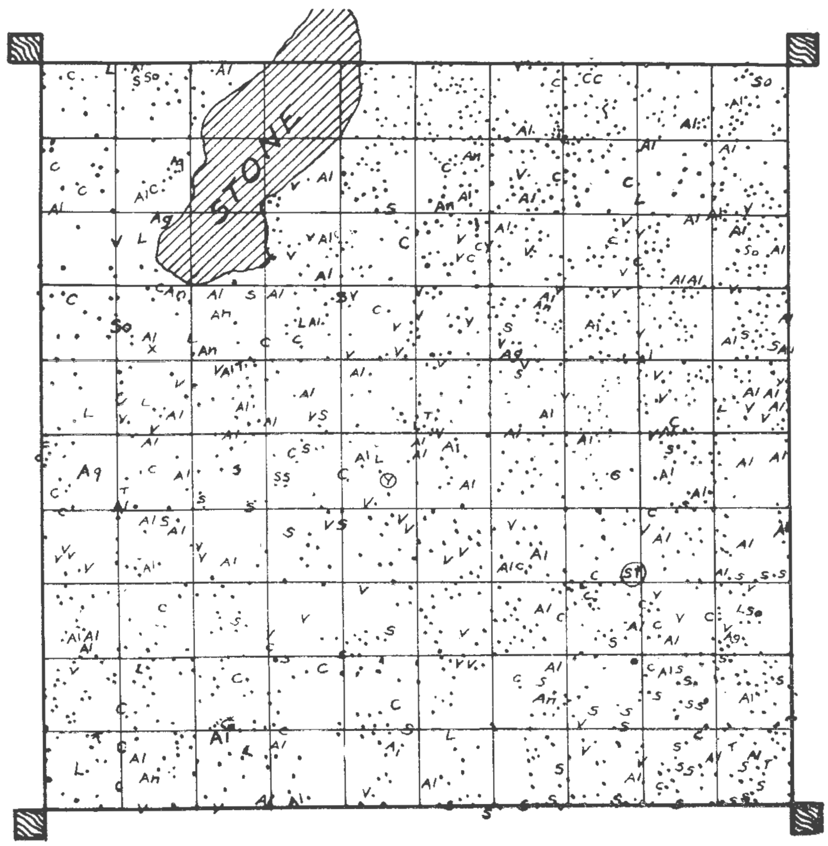


DENUDED PLOT NO. 18.

Legend

. —Polygonum
A—Achillea
T—Taraxacum
S—Sophia
R—Delphinium
C—Chenopodium
Pl—Plantago
St—Stipa
K—Trisetum
G—Galium
Ag—Agropyron

tically three 8-hour days were required in the recording of plots 18 and 19. In the establishment of plots, therefore, the amount of work subsequently involved should be carefully taken into account. Further, a great deal more time is required in segregating and listing the data, as shown in the following, from the charts made in the field.



DENUDED PLOT NO. 19.

Legend

. —Polygonum	An—Androsace	St—Stipa
Al—Alsine	L—Lathyrus	C—Chenopodium
S—Sophia	Ag—Agoseris	K—Physaris
V—Viola	So—Solidago	T—Taraxacum

The analysis of the composition of the two plots follows.
Analysis of *Sample Plot No. 18*, first series:

	No. of Specimens
*Achillea**	37
Alsine	41
*Agropyron**	1
Chenopodium	26
Galium	10
Oenothera	5
Plantago	3
*Poa**	1
Polygonum	385
Rumex	11
*Sophia**	2
Stipa	10
*Taraxacum**	39
*Trisetum**	7
Viola	16
Unidentified Seedlings	5
Total	599

Analysis of *Sample Plot No. 19*, first series:

	No. of Specimens
*Agoseris**	5
Alsine	87
Androsace	8
Chenopodium	50
*Lathyrus**	18
Physaria	1
Polygonum	1468
Solidago	5
*Sophia**	54
*Taraxacum**	7
Viola	68
Total	1771

From such specific figures as the above, prepared after each mapping (at least at the end of each growing season, if not oftener), the exact number of individuals on each plot and the

*Indicates plants of high forage value.

increase or decrease in specific cases, as well as invasion by new species, should be plainly shown. By so doing, the effect of climatic conditions and the particular management under consideration may be clearly determined.

