"More knowledge of how to cooperate with nature for our own good is the world's greatest need."

Henry A. Wallace.

RANGE AND PASTURE TECHNIQUE

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BY

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Nolen R. Denton

PREFACE

Up until the last fifteen or twenty years there had been very little range or pasture research work. This was because of the presence of abundant range and woodland pasture and because the soil generally up to that time was sufficiently fertile to produce good pasture.

Now the subject of Range and Pasture Management is receiving no small part of the consideration of those who are interested in better livestock husbandry. This has been made especially true during the years just passed when we have come to realize that we must keep nearer nature's plan of balancing plant and animal life on the earth by properly meeting the requirements of each without seriously hindering the other.

Nearly every agronomist recognizes pastures as being probably the greatest undeveloped agricultural resource of our country and livestock men are seeking information on the establishment and management of productive pastures. Since we have thus looked at the situation much work has been done to determine just what has been the cause of the present condition and to find the course we should follow in cooperating with nature to reach optimum conditions.

The loss of billions of tons of rich top soil and the failure to properly meet plant requirements stand out as the major evils in agronomic development. These two evils have advanced together and in one sense are inseparable. Directly responsible for a large portion of the presence of these evils,

is the fact that the once thickly-growing and luxurious grasses of our prairies were misused by overgrazing both because of overstocking in normal years and because of drought which greatly reduced their carrying capacity.

In reaching conclusions on the above and in order to make recommendations for remedying the situation, a great deal of experimental technique has been applied. This, together with some of the methods and practices with which it is connected is discussed herein.

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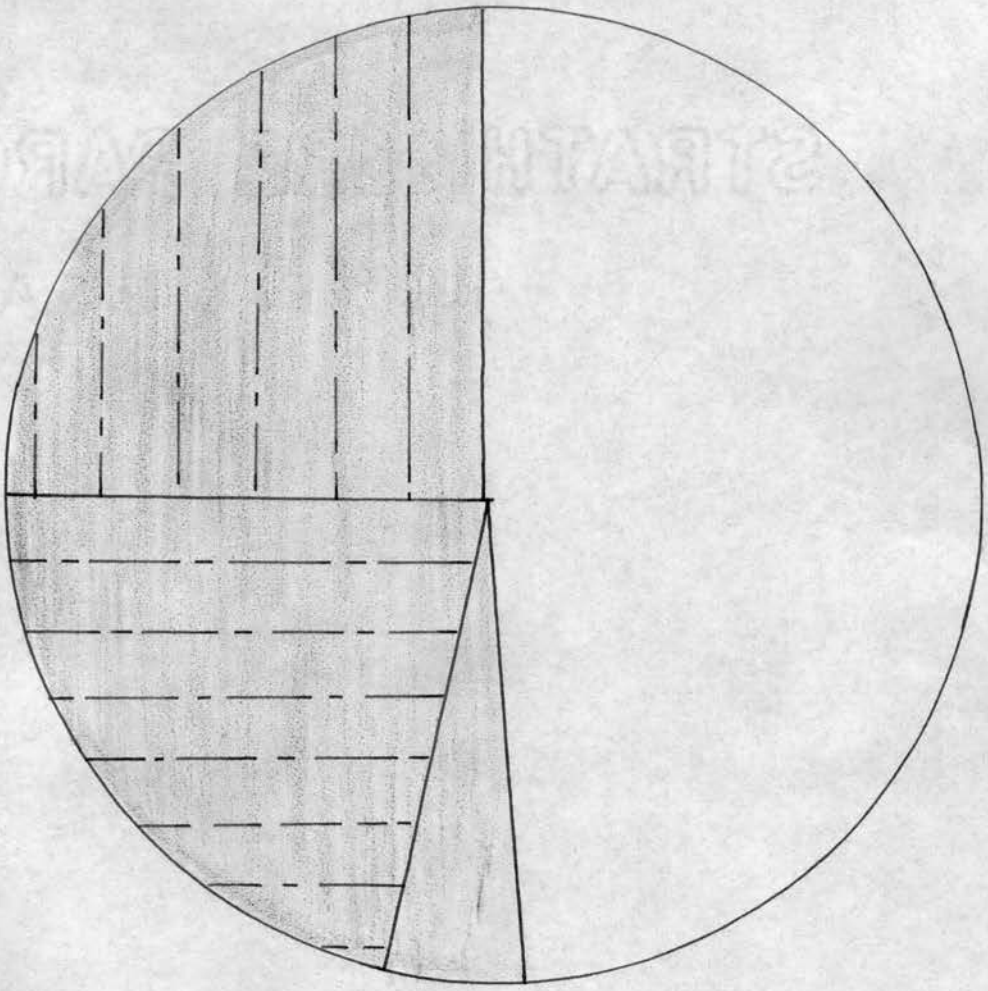
LAND USE IN THE UNITED STATES[1]



Land in farms

Pasture lands

Crop lands

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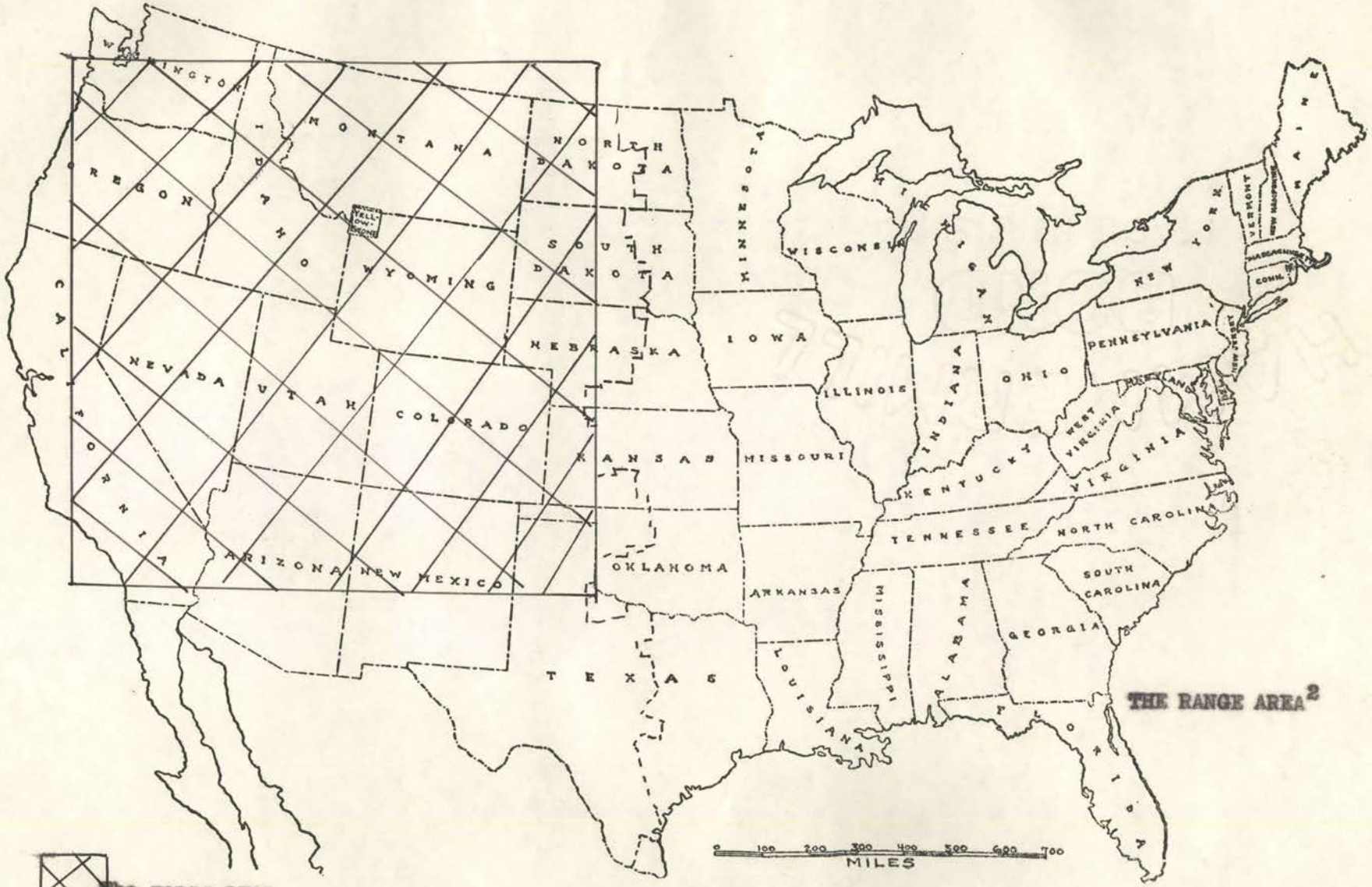
1. Agriculture General Report, IV, 1938.



