A. Hormay
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Some considerations in planning range pasture experiments with cattle.

I. Introduction

The conduct of range experiments under pasture conditions usually requires heavy expenditures of time and money. Experiments of this nature may be carried on for a number of years before the accumulated data can be evaluated and before judgment can be made on whether the information needed is actually being obtained.

Careful planning is of course the best way of reasonably insuring efficient work and of getting desirable information. This planning involves both theoretical and practical considerations, and preliminary field tests of one kind or another are often necessary to determine whether a given plan can b e followed out on the ground.

From 1935 to 1939 various field measurements, bearing on pasture experimentation, were made at the Burgess Spring Experimental Range on the Lassen National Forest in northeastern california. The results of this work are presented in this paper with the view primarily of indicating the size and also some of the minimum requirements involving the use of cattle of range pasture experiments. The forage rather than the livestock is presented as the main object of study in the following discussions.

II. Design of experiment and importance of replications.

It will be assumed that range pasture experiments are the best means of getting certain kinds of information and no attempt will be made to justify them. Like other experiments they should have a definite purpose which should fully justify the time and money expended. They should not depend on the probability of getting "important by-product" information, but should be well designed to meet certain definite objectives.

Range pasture experiments at best only define or clarify the effect of given treatments, or measure certain comparisons. Explanation of these responses , or differences, however, usually require [redacted] detailed work in basic subjects such as chemistry, physics, physiology, ecology, and nutrition. Pasture experiments, therefore, should be planned where possible with these [redacted] investigations in mind. This helps to crystalize the plan.

It cannot be over emphasized that the object of an experiment must be clearly visualized and sharply defined. This forms the main basis for a sound design. With the need of the experiment justified and the objective clearly stated, a large part of the work is done. A good design should (1) be ~~half of the work~~ efficient in the use of space, labor and materials: (2) have a broad inductive basis and (3) be unbiased and capable of analysis and interpretation.

Modern statistical methods provide various experimental designs that may be applied in pasture work. A discussion of these may be found in (present day various books and publications on) statistics literature and need not be reviewed here. There is one point however that bears emphasis since it is basic in the consideration of all designs, namely replication.

Replication refers simply to the number of cases used in calculating certain statistics for the purpose of making comparisons. This applies to all types of measurements — to sampling the forage in a pasture, to determining the number of livestock needed in an experiment or to deciding the number of pastures to be used. In general replication increases the accuracy and scope of an experiment and allows experimental error (variation) to be determined and controlled.

Too few replications may result in the failure to detect treatment difference while too great a number results in waste of time and money. There is little liklihood of over replication of pastures in range studies, but there is real danger of under replication. It is often found prohibitive to establish the number of pastures desired in an experiment either because of the expense involved or the lack of manpower to carry out the experimental work. The number of pastures that may be constructed and examined, of course, depends on the work required on a single pasture. It follows that in order to approach optimum replication the work per pasture should be held to a minimum consistent with the object of the experiment and the accurracy desired in the work. It will be seen in the following pages that certain minimum requirements are demanded by essential parts of ~~an~~ experiment. After these are m et the success of the experiment depends on the balance and efficiency imparted to it by the researcher.

The researcher very early realizes the importance of balance in an experiment. In working under the usual handicap of a ~~usually~~ limited budget it becomes imperative that time and money be expended on those phases of the work that promise to yield the most good.

What then are some of the important considerations in pasture experimentation? They include size, number, shape and orientation of pastures and quadrats, number and kind of livestock ~~and accuracy~~ and methods of making experimental measurements. In the following pages the close relationship among all of these factors will become apparent.

~~since~~ It is almost impossible to discuss one without ~~qualifications~~ qualifying it with ~~by~~ one or more of the others.

III. Livestock number

The number of livestock needed in an ~~pasture~~ experiment depends on how the animals are used and the amount of variation among them. If the animals are used primarily as harvesters of the forage - that is to bring about a given forage utilization- it ~~is~~ becomes desirable to measure the relative differences among animals in such factors as trampling, and time, amount and kind of forage consumption . Unfortunately there is no easy nor direct way of evaluatin g such differences at present. Results from feeding trials give some indication of variations in feed consumption and field observations give some information on the amount and time of selection different forage species by individual animals but these fall short of supplying a quantity that can be measured in the field experiment.

no per comparison pasture

The smallest number of livestock that can be used per pasture depends principally on the variation among animals. If the livestock are uniform a smaller number may serve the purpose of an experiment than when the animals are variable.