The work involved in mapping and recording may be greatly decreased in two ways, namely, (1) by charting only the commercially valuable species and possibly those which figure strongly in root or aerial competition, and (2) by combining the list and chart methods as already stated. The value of these methods lies not only in the decreased amount of work, but makes possible the mapping of much larger plots than where all vegetation is charted.

The results obtained from mapping according to the first condition, i. e., taking into account only a few of the leading species, is shown by the following figures obtained through the charting of a 3-meter square unit plot established in September, 1913, and recharted in August, 1914.

otal Area in sq.cm.	Artemisia	Achillea	Taraxacum	Pentstemon	Erigeron
1914	45.75	7.65	23.15	16.70	1.05
1913	23.65	2.85	....	15.45	.75
Increased area in sq. cm.	22.10	4.80	23.15	1.25	.30
Per cent Increase	93.45	168.42	....	8.09	40.0

In this instance increment through *vegetative* means is shown. This means of reproduction is most important where there is keen competition, so the method in question has a high value.

A plot established according to the second method, i. e., by the application of the chart-list plan, accompanied by the analysis of the two most important commercial species, follows. The sketch (Chart—List Plot No. 26) represents the vegetative cover as found in August, 1914.

	Phleum pratense	Taraxacum offinale
Total specimens in 1914	1166	457
Total specimens in 1913	1129	457
Total increase in No. of specimens	37	0
Per cent of Increase	3.2	0

The occurrence of *Phleum pratense* is due to artificial seeding to this species, a practice carried out on seriously depleted range lands where growth conditions are favorable but where natural vegetation is unsatisfactory because of the absence of seed plants. It is noted that there is an increase in number of *Phleum* species in 1914 over 1913. This is doubtless due to a part of the seed tiding over the first season. Subsequent charts