THE RANGE AREA[2]

The range area

The boundry of the range

2. The Western Range, United States Department of Agriculture Senate Document 199, 1936.

INTRODUCTION

Pastures Defined

Pastures may be defined as grass lands used for grazing. They may be divided into native and tame pastures.

A range is a very extensive native pasture.

Natural or native pastures are uncultivated lands occupied wholly or mainly by native or naturally distributed introduced plants useful for grazing. They include:

(1) Ranges--Very extensive native pastures.

(2) Brush Pastures--Pastures covered largely with brush and shrubs, where a considerable portion of feed obtained by the livestock comes from browsing woody plants.

(3) Woodland Pastures--Wooded areas with grass and other forage plants growing in open spaces among the trees.

(4) Cut-Over or Stump Pastures--Land from which the trees have been removed but on which there are stumps and new growth.

Tame Pastures are lands once cultivated that have been seeded with and are now occupied largely by domesticated pasture plants and used chiefly or entirely for grazing livestock. They include:

(1) Permanent Pastures--Pastures occupied by perennial plants or by self-seeding annuals, usually both, which remain unplowed for long periods (five years or more).

(2) Rotation Pastures--Fields used for grazing which are seeded to perennials and, or self-seeding annuals, but which form a unit in the crop-rotation plan and is plowed within a

five-year or shorter interval.

(3) Supplemental or Temporary Pastures--Fields used for grazing when the permanent or rotation pastures are unproductive and do not supply enough feed for the livestock kept on the farm. Supplemental pastures may be provided by the aftermath of meadows, small grain stubble, seedling small grains, annuals like Sudan grass, or biennuals like sweet clover.

(4) Annual Pastures--The term annual pastures is usually applied to pastures that are seeded each year to take the place wholly or in part of the permanent pasture. Such pastures may include a series of crops like winter rye, Sudan grass, soybeans, lespedeza, hopclover, and rape, which combined will furnish pasturage nearly all year.

In this discussion the various native pastures are the ones chiefly considered.

PART II

TECHNIQUE IN RANGE AND PASTURE MANAGEMENT

CHAPTER I

Establishing Permanent Pastures

It is often desirable to establish pastures on land which has been previously in cultivation or which has been abandoned.

The first consideration in doing this is a thorough preparation of the soil, and this is usually balanced by an increased production the first two years. The seeds planted, also, have a great deal to do with the kind of seedlings produced. Small undeveloped seeds are very likely to produce weak seedlings.[1]

Briefly stated the establishment of permanent pastures should be in this manner: Good seed lightly covered in a well-prepared seedbed. Often, it is desirable to use some small grain as a nurse crop. However, if pasture mixtures are sown in the fall or early spring, they will be more productive the first year without being sown with a nurse crop. If such a pasture is properly grazed this first year, it will provide a larger net return than the grain crop.

Generally, it will be wise to apply some fertilizer e. g. 600 pounds of 4-8-4-. A light disking could well be the first preparation after the application. If seeds are sown broadcast, they may be covered with a cultipacker, or a spike-tooth or drag harrow. Drilling is best where it is practical, because of the more even covering and better distribution of the seeds.

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1. Semple, A. T., A Pasture Handbook, United States Department of Agriculture Miscellaneous Publication 194, 1934.

When sowing a mixture of grass and legumes the grass should be sown in the fall and the legumes sown on the grass in the spring. In the case of distinctly summer grasses on heavy, heaving land of the north, it would be best to sow them in the spring because of the danger of the seedlings being uprooted by the heaving of the soil.

The clipping of weeds above the pasturage once or twice the first year may be advisable.

CHAPTER II

Management

A. General

Good pasture management means a system of fertilization and grazing which insures that an animal is able to consume, during each day of the grazing season, the maximum amount of feed of a chemical composition suitable for the maintenance of health and condition and for the production of milk, meat, bone, wool, or other product desired.

Cattle desire short leafy herbage in the early stages of growth. A dense sward about four inches high of leafy plants seems to be ideal for cattle grazing. It is desirable to have the forage as much as 50% legumes if possible to increase the carrying capacity of the pasture. Leaves are preferred to stems by grazing animals and short young herbage low in fiber is preferred to old, tall, stemmy and highly fiberous herbage. Certain grasses, legumes, and weeds are eaten in preferance to others.[1]

Not only is young tender growth preferred by animals, but the valuable food constituents are present in greater proportion and they are also more digestible than in later stages. The fact that at a later stage the natural production of nutrients per acre does not necessarily mean that these larger amounts will have a greater feeding value.[2]

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1. Johnstone, D. B., Journal American Society of Agronomy 29, p. 441, 1937.

2. Pieters, A. J., Journal American Society of Agronomy 29, p. 436, 1937.

There are, however, limits to the keeping of such growth at all times because there are other considerations in the production and use of forage such as the vigor of the plants and the protection of the soil. Because of the varying conditions of soil, climate, vegetation, and grazing animals, a general recommendation cannot be made as to the management of pastures or ranges but certain principles and practices are known to be of value or are known to be definitely detrimental.

Any system or method of grazing is likely to be a success or a failure to the degree in which such a system meets the requirements for the plant used and the wise utilization of the forage produced.

B. Systems of Grazing

Nothing in range and pasture management should receive more serious consideration than the system of grazing.

Any system or method of grazing is likely to be a success or a failure to the degree in which such a system meets the requirements for the plant used and the wise utilization of the forage produced.

The most important requirements aside from nutrients and moisture for range and pasture plants are that (1) they have ample growth before they are grazed, (2) at all times a vigorous growth be maintained, (3) they be allowed to mature seed at convenient intervals of years, and (4) seedlings may be protected until they have become rather well established. The last two are of importance mostly when revegitation is desired.