Uniformity in livestock is therefore desirable. Careful selection for type, age, conformation, breeding etc. will go a long way toward reducing differences among animals. However, selection on the basis of performance records under comparable conditions appears more satisfactory if it can be carried out. For example a herd of experimental cattle may be grazed for a sufficient period in a single pasture and the necessary measurements made on the animals that will later be made in an experiment. The most comparable animals can then be selected for allotting at random to the various pastures. The number needed ~~per pasture~~ can be calculated from the observed ~~differences~~ [variation] among the animals. As few as two head [per pasture] may prove to be sufficient in certain experiments. A minimum of two are essential in order that there may be ~~a~~ [some] basis for measuring variation between animals in the experiment. In the simplest experiment involving two replications the smallest number of animals used in any treatment or condition would therefore not be less than four. [Thus] ~~A~~ [a] small number of animals per pasture [may] permit~~s~~ using a greater number of replications.

Differences between animals are not easily measured in all cases. It depends on the type of measurement to be used. For example live weight is a tangible body measurement and is relatively easily obtained, but the quantity of forage consumed by each animal in a pasture is not. In many range experiments the latter type of measurement or one dealing with animal habit is often needed. Probably the most important case — that of determining stocking rate — is pointed up by the following question. Will four head of [live]stock produce twice the grazing effect of two head? In range experiments, pastures are stocked with different numbers of animals usually with the assumption that the grazing effects produced are proportional to the number of livestock used. Where the number of animals per pasture are large there is reason to believe the assumption would not be greatly in error but where numbers are limited to two or three animals per pasture abnormality in a single animal may effect comparison between pastures. At the present time there is no way of measuring such intangible ~~differences between~~ [quantities in] livestock.

Accuracy of Cattle Weights

Even the tangible measurements made on the livestock are subject to "error" or variation. In many cases this is so small that it can be disregarded. In other instances such as in measuring live weight in cattle it is large enough to warrant serious consideration.

How close can the differences in weight between individual animals be measured? This depends on the sensitivity of the scales used and the factors affecting the weight of the livestock. Lush and others (5) found that weighing on scales of two-pound accuracy does not lead to any serious loss of information, except with small cattle. The reliability of the weights, however, do not rest so much with the sensitivity of the scale, as in the behavior of the livestock. The weight of a given animal may vary in a short space of time from such causes as changes in the weather, time of drinking and grazing in relation to weighing, and method of handling or herding.

At Burgess Spring[1], where cattle of various classes and ages were weighed at two-week intervals on scales of two-pound accuracy for four years it was found that the excitability of certain animals under favorable conditions, and of most of the animals under unfavorable conditions markedly affected their weights. Individuals that were easily excited often disturbed the other animals while they were being rounded up or weighed with the result that the weights of all the animals were more or less effected. Under other circumstances only the weights of the excitable animals were effected. An excited animal usually ran considerably or refused to drink "normally."

Rapid herding or repeated handling of the (live) stock is undesirable. Twelve cattle which were weighed and released into the Burgess Spring pasture and then rounded up and reweighed two to three hours later showed a significant weight loss of 7.7 pounds.

The failure of all cattle to drink prior to weighing when they have access to water, or to have approximately the same fill at weighing time when water is kept from them for several hours is a source of variation that is difficult to overcome. Records kept at Burgess Spring showed that cattle drank from five to eight gallons of water a day. The animals drank on the average but once a day. Under these conditions a single fill of water ranged from 40 to 64 pounds, and the livestock weights were affected up to these amounts depending on the amount of fill taken. When watering is permitted just prior to weighing different degrees of fill may be taken by the different animals and some may not drink at all. Under adverse handling individual cattle at Burgess Spring

Be more specific

showed losses of 20 to 40 pounds when the trend of the weight curves indicated that they should have been gaining. When the (live) stock were reweighed four days later under more favorable conditions these losses were replaced by considerable gains. From August 25 to September 11, fifteen cattle showed an average loss of 5.8 pounds. From September 11 to September 15, they showed a gain of 18.0 pounds. This apparent large increase in weight in four days represents a large measure the difference between a partial and a "normal" fill of water.