	1	2	3	4	5	6	7	8	9	10
1	Ph 18 T 7 Pg 3 A 1 B 1	Ph 23 T 7 A 1 An 1	Ph 25 T 16 Pg 2	Ph 8 T 10 V 1 Pg 3	Ph 28 T 5 Pg 2	Ph 19 T 3 Pg 1	Ph 18 T 47 Pg 2 Al 6 B 1	Ph 1 T 25 Pg 5 Al 9	Ph 6 T 15 Pg 2 Al	Ph 9 T 16 Pg 7 B 1 S 1
2	Ph 7 T 12 A 4 Pg 2 Al 1 B 1	Ph 32 T 7 Pg 1 V 1	Ph 8 T 7	Ph 24 T 6 V 1 Al 2	Ph 16 T 4 Pg 3	Ph 33 T 2 Pg.	Ph 5 T 10 Pg 8 B 1 Al 1	T 70 Pg 5 Al 2	Ph 11 T 17 Pg 6 C 1 Al 1	Ph 13 T 16 Pg 15 Al 1
3	Ph 24 T 1 Pg 2 A 6	Ph 29 T 3 Pg 2 | A-1 L 1 V 1	Ph 24 T 14 Pg 1 | Al B 1 Al 2	Ph 31 T 9 Pg 4 V 1 B 1	Ph 37 T 11 Pg 4	Ph 36 T 9 B 2 Pg 1	Ph 12 T 9 C 1	Ph 8 T 6 Pg 2	Ph 10 Pg 6 T 20 Pg 7 Al 3	Ph 6 Pg 6 T 25
4	Ph 13 T 11 Pg 3 B 2 Al 2	Ph 6 T 17 A 1 Pg 6 Al 1	Ph 13 T 13 Pg 4	Ph 26 T 17 Pg 5	Ph 29 T 9 Pg 3 Al 3 B 1	Ph 40 T 14 B 1 Pg 9 Al 2	Ph 19 T 10 Al 3	Ph 13 T 6(1	Ph 2 T 5 Pg 5 B 1 Al 1	Ph 16 T 12 L 1 B 1 | A-1 Pg 3 | Al-1
5	Ph 16 T 15 Al 2	Ph 30 T 5	Ph 15 T 3 Pg 7 Al 1	Ph 9 T 40 Pg 4 B 1 Al 2	Ph 43 T 13 Pg 4 B 2	Ph 50 T 7 Pg 8 B 2 Al 1	Ph 50 T 6 Al 3 V 2	Ph 24 T 9 Pg 2 Al 4	Ph 13 T 15 B 2 Al 1	Ph 20 T 8 L 1 Al 3
6	Ph 20 T 10 Pg 2 O 3 Al 1	Ph 11 T 3 Pg 3 B 1 Al 2	Ph -4 Pg -2 B -4 T -6 V -1	Ph 11 T 5 B 6 Pg 1 Al 1	Ph 20 B 11 Pg 3 T 9	Ph 44 S 2 B 6 T 9 Al 2	Ph 39 T 6 Pg 4 B 5 Al 2	Ph 12 T 11 O 3 B 3 Al-2 A 1	Ph 7 T 33 B 1 Al 5	Ph 13 T 9 Pg 3 Al-1 A 2 S 1
7	Ph 19 T 4 A 2 B 2	Ph 28 T 20 B 4 Pg 1 Al 1	Ph 37 T 6 Pg 1 | Al-1 B 12 A 1	Ph 22 T 13 B 14	Ph 16 T 12 A 3 B 5 Pg 2	Ph 27 T 14 A 1 B 6 Al 1 Pg 2	Ph 25 T 17 A 1 B 3 Al-2 Pg 1	Ph 10 T 20 Al 5 An 3	Ph 15 T 16 Pg 5 Al 1	Ph 2 T 15 An 2 Pg 3 A 2
8	Ph 10 T 16 An 4 Pg 7	Ph 10 T 17 P 1 An 1 | Pg 3 Al | Al 3	Ph 15 S 1 T 17 B 2 | A 2 Pg 2	Ph-25 T-17 Pg-4 B 5	Ph 17 T 12 B 6 A 1	Ph-8 T-14 An-2 | Pg-1 O-1 | Al-2 A-1	Ph-4 T-28 B-6 Pg-7 Al-6	Ph 7 T 29 O 1 Al-3	Ph-7 T-10 Pg-3 Al-2 A-1 An-2	V-1 A-1 B-4 T 8 Pg 3
9	Ph-7 T-13 Pg-9 B-1 P-1	Ph-11 T-30 Pg-3	Ph 12 T 20 E 3 B 3 | A-1 Pg 1	Ph-6 T-16 O-1 Pg 4 | Al-1 B-4	Ph 11 T 24 A 2 B 3	Ph 22 T 9 An 2 Pg 2 A 2	Ph 8 T 23(1P An 2 B 2 | A-1 Pg 3	Ph 5 T 24 An 3 O-1 Al-2	Ph-6 T-15 Pg-4 Al-2 An-3 | B-2 A-1	Ph 1 T 15(1- Pg 3 Al 2 A 2
10	Ph-3 T-16 V-1 Pg-2 A-1	Ph-7 T-10 Pg-1	Ph 18 T 9 B 4 Pg 1	Ph-22 B-10 A-2 Pg-1	Ph-5 T-32 B-2 A 2 | V-1 Pg 3 | Al-2 P-1	Ph 11 T 22 B-1 A-1 | Pg 4 Al-3	Ph 8 T 15 Pg-5 | An 2 Al-1 V-1	T-16 O-1 An 5 | Pg 2 A-2 | Al-2 B-2	Ph-1 T-7 B-7 A-2 An-1	Ph-8 T-10 B-4 | A-3 P-1 | An 2 Pg-2 | O-1

CHART-LIST PLOT NO. 26.

Legend

Pg—Polygonum	C—Chenopodium	Al—Alsine
A—Achillea	An—Androsace	O—Oenothera
T—Taraxacum	V—Viola	H—Helianthella
S—Sophia	B—Bursa	D—Draba
Ph—Phleum	S—Stipa	P—Poa

*Indicates plants of high forage value.

will show the vegetative increment, as well as the origin of new individuals and the ability of the plant to withstand vegetative and climatic competition as well as grazing.

Concluding Statement.

From the results cited, it is evident that the quadrat method has a high value and is readily applicable to widely diversified investigations in forestry. While the effects of individual environmental factors on the limitations and causations of vegetative activities may not be definitely determined by the quadrat method, the effect of the accrued climatic factors is quite definitely expressed. When more definite information is available than at present, showing the relation of each potent factor as well as of the complexes of the environmental conditions to plant activities, it is quite probable that the quadrat method will have even a wider general application than at present.