Keeping in mind that forage is more palatable and more nutritious in the early growth stages but that at the same time more forage is generally produced if plants are allowed to mature before harvesting, the wisest plan for the utilization of forage is not an easy thing to find. Consideration must be given to the uniformity of grazing, the growth periods of forage plants, and other like matters. It should always be remembered, also, that the largest gain per head is not the largest gain per acre.

Different systems vary widely in the extent to which these requirements are met as it will be noticed by the following discussion.

1. Overgrazing

The effects of overgrazing are very noticeable. Many have said that this has been the chief cause of the deterioration of the range. Surely this, coupled with drought, and other factors has had a large part in bringing about the present condition of our western country.

The faults of overgrazing are many. Some of them follow.

1. The erosion of land because of the lack of a sufficient ground cover to protect it. This lack of cover lowers the resistance to run-off water thus losing valuable water and soil, as well as, exposing the soil to the beating effect of raindrops which pack the soil to prevent infiltration. This beating effect of the raindrops, also, loosens small particles of soil which are then more readily washed away.

2. Plants not being able to mature normally at any time are unable to store up nutrients in root tissues. This weakens them, reduces their production, and lowers their resistance.

3. Roots and plants are damaged by excessive tramping.

4. The soil is in poor physical tilth because of heavy packing.

5. Practically no seed of desirable species of forage plants is produced.

6. Actually less forage is produced by most desirable plants than would be produced under conditions more favorable for plant growth.

7. Land values are reduced because of the increase of weeds and non-palatable grasses.

8. There is less gain per head than would be the case under more favorable grazing conditions.

The experimental methods and the results of a few experiments which dealt with the effects of overgrazing follow:

In the Blue Mountains of Northeast Oregon and again in the Wasatch Mountains of Utah various species of bunchgrass and other plants were harvested monthly for three years in succession, three cuttings being made each year. On other plots in the same localities plants were harvested once each season and this was near the end of the season.

After three years the plants cut monthly had only a few weak spears of leafage per plant. Moreover, each season as the experiment progressed the frequently-clipped plants began growth correspondingly later each year until finally no flower stalks were sent up during the season. At the end of the three years the plants clipped but once each season were also 150% greater in volume and 300% greater in yield of forage. They also started growth from 10 to 15 days earlier in the spring and had a markably higher content of food in the roots.[3]

Determinations were made on the effects of overgrazing in Wisconsin by taking data from areas of bluegrass separated by division fences and receiving different intensities of grazing.

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3. Sampson, A. W., Range and Pasture Management, p. 63, 1923.

Conclusions were that:

1. White grub injury is pronounced on areas low in reserves of organic food because of overgrazing. This was due to the fact that there were less roots on the overgrazed pasture and not because grub injury was more intense.

2. The reduction of roots and rhizomes ranged from 35 to 50%.

3. Overgrazing weakens and lowers productivity of weeds, also, but not unpalatable weeds and these quickly cover overgrazed and prematurely grazed areas.[4]

Chapline states:

> Erosion following depletion of the once dense carpet of herbaceous and browse plants, has not only seriously depleted the productivity of range lands but is also endangering established irrigation projects and making prospective ones uncertain.[5]

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4. Graber, L. F., Journal American Society of Agronomy, XXI, pp. 29-34, 1929.

5. Chapline, W. R., Ibid., XXI, pp. 423-429, 1928.

Denudation by poor grazing practices causes serious erosion.

2. Continuous Grazing

Continuous grazing or the keeping of animals on grassland continually does not necessarily imply overgrazing, but this is too often the case. At least we may say that continuous grazing does not take into consideration the full requirements of vegetation.

Cropping too early in the season and again when second growth is only partially developed favors the increase of unpalatable annuals and short-lived perennials. Many grasses like western wheat-grass produce only a small amount of growth after being bitten off once or twice. Other grasses like Bermuda and especially buffalo are not so easily harmed but seem to be benefited by moderately close grazing.

On a western wheat-grass type of range at Ft. Collins, Colorado, a nine year experiment was carried out. One area was submitted to continuous grazing and another was grazed by the rotation and deferred method. At the end of the time a difference of 53% of stalks was found to exist in favor of the rotation and deferred plot. This plot also contained 54% more stalks of desirable species, 18% less of undesirable species, and 27% more stalks of immaterial species. The height and weight of seed was also greater in the rotation and deferred plot.[6]

A. E. Aldous clipped prairie grass vegetation near Manhattan, Kansas for three seasons at two-week intervals,

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6. Hanson, H. C., Colorado Agricultural Experiment Station Bulletin 377, 1931.

three-week intervals, and at the end of the season. Yields of vegetation varied inversaly with the frequency of the cutting, being least on the plats clipped at two-week intervals throughout the season and highest where clipped once at the maturity of the vegetation.

The density of the vegetation also decreased about 60% on plats clipped at two-week intervals for three seasons while the plats clipped at three-week intervals decreased in density by about 13%.

The composition of the vegetation on the plats clipped at two-week intervals deteriorated in the period of the experiments to the point where these plats contained about 50% of annuals which were practically worthless for feed. When the plats were clipped at less frequent intervals there was very little change in their original composition.[7]

In an experiment at Cornell timothy, tall oat grass, and orchard grass yielded approximately ½ as much under pasture as under meadow management. Redtop, meadow fescue, English ryegrass, and brome grass yielded approximately 3/4 as much. Bluegrass yielded 13% more under pasture management. The first group of grasses is rather coarse, generally speaking the next group is about medium and the bluegrass is fine and turf-forming.[8]

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7. Aldous, A. E., Ecology, XI, pp. 752-759, 1930.

8. Wiggans, R. G., Cornell University Agricultural Experiment Station Bulletin 424, 1923.

3. Hoenheim System of Grazing

In direct contrast to continuous grazing, often with consequent overgrazing, is the Hoenheim system of grazing, developed in Germany because of a need for maximum pasture production. This system has as its chief aim to keep the producing herd grazing on a plentiful supply of tender, nutritious grass which is high in protein and rich in minerals.

Variations exist in carrying out the essentials but in general a base treatment of 50 to 70 pounds of phosphoric acid and a like amount of potash is given. Durin the growing season, the pastures are top-dressed with 80 to 100 pounds of nitrogen from some readily available source in two or more applications. The pasture is divided into three or more fields and the producing herd is turned into the first field as soon as there is an abundance of tender grass available. They remain in this for a few days and are then changed to the next field, while dry cows and yound cattle are turned into the first field to clean up what is left. This process is continued, using all the fields and then started over on the first field again. After the second herd is removed the area is harrowed to scatter the manure and fertilizers are also applied then if it seems wise.

The essential points are:

1. Dividing the pasture into several small areas.
2. Dividing the grazing herd according to production.
3. Frequent rotations of these groups of cattle.
4. Intensified fertilization with more attention to high nitrogen applications.

This system of pasture management has been followed by numerous other methods of better utilization many of which are in some way based upon the Hoenheim system.

It is obvious that an intensive system of pasture management like the Hoenheim system is better adapted to Germany, the Netherlands, and the British Isles than to many sections of the United States. Applications of nitrogen are not utilized effectively except in the presence of soil moisture. In the European countries the rainfall is well distributed and the summers are cool; both of these factors contribute to a uniform level of production during the grazing season.