Lush et. al. (5) determined that under rather uniform feed lot conditions an experimental error (standard deviations) of 6 to 12 pounds may be expected in weighing individual cattle. Some weights were subject to errors of 16 and 17 pounds. Experimental errors for the cattle at Burgess Spring for the four years, from 1836 to 1939, were 19, 21, 17, and 18 pounds.2/

The experience at Burgess Spring indicates that in order to hold this error to a minimum under pasture conditions every possible means should be used to obtain uniformly, gentle livestock. The livestock should be handled with the least disturbance and special attention should be given to weighing when "fill" of feed and water is least likely to be in a state of flux.

It is probably readily seen that if special attention is given to livestock selection, weighing, and handling to reduce differences between animals considerable reduction in the size of the experiment may be affected, since fewer animals may be used.

2/Calculated by the method used by Lush et. al. for purposes of comparison.

Frequency of Weighings

In range work the entire weight curve is of value to the researcher. The start and end of gains, the periods of maximum gains and losses and other points along a well defined curve are of interest. Frequent weighings, therefore, are desirable. Weighings made at two-week intervals are rather easily carried out under pasture conditions and have been obtained at Burgess Spring and elsewhere. Ten-day or even weekly weighing would serve to better define the trend in the curve. Clawson (4) weighed cattle at seven-day intervals under pasture conditions without undue difficulty.

Frequent single weighings would appear to serve most purposes best. However, where interest centers only in total gain the average of two or more weights obtained on consecutive days will better define the mean weights to be compared.

Critical periods

The frequency of weighings depend on the comparisons to be made in the data. For example, it may be necessary to determine when livestock start to gain weight at the beginning of the season in each of two types. A two-week difference may be judged to have practical significance, hence weighing at monthly intervals would most likely fail to answer the purpose. Weights taken at 14- or 10- or even 7-day intervals may be necessary. The experimental requirements must of course be balanced against practical considerations. A large number of livestock may make frequent weighings impractical.

IV. Pastures

Size

The size of a pasture is governed principally by the number of livestock to be grazed in it, by the period and degree of forage utilization desired, and by the grazing capacity of the range. The smallest pasture would have to be large enough to provide forage for at least one cow. If an experiment were attempted with but one cow per pasture, however, it would soon be found that the effect produced by grazing or the response of the livestock to the forage could not be differentiated from the effect of place.

For example, suppose it were found desirable to determine the response of cattle weights to the forage in two range types and a pasture enclosing but a single animal was placed in each type. It is rather clear in this case that a greater gain in weight of one of the animals over the other might be due not only to the differences between the types but also in part to differences in the animals. The part of the weight gain due to type differences and the part to livestock differences could not be segregated in this case.

On the other hand, if two animals were placed in each pasture a basis is established for calculating the variation in the livestock. If the variation between types were not greater than the variation between animals grazed in the same pastures no sound basis would exist for indicating a difference between types. If the variation between types were greater than that between animals by an amount which could not be expected by chance (except in a small number of cases) a difference in type could be indicated.

While the actual number of livestock needed per pasture in a given experiment depends on the object and design, the minimum number could hardly be less than two. The smallest pasture, therefore, would have to be large enough to provide for two head of livestock. At the Burgess Spring Experimental Range.1/ This is equal to an area of approximately 72 acres. If the number of pastures required is large the magnitude of this type of experimentation starts to make itself apparent.

Deserves to go in main discussion

1/The Burgess Spring Experimental Range is a fenced pasture of 537 acres located on cut-over pine land. Approximately 85 percent of the virgin timber was removed during logging. Logging was done with tractors and the slash was piled and burned.

The area lies at an elevation of about 6000 feet on the lower southeast slopes of Harvey Mountain, some 12 miles east of Hall's Flat, in Lassen County. The general shape and topography of the pasture are shown in figure 1.

Some of the important herbaceous and shrubby plants that occur on the area are: Idaho fescue (Festuca idahoensis), bottle brush grass (Sitanion hystrix), needle grass (Stipa spp.), sedge (Carex rosea), wooly mules ears (Wyethia mollis), lupine (Lupinus calcaratus), big sagebrush (Artenisia tridentata), and bitter brush (Purshia tridentata).