The system has been tried in many instances in the United States with varying degrees of success or failure. It has been under investigation since 1928 at the Massachusetts Agricultural College, Amberst, Massachusetts, at the United States Dairy Experiment Station, Beltsville, Maryland, and by the Wisconsin Agricultural Experiment Station in connection with fertilizer trials at Ft. Atkinson, Wisconsin.

The effect of the heavy fertilization at the Massachusetts Agricultural College was pronounced but no measure of the value of rotation grazing was obtained. At Beltsville, Maryland, the incomplete work indicated an increase of about 10% in production due to rotation grazing and a further increase of 40% or more in production due to the fertilizer applied. Here the claim that rotation grazing, in itself, results in more uniform grazing of the herbage was not supported and it was evident that midsummer applications of nitrogen were poorly utilized.[9]

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9. Archibald, J. G., Journal of Agricultural Research 45, pp. 627-640, 1932.

The 1932 report of the United States Dairy Experiment Station gives the following: The average number of acres required to pasture one milking cow and one hefier during the season of 1931 on the different pastures, except one seeded to Reed canary grass, based on a grazing period of 164 days was as follows:[10]

Treatment	Acres
Fertilized, rotation-grazed pastures	1.37
Fertilized, continuously grazed pastures	1.53
Unfertilized, continuously grazed pastures	2.14

When ammonium sulfate was applied at different rates and frequencies to a mixed bluegrass and redtop sod at the Ohio Station, a high effeciency of grass in the utilization of fertilizer nitrogen in production of both dry matter and protein was indicated. The time frequency and quantity of the applications were closely related to the yield of dry matter and crude protein. The crude protein content of grass harvested rose from 16.6% on the unfertilized plots to 21.7% on the most heavily treated plat.[11]

The results for three years at the Massachusetts State College Farm show that considerable increases occur in dry matter production per acre and in its nitrogen content, and at the same time a lower dry matter content of the fresh grass is noticed by the use of the Hoenheim system. Increases occured in all other constituents except crude fiber. Nitrogen fertilizer had a very marked effect in producing a succulent

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10. Woodward, T. E., United States Department of Agriculture Miscellaneous Publication 179, p. 36, 1932.

11. Williams, G. G., Ohio Station Bulletin 431, p. 26, 1929.

grass and a relatively large quentity of dry matter. The fertilizer treatment had little effect on seasonal variations in composition except in calcium and phosphorus with which assimilation was evidently stimulated; however, it accentuated markedly the peak of production in June.[12]

12. Archibald, J. G., Agricultural Research, XCV, pp. 627-640, 1932.

4. Rotation and Deferred Grazing

Deferred grazing is designed to allow one division of a pasture to mature a crop of seed for one year before being harvested by the cattle in the fall of that year. The next year another division is allowed to mature. Grazing should be such that each unit or division has a chance to produce a maximum crop normally before it is disturbed.

The seeds of the grasses which are scattered on the ground are aided in their planting by the trampling of the cattle and the covering given by the grass and weed mulch. This manner of reseeding is important in some sections especially those in which overgrazing has been practiced for a number of years and the stand of grass has been weakened. Besides the advantage gained by reseeding there is, also, the advantage of the physiological effect upon the plants. When plants are allowed to mature normally they store up food in their root systems to aid in the production of next years crop. This is important in that the continual removal of the early green shoots by grazing gradually reduced the vitality of the plants until they finally die.

Rotation grazing meaning the grazing of two or more areas in regular order with definite resting periods taken alone does not necessarily infer that grasses will be reseeded. If, however, a plan of reseeding and revegetation is being carried out, grazing should start each season so that a division which for the preceeding year has been deferred until the fall before grazing is not grazed first but second. If this is done

seedlings which have started from the previous years seeding, will have a chance to become established before the division is grazed.

The time of grazing the division which is allowed to mature seed in the deferred system will vary with the time of seed production of the desirable species and to some extent with the undesirable ones. The ideal situation is where the desirable species mature seed some time before the undesirable ones, and the division can be grazed between these two dates, thus, minimizing the propogation of the undesirable types and getting maximum economical increase of the desirable ones.

It may be desirable to start grazing rather early in the season to get the most from a pasture e. g. over twice as much production, as measured by heifers, was obtained in the northeastern part of the United States by starting grazing May 5 rather than June 10 and this was in spite of the fact that a much higher yield of dry matter was produced where pasturing was delayed until June 10. This seems to be largely due to the fact that if the pastures there are not grazed considerably in May and June, there will be a rather decided reduction in percent of clovers.[13]

The system of rotation and deferred grazing, unless wisely used, may cause injurious results. This would be true if the harmful or less-desirable plants were benefited materially more than the desirable pasture or range plants.

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13. Sampson, A. W., Range and Pasture Management, 1923.

The advantages, however, usually far outweigh any disadvantages which might appear. Deferred grazing allows for better root development, thus, allowing plants to secure more moisture during dry periods. Plant food may, also, be stored under this method of grazing. Under rotation and deferred grazing there is less poisoning because there is more forage available and animals are not tempted to eat poisonous plants nearly so frequently.

The summaries of some significant experiments follow.

Only two-thirds as much range is required for sheep that spend only one night at a bedding ground. This keeps down continuous grazing over any certain area.[14]

Effect of Frequency of Clipping on Percent of Grasses and Yield of Grass[15]

Frequency of Clipping	Percent of Grasses	Yield in Grams of Grass per Plot
10 days	91	47
20 days	84	55
30 days	82	69
40 days	88	94
365 days	96	91

By only two years of light stocking during the grazing season, on a gramma grass range in New Mexico there was a 33% improvement of the grass.[16]

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14. United States Forest Service on Government Ranges.
15. Black, W. H., United States Department of Agriculture Technical Bulletin 547, p. 9, 1937.
16. United States Department of Agriculture Yearbook 1915, Plate LXX, Fig. 2.

By three years of deferred grazing in California, a 15% increase was noted in the percent of grasses.[17]

Sod-forming grasses are not benefited as much by rotation and deferred grazing as are bunch grasses because they withstand grazing better and do not need to mature seed, yet with continuous close grazing the yield and vigor of sod-forming grasses are decreased and it is wise to use this practice on them also.

The following plan of grazing allows each pasture to mature a seed crop for two successive years before being harvested by the cattle in the fall:

	*																						
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
** A			X			X		X		X			X				X				X			X
B		X			X			X			X				X			X			X			
C	X				X				X			X		X		X				X				

*1--Spring
2--Summer
3--Fall

**A-B-C--Separate pasture

X--Unit being grazed

No significant difference is noticed between using three divisions and in using more for grazing which would indicate that three divisions are ample for economical rotation and deferred systems of grazing.[18]

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18. Laidunyhd, Suom, Vuosik 1934, VII, pp. 92-95, 1935.

5. One Day Pasturing

A system which has possibilities for use in an intensive farming area is one in which no additional feeding of milk cows would be necessary. The total pasture area could be divided into 12 to 20 (or more) divisions so that the required number of acres are calculated for one cow. This of course will depend upon the carrying capacity of the pasture.

In each division the best milking cows should begin the grazing, followed on the second day by average dairy cows and on the third day by young stock. The growth would be kept dense and short, and would furnish high quality forage. The nutrients needed for that area should be applied.

This would be useful only in an area of sod grasses unless the time elapsing between grazings were lengthened.

6. Yearlong Grazing With An Occasional Total Exclusion Of Stock

Yearlong protection, as would be the case in this system of management, at different intervals restores in a few seasons the vigor of the weakened vegetation and increases appreciably the forage production of the plants already in existance. This method, however, has the defects of the continuous system in the years when it is not being protected from grazing. Also, yearlong protection is not an economical practice because the most valuable perennial species may fail to reproduce by seed to any great extent and the recuperation of annuals is favored because of their strong seeding habit.[19]

While the carrying capacity of the land is increased, this increase is slow and does not compensate for the waste of the forage crop during the long period necessary for revegetation.

With this method there is more danger from fire, a loss of forage, less seed production, poor reseeding and a poorer quality of forage than is produced in rotation and deferred grazing.

Certain grasses produce less when harvested only once or twice than when harvested or grazed more often. At Cornell bluegrass gave a 13% increase in total yield when cut five times per season over only one cutting.[20]

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19. Sampson, A. W., Range and Pasture Management, p. 73, 1923.

20. Wiggins, R. G., Cornell University Agricultural Experiment Station Bulletin 424, 1923.

7. Undergrazing

It may appear logical that undergrazing, or the inclusion of fewer animals than an area will support, for a few years would take the place of rotation and deferred grazing in rejuvenating and reseeding grasses. This is true to the extent that there is likely to be some seed production and some plants will have a chance to recover.

The objections to undergrazing, however, are akin to both those of yearlong protection and to overgrazing. Grazing animals will not graze the forage evenly, but will keep a portion cropped rather closely while much of the forage will scarcely be touched. Naturally, the most palatable species are the ones most closely grazed. This gives unpalatable plants the advantage in reproduction.

Those seedlings which are produced by this method of grazing have little chance of surviving since the area is continually being grazed. Much of the forage produced is not utilized and the danger from fire is increased.

Allowing grass to mature normally stores food in the roots and produces viable seed.

C. Burning

Though much remains to be determined of the full effects of burning under different conditions some very significant things may be said about this practice.

Certain advantages of burning may be set forth, but most of these are not grounded on scientific facts but on common belief. Some such claims follow:

1. Evener grazing
2. Earlier growth
3. Controls weeds
4. Controls shrubs
5. Forage more palatable
6. Greater fertility of soil
7. Grass stand improved
8. Forage yields increased
9. Value of water drained from a watershed for irrigation and navigation.

A Kansas experiment by A. E. Aldons to determine the effects of burning of Blue Stem Pastures in Kansas follows:

Two pastures, a Casement pasture which was non-tillable and was a typical flint hill type of blue stem pasture, and a College pasture at Manhattan which was tillable but had never been broken and which had 9 inches of silt loam as top soil and 36 inches of silty loam for sub soil, were divided into plots.

The rainfall of that section averaged 31.5 inches annually, and the average length of growing season was 172 days.

Experimental Methods:

(1) Plots approximately 33' by 66'.

(2) Five Casement plots, 4 burned annually and 1 check.

(3) Ten college plots, 4 burned annually, 4 burned biennially, and 2 checks.

(4) Fields determined at maturity in October.

(5) Population counts made at 3 or 4 times through the growing season.

(6) Clipped vegetation scattered on plots for winter protection and burned with plot.

(7) Unburned plots raked in early season.

Experimental Results:

(1) On Yield--

Burning decreased the yield of mature vegetation.
Unburned plots produced greatest total weight.
Late spring burning (May 5) second, more grassless weeds (than any other burning).
Medium spring (April 10) third.
Early spring (March 20) fourth, and
Late fall (December 1) burning produces least.

(2) On Weeds--

Little effect unless done in late spring or after April 20.

(3) On Brush--

Little effect on buck brush unless done in late spring or after April 20. Burning of Sumac not practical, as low food reserve point does not

occur until May, or after spring grass growth makes burning impossible.

(4) On Quality of Vegetation--

Bluestem grasses on burned plots more leafy during early part of growing season than on unburned plots. The nutritive content depended upon the amount of growth.

(5) On Soil Moisture--

Unburned plot had highest moisture content at all seasons of the year, and lowest content in fall burned plot. Greatest difference during the droughtiest year of the experiment, 1933.

(6) On Vegetative Composition--

Plant population greatest on plots burned in late fall and least on those burned in late spring. The plots burned in late fall and early spring had a greater number of plants than the unburned plots.

(7) On Succession--

Plots burned in late fall had a successional change toward the little bluestem, while in the plots burned in the late spring the change was toward the coarser grasses, mainly big bluestem. Kentucky bluegrass increased in all unburned plots and was either decreased or eliminated on all burned plots.

(8) On Starting Growth in the Spring--

Burning stimulated early growth in the spring, owing mainly to the higher soil temperatures. The plots burned in the early spring and late fall contained a greater vegetative growth until early June, when moisture rather than temperature was the controlling factor.

(9) On Soil Temperature--

Burning increased the mean temperature and the mean maximum temperature.

(10) On Fertility--

Burning did not decrease the organic matter or total nitrogen of the soil* during the five year period. The accumulation of organic matter was a little higher on the unburned plots, due probably to stimulated root development rather than from acculumation of surface material, since the increase was mainly in the second foot.

(11) On Utilization of the Pastures--

1. Burning seems advisable on steep slopes or parts of pasture or range where stock graze less, in order to prevent over-grazing of bottoms and ridge tops and parts near water.
2. Burning seems to be advisable about every other year if pastures are stocked about the same, each year.
3. Pastures should not be burned only in the

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* This is the contrary to the widely recognized fact that organic matter incorporated the soil, increases total nitrogen.

spring following years having a large carry over of dead grass.

4. Places where stock prefer to graze should never be burned.[21]

While these investigations by Aldons do not show burning to be harmful to bluestem grass, it should be taken into consideration that the burning was always done when the ground was moist, thus preventing excessive burning of the soil and the crown of the plants.

While this experiment might appear to minimize the harmful effects of burning pastures, it is well to note that varying results have been secured by other men in many experiments.

On the foothill range in Utah burning though not decreasing total plant density tended to decrease perennial grasses and to increase annual ones. Although unpalatable sagebrush was destroyed by burning, the grazing capacity was slightly decreased.[22]

In Wisconsin bluegrass sod was burned in late winter when it was frozen and in late spring after growth had started. There was a 71% decrease in yield from the late burning, and a 52% decrease from the early or winter burning. The burning caused a 34% decrease in the weight of roots and rhizomes. Late burning greatly increased the weeds. The area burned in the late winter produced more vigorous grass with less weeds than the spring burned plot.[23]

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21. Aldons, A. E., Kansas Agricultural Experiment Station Technical Bulletin 38, pp. 1-65, 1934.
22. Pickford, G. D., Ecology, XIII, pp. 159-172, 1932.
23. Graber, L. F., Journal American Society of Agronomy 18, pp. 815-19, 1926.

Very little difference in protein content was found to exist between grasses grown on burned and on unburned areas in Colorado. The protein content was increased by burning on poor lands but not on more fertile ones.[24]

On an established bluegrass pasture in Wisconsin the old grass was burned off as follows:[25]

One strip burned March 9, one left unburned, and one burned May 11. The one burned March 9 showed very green in the early spring, but the unburned strip did not show up much because of the dead grass. By the fall of the same year the one burned May 11 had short grass and was badly infested with weeds (witchgrass, ragweed, and other). The one burned March 9 grew more vigorously through the summer, had a better growth in the fall and weeds were not nearly so abundant. The plot which was unburned was the most luxuriant of them all in growth, and there were no weeds present.