The dominant tree species are ponderosa and jeffrey pine (Pinus ponderosa, P. jeffreyi). Small groups of white fir (Abies concolor) occur in the north end of the pasture while scattered junipers (Juniperus idahoensis) may be found principally in the southern half associated with big sagebrush.

Number of Pastures.

What determines the number of pastures to be employed. Probably most important are, (1) The need for measuring the variation in the type or types studied and, (2) The number of livestock needed in the whole experiment. For example, using the type comparison previously cited, supposing it was found necessary to use about 14 head of cattle in each type. If all 14 head were placed in a single pasture in each type no estimate of the variation of within types would be available and at best it could only be assumed that the particular pastures reasonably represented the types. Broad application of such results could hardly be justified. If on the other hand the number of animals per pasture were reduced to two in a given locality and seven localities were chosen, a much more reliable comparison between types could probably be made even though some sacrifice is made in estimating the variation in the animals.

Shape and Orientation of Pastures

Long narrow pastures properly oriented tend to overcome field variation to a greater extent than more compactly shaped ones. This is true because long pastures cut through a greater number of field conditions thus tending to include variation within pastures and leaving less between them. This makes pastures more alike and treatment differences between them can be more easily detected.

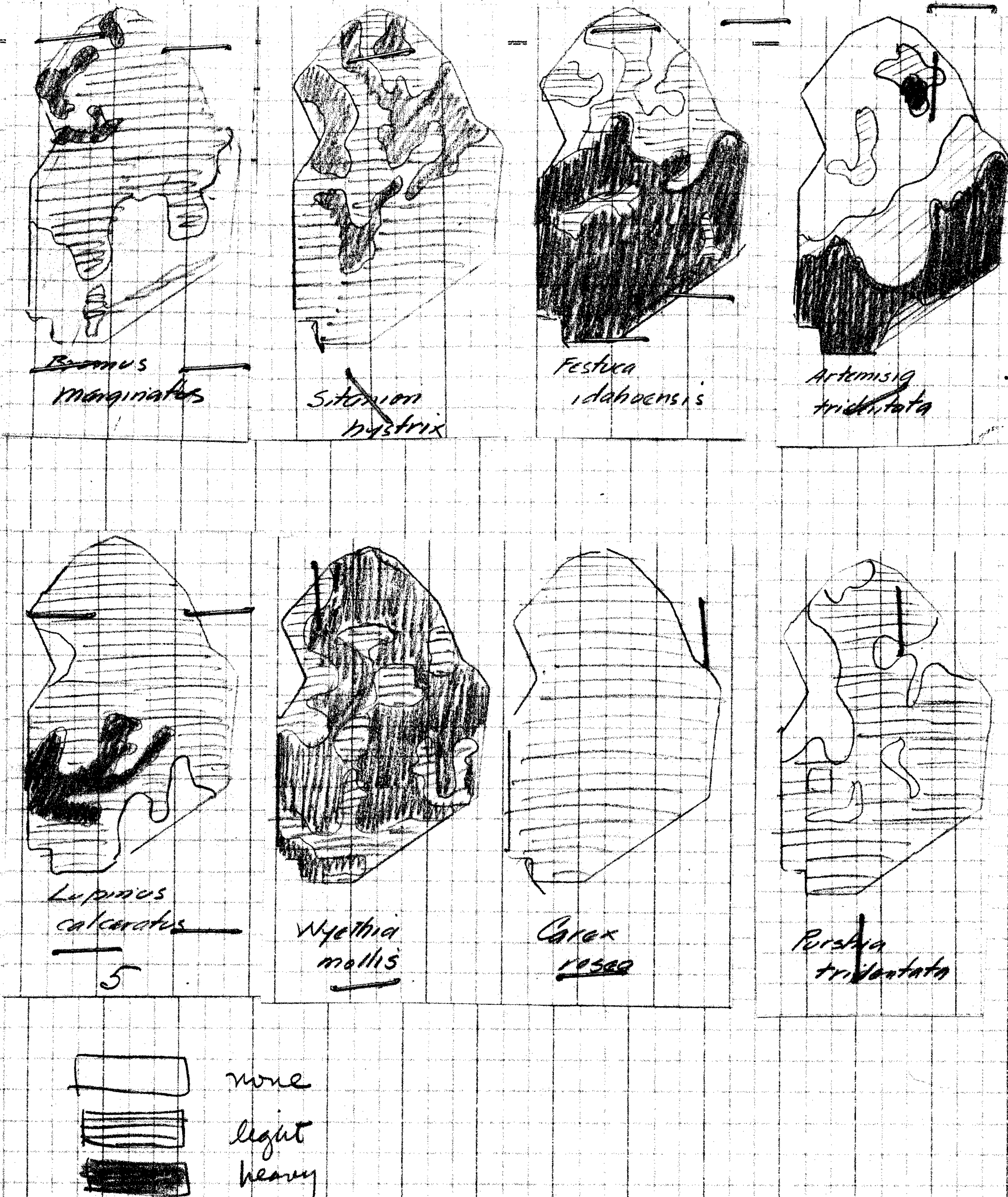
Long narrow pastures would seem to best serve the purpose of many range experiments. It may be well to show some of the advantages to be realized from their use. Data from Burgess Spring will serve the purpose.