A part of each of the three plots had been grazed and a part protected from grazing. The effects of the burning may be seen from the following table:

Date	Percent decrease in grass	Percent decrease in rhizomes
Burned May 11	71.3	34.3
Burned March 9	52.4	34.0
Unburned	00.0	00.0

At the Colorado Experiment Station, burning sagebrush land was very effective in increasing forage yields.

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24. Hanson, H. C., Colorado Agricultural Experiment Station Bulletin 356, pp. 1-12, 1929.

25. Graber, L. F., op. cit., XVIII, p. 815.

The use of the entire plant as a mulch is a very effective method of reestablishing grasses. Burning destroys this mulch and, thus, greatly reduces the number of seedlings.

The increase in the yield of vegetation the first year after burning varied from 40 to 222% over the yield of the native sagebrush the year before. The increase in the yield in the second year over the yield in the native sagebrush two years before varied from 238 to 336%. The yield of grass was much greater than the yield of weeds and the grasses increased greatly the second year while the weeds decreased.[26]

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26. Hanson, H. C., loc. cit.

D. Salting

Common salt is one of the prime essentials to livestock production and is rather closely associated with the grazing of a pasture or especially a range. Salting is more important on a range in the management of cattle simply because they have more acreage to cover there and the places they graze can be more or less regulated by the use of salt.

Several benefits may be derived from the proper use of salt. They are:

Healthier animals
More easily handled animals
Better contented animals
Less traveling
More uniform grazing

The need for salt is greater when livestock are grazing succulent forage than when on dry grass or feed. Generally speaking cattle require about 12 pounds per head annually, and sheep about four pounds.

Crystal rock salt is considered the best kind of salt to use for range and pasture conditions. The distribution of this will have a great deal to do with how evenly animals are distributed over a range which in turn determines largely the eveness of grazing.

E. Fencing

In controlling the actions of livestock and especially their grazing actions, fencing is unsurpassed and good fencing will pay in most instances. There are yet some range lands which seem unprofitable to fence. If, however, a system of pasture improvement and utilization, such as rotation and deferred grazing is used, fencing is almost necessary. Even on large ranges it is often advisable to fence the spring, summer, late summer, and fall ranges into large units. This may be rather expensive but the saving of herding over a number of years will pay for this and it is more effective than herding. Moreover, it is often possible to fence between natural barriers and divide large areas of range land into suitable grazing areas.

The fencing of areas badly infested with larkspur or other poisonous plants may be advisable at times if means of eradication are more expensive and the area is not especially valuable as grazing land.

If springs or seeps are used as a source of the water supply, a fence around them to protect them from being clogged and stirred by animals is very desirable. Such a fence may multiply the effeciency of springs or seeps many times.

Fencing can, also, be used to advantage in separating test or experimental plots. Woven wire is generally best for this use, since it more nearly protects the vegetation from grazing.

F. Grazing Associations

It is desirable to get the very most from a pasture so long as the vegetation is not harmed or the value of the turf reduced. In order to do this, it is often wise to use more than one class of livestock for grazing an area. This is especially true if there are several types of forage available.

Cattle alone graze more uniformly, and will keep a pasture in better condition than horses or sheep alone. Cattle and sheep grazed together will give much better utilization than either grazed alone. Horses or mules may be grazed with old cattle, but it is dangerous to include young cattle with them.

G. Weeds

Although there are some palatable and nutritious weeds, for the most part they are troublesome pests on grazing lands and are to be eradicated rather than propogated. Poor pasture management allows weeds to become established and with good management they can usually be eliminated.

W. S. Ball of the Colorado Experiment Station gives some practical methods of weed control which follow:

Annual Weeds--the prevention of seeding over a number of years will control them. One year of such treatment would control them if it was highly effecient and the seeds did not live more than one year. Ways of preventing seeding are mowing, cultivating, burning, and spraying.

Annual weeds may be either summer annuals, which germinate in the spring and die during or before winter, or winter annuals which germinate in the fall and produce seed in the spring.

Plowing, though seldom practical in a pasture, is one good means of preventing annuals from seeding. Mowing annuals will not always suffice because many of them send up new shoots.

Biennial Weeds--may be treated as annual weeds in control measures. These measures should be applied the first year.

Perennial Weeds--the eradication of plants and the prevention of seeding must both be applied here. It is much easier to kill the seedlings of such plants than the mature plant. Ways of eradication are: Mowing in the flowering stage to prevent seeding, the use of contact sprays, burning to kill

seedlings, and shallow cultivation.

All weeds need light, oxygen, water, and nutrients. The limiting of any of these by cultivation, smothering, immersion, or by competition will reduce their vigor and if any one of these are completely removed the weed will die.

Contact Herbicides--These kill where they touch. Some of them are oils, dilute sulfuric acid, dilute sodium arsenite, 2% sodium chlorate, iron sulfate, copper sulfate, and sodium metaborate. Contact herbicides are used mostly on annual weeds to prevent seeding and to reduce fire harard, which exists when certain other sprays are used.

Selective Sprays--These sprays kill broad-leaved annuals having exposed growing points but do not seriously affect grasses nor cereal plants. Some such sprays are dilute sulfuric acid, iron, copper, and ammonium sulfate, kainite, and calcium cyanamide.

Translocated Sprays--These sprays are used mostly for deep-rooted perennial plants to carry poison down to the roots. One such spray is made of ½% arsenic trioxide, in the form of sodium arsenite, and 5% sulfuric acid. Others are arsenic acid, arsenic trichloride and sodium chlorate.[27]

An experiment to determine the effectiveness of different methods of control in pasture of Kansas follows:

Two applications of sodium chlorate at the rate of 100 pounds per acre killed 78% of the sumac stems present, and, also,

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27. Ball, W. S., Colorado Agricultural Extension Circular 97, p. 89, 1936.

reduced the forage stand ½. The same treatment with 50 pounds per acre killed 25% of the stems and had little effect on the forage. A 2% solution of sodium arsenate was 10% effective in killing sumac.

The effects of burning were:

(1) Weeds

	Dry weight of weeds in pound per acre		
	1927	1928	Average
Check	548	299	424-
Early spring burned March 15	411	460	435+
Medium spring burned April 15	870	430	650
Late spring burned May 10	64	3	34-

(2) Brush

	No. stems originally	No. stems Oct., 1927	Ave. height stems in In.	No. stems Oct., 1928	Ave. height stems in In.
April 15	480	1607	20	1075	13
May 10	164	84	8	42	6
Check	329	334	36	342	36

An analysis of the roots of burned and unburned plants in October after spring burning showed roots of unburned plants to be 27% starch, and those from burned plants to be 21.5% starch.

The effects of cutting on buckbrush were:

	Percent effectiveness
May 10	87
May 25	53
June 9	24

After three cuttings all the plants were dead on the plot cut on May 10 and practically all were dead on the other two plots.

The best date for cutting sumac was June 8 at which time the cutting was 60% effective.[28]

The above experiment shows that different weeds have their low food reserve at different times. If the burning or cutting is done when the food reserve is lowest in their roots, the best results will be obtained.

Many of our most noxious weeds need special attention. One such plant is tall larkspur, which is responsible for the loss of many cattle on the western ranges. Since this is a perennial plant, the most feasible method of control is grubbing up root and all. The cost of this will range from $3.65 to $10.10 per acre for the first grubbing, and the second can be done for $1.00 per acre. This cost is about ½ to 2/3 of the value of the cattle lost each year because of the plant. From 80 to 95% of the plants are killed at the first grubbing. Other means of control are the fencing of infested areas or the grazing of the plants by sheep before the cattle, which are susceptable to the poison, are placed on the range.[29]

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28. Aldous, A. E., Journal American Society of Agronomy, XXI, pp. 660-665, 1929.

29. Aldous, A. E., United States Department of Agriculture Farmers Bulletin 826, pp. 1-23, 1917.

H. Improvement

In seeking new plants or in improving well-known species to meet the aims of improvement, it is necessary to decide whether to concentrate on a search for plant forms which are adapted to poor or depleted soils, or to seek those which are superior on soils which have been well managed with adequate lime and mineral treatments. In other words, shall we attempt to improve forage species for soils as they are now, or shall we improve these soils with the purpose of supporting better species and strains?

Probably a combination of the two methods should be undertaken. Since the best species are those making satisfactory growth only on reasonably fertile soils and since there is an inherent weakness of breeding strains adapt to poor soils, surely one without the other is not wise if we desire maximum results.

Because of the grazing habits of livestock, neither is it wise to improve a part of an enclosure and neglect the other as one will be overgrazed and the other undergrazed.

I. Fertilizing

Where yields of pasture or range plants are not limited by moisture the fertility of the soil greatly influences yield and quality of the forage produced. If land is poor, lax management practices will show up readily. Under proper grazing conditions fertility of pasture soils is reduced very little, if any, but yields may be materially increased by the proper use of fertilizers.

In the humid sections of the United States the average pasture will support an animal unit on about 4 acres, while in Europe, reports indicate that, much less is required.* Where chemical fertilizers are used, there some areas support an animal unit on ½ acre. Of course there is some justification for this difference but not for all of it, and we should be making more effecient use of our grasslands.

When measures of improvement are carried out and increased yields of forage are the result, it is evident that larger quantities of plant food are being removed from the soil. This is all the more reason that fertilization should accompany most plans for improvement.

Not only is the production better if the soil is fertile, but there appears to be marked differences in the fat and flesh-producing qualities of grass depending, apparantly, on the character of the soil on which it is grown.

Since different soils are defecient in different elements, the elements which are the limiting factors are necessarily the

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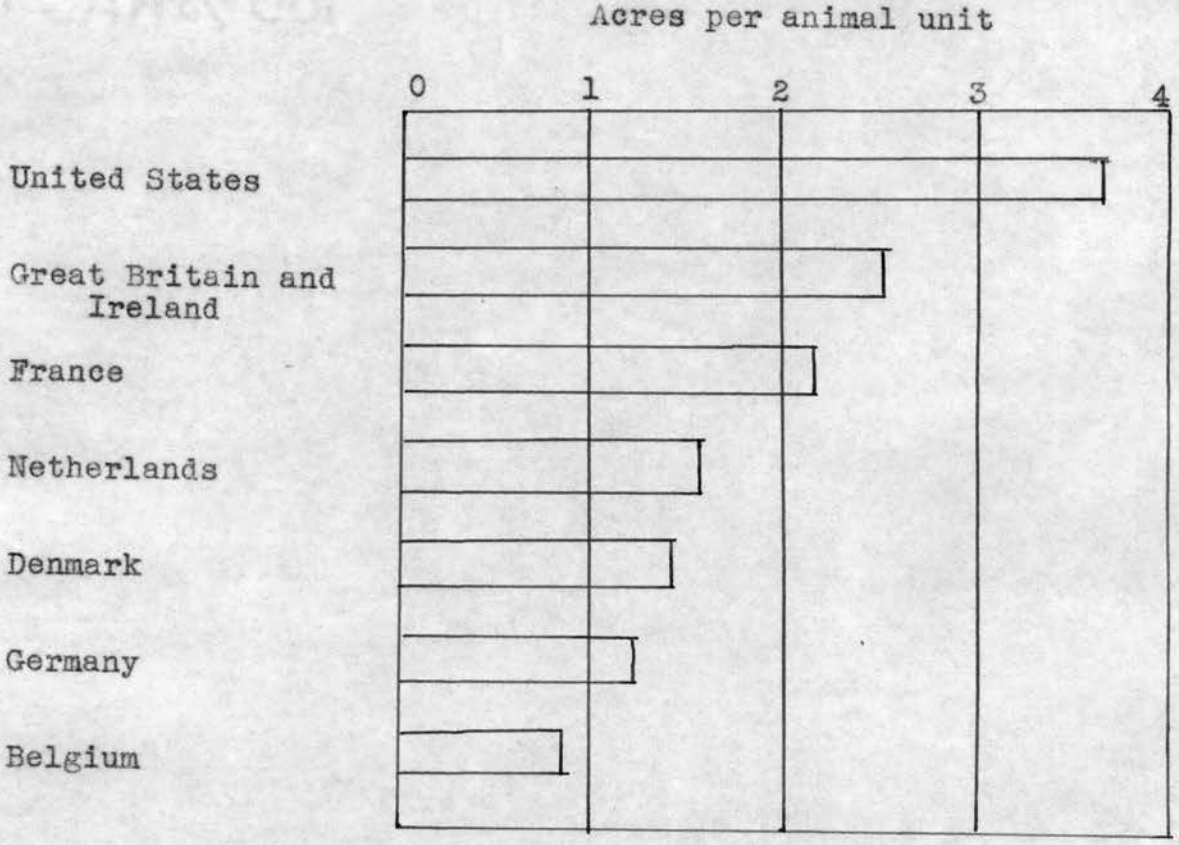
* Referring to the chart on page 48.

AREA OF HUMID PASTURE

(other than woodland)

PER ANIMAL UNIT



30. United States Department of Agriculture Yearbook 1923, p. 470.

ones which should receive the most attention. The response which a pasture will give to a fertilizer shows its need for that particular fertilizer.

A typical experiment to determine the needs of an area and to find the mixture best suited for that area follows:

Twenty 1/200 acre plats in duplicate were used.

Fertilizer was applied at the rate of 600 pounds per acre in variations of the basic formula 6-12-6. The following fertilizer analyses were included and duplicated: 0-0-0; 6-0-0; 0-12-0; 0-0-6; 0-12-6; 6-0-6; 6-12-0; 4-12-6; 6-8-6; 6-12-4; 8-12-16; 6-12-8; 8-16-6; 6-12-6, nitrogen applied annually; 6-12-6, check; and 6-12-6 plus lime.

The nitrogen was applied annually and the phosphorus and potassium were applied every third year.

The land was divided into three sections and seeded to bermuda, centipede, and carpet grass.

Yields were determined by clipping with a lawn mower at frequent intervals through the growing season.

The responsiveness of American pastures to fertilization is clearly shown in the following results:

In southwestern Virginia 1913-1917 inclusive[31]

Treatment	Increase in live weight of animals over check
10 tons manure 1913	49%
300 pounds per acre superphosphate 1913-1915-1916	87%
250 pounds per acre bone meal 1913-1915-1916	0

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31. Hutcheson, T. B., Virginia Agricultural Experiment Station Bulletin 221, pp. 39-42, 1919.