Figure   includes a series of maps[1], showing the distribution of the forage species on the Burgess Spring Experimental Range. If an area comparable to this were chosen as the site for a pasture experiment in what direction would the pastures be oriented and what shape would they have? The study of the specie map will aid in answering these questions.

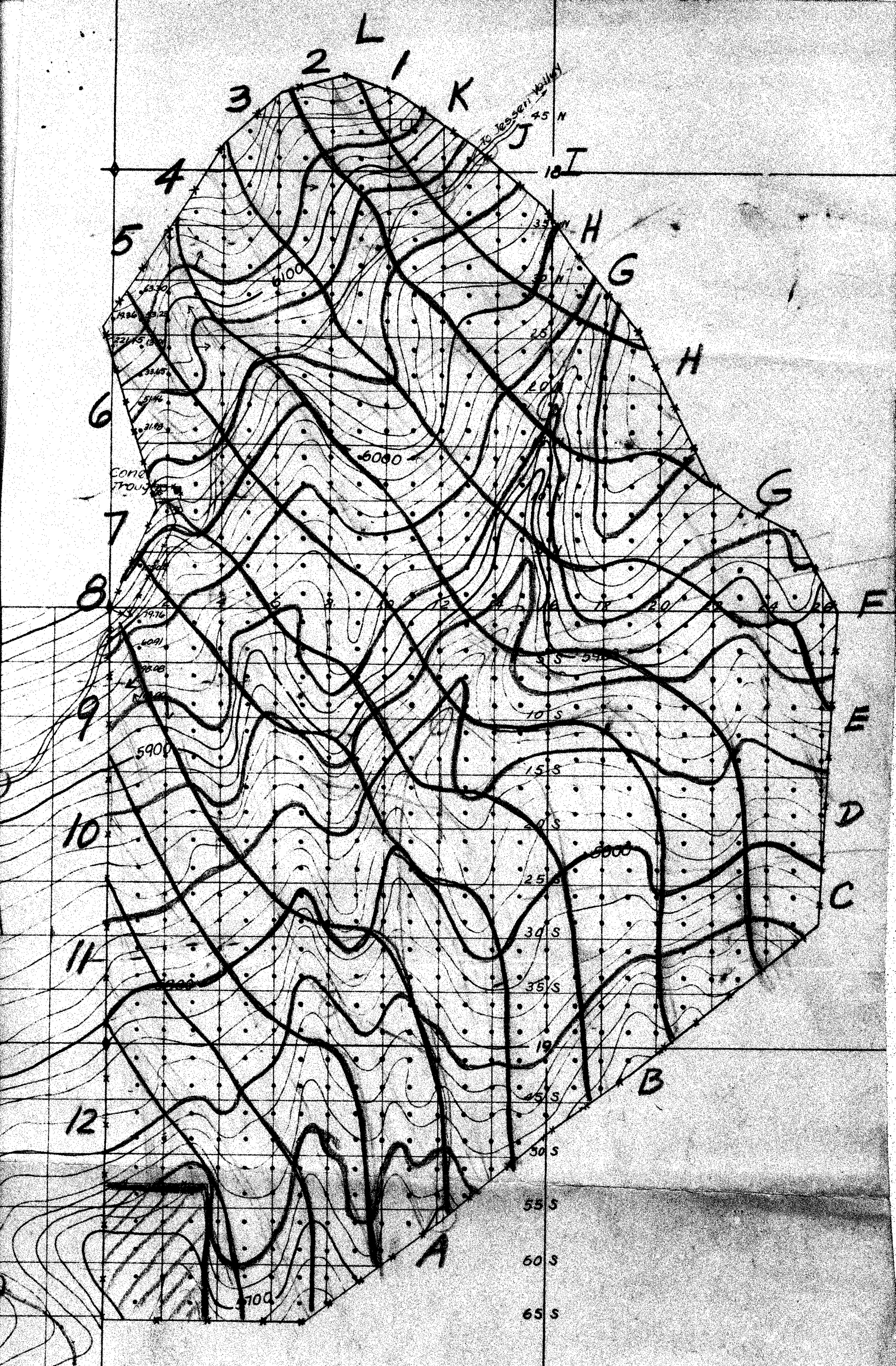
It may be seen that certain species such as *Sitanion hystrix* and *Bromus marginatis* tend to grow in greater abundance in the upper part of the pasture. *Festuca idahoensis*, *Artenisia tridentata* and *Lupinus calcaratus* on the other hand occupy mainly the lower part. Other species like *Wyethia mollis*, *Carex rosea* and *Purshia tridentata* are rather uniformly distributed over the whole.

Thus, if the pastures were made long and relatively narrow and oriented in general at right angles to the species strata — in this case approximately at right angles to contours, each pasture would have a good chance of including some of each of the species and so tend to be comparable. In contrast long pastures placed parallel to the species strata might differ considerably. One along the upper slopes would be dominated by one set off by species while another on the lower slopes by another set. Such pastures would hardly be comparable. Compactly-shaped pastures would also tend to differ among each other because of the limited number of conditions that could be enclosed within them.

The question arises. Might not the yield of forage which is a quantity not shown by the maps require that the pastures be oriented in some other direction than that indicated by the distribution of the species. Calculations showed that the yield of the perennial forage



Bromus marginatus
Sitanion hystrix
Festuca idahoensis
Artemisia tridentata
Lupinus calcaratus
5
Wyethia mollis
Carex rosea
Purshia tridentata
none
light
heavy



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5 S
E
9
5900
10 S
15 S
D
10
20 S
5800
25 S
C
30 S
11
35 S
19
B
12
45 S
50 S
55 S
A
60 S
5700
65 S

cover was rather uniform throughout the Burgess Spring pasture. No gradation in yield was detected up and down or across the slope by the method of analysis employed.

The pasture was divided into "contour units" and "vertical strips" (at right angles to contours) as shown in Figure . The mean yield and its standard deviation was calculated for each unit and each strip. The average of the standard deviations for contour units did not differ significantly from the average of those of the "vertical strips" (Table). Thus, the variation in yield in the two directions was about the same. Of course the means of the yields from "contour units" and "vertical strips" were equal.

Thus, it may be seen that the size of a pasture in a given type or locality is governed by the number of livestock to be used. The number of livestock in turn is determined by the variation among animals. The reduction of the latter to a minimum involves many practical difficulties. It is not out of the question, however, to use but two animals in certain experiments. There is some risk involved in using this restricted number in case an animal becomes ill or dies. In some experiments there should be little objection to replacing such an animal from a reserve supply which can be kept on hand in a nearby pasture, particularly if the reserve livestock are weighed periodically with the rest of the experimental animals.

It will be assumed that an absolute minimum of two head of cattle can be used satisfactorily per pasture. The minimum size of such a pasture will then depend on the grazing capacity of the range, the length of the grazing season, and the degree of utilization desired. For example, at Burgess Spring in 1936, 537 acres satisfactorily carried a herd of 15 cattle for 99 days. Approximately 36 acres were needed per head. In this particular case two cattle required 72 acres. This is a sizeable area and the quantitative measurement of the forage in it presents one of the most difficult jobs in range research. Some of the considerations that must be given to measuring the forage in a single pasture will give one an idea of the work involved.