In four counties in southeastern Ohio two tons of limestone and 400 pounds of superphosphate per acre increased the total vegetation 3 to 5 times and the crude protein from 5 to 7 times the amounts from the untreated pastures. Legumes increased markedly after treatment followed in a few years by an increase in bluegrass.[32]

To a good grass pasture in Massachusetts was applied a topdressing of 55 pounds of nitrogen, 55 pounds of phosphoric acid, and 67 pounds of potash per acre at the beginning of the growing season, and this was followed by three applications of 10 pounds each of nitrogen in the form of "Calurea".

The fertilizer decreased considerably the percent of dry matter in the grass and decreased slightly the percentages of crude fiber and calcium in the dry matter. The percent of nitrogen, phosphorus, and ether extract was increased, the nitrogen markedly so. Acre production of all constituents was increased, nitrogen being nearly doubled, while phosphorus and ether extract were increased by about half.[33]

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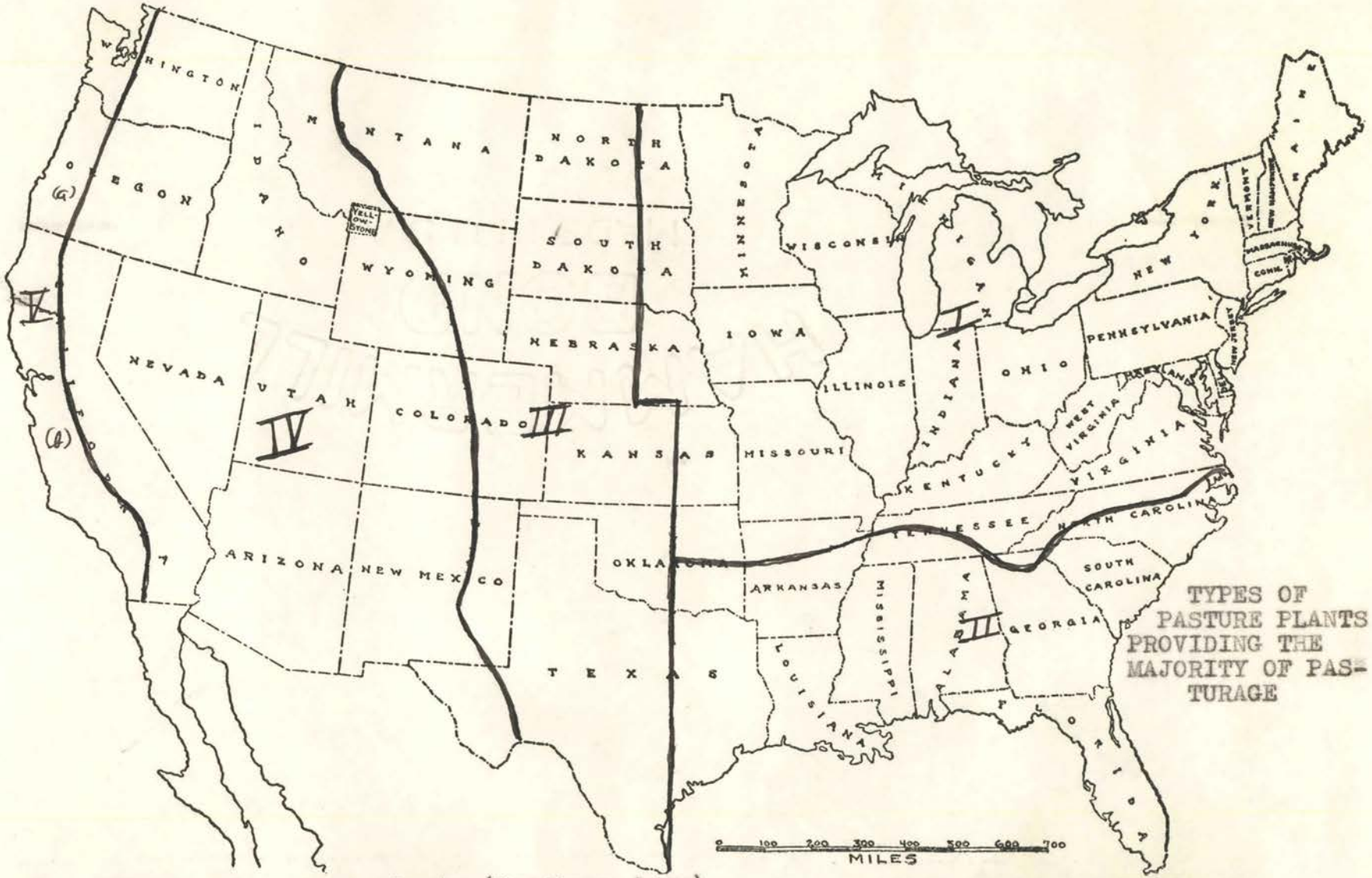
32. Barnes, E. E., Journal American Society of Agronomy 16, pp. 241-251, 1924.

33. Beaumont, A. B., Fertilizer Tests on an Important Pasture Soil Type, Massachusetts Agricultural Experiment Station Bulletin 306, 1934.



TYPES OF PASTURE PLANTS PROVIDING THE MAJORITY OF PASTURAGE

I. Introduced pasture plants (Northern type)
II. Introduced pasture plants (Southern type)
III. Native short grasses
IV. Native Desert grasses and shrubs
V. Introduced pasture plants
(a) Northern type
(b) Winter annuals

CHAPTER III

Pasture Sections Of The United States And Plants Best Adapted To Them

Although some few plants are rather well adapted to most all sections of the United States, most of them thrive in only a limited section. In the humid northern states timothy, Kentucky bluegrass, redtop, orchard grass, perennial ryegrass, tall oatgrass, meadow fescue, Canada bluegrass, and bromegrass are the most important pasture grasses. In the more arid regions of the north crested wheatgrass, bromegrass, and slender wheatgrass are the most important.

Southern pasture grasses are Bermuda, carpet, Dallis, johnson, centipede, Rhodes, Napier, rescue, and Vasey grasses. In the subtropical belt along the Gulf Coast we find Para, Guinea, and molasses grasses.

Some of the most important legumes and the sections to which they are adapted are as follows:

Alfalfa.	.West
Lespedeza.	.South
Alsike clover. . . .	.General, chiefly N.E. and extreme N.W.
Red clover	.Same as Alsike
White clover	.Anywhere there is sufficient moisture
Little Hop clover. .	.Northwest and southeast
Low Hop clover . . .	.Southeast
Strawberry clover. .	.Northwest ¼ of the United States
Sour clover.	.Southeast ¼ of the United States
Yellow trefoil . . .	.Southeast
California bur clover.	.South ½ of the West ½
Southern bur clover.	.South part of the southeast
Korean lespedeza . .	.Northern part of the southeast

A pure stand of some desirable pasture grass is very desirable yet by the addition of some legume or legumes to that pasture its value may be greatly increased. Some of the

advantages of mixtures including legumes follow:

1. Legumes in pasture mixtures help to maintain the nitrogen content of the soil, add calcium and vitamins to the ration, and reduce the need of nitrogen fertilizers.

2. Mixtures result in a more uniform stand and higher production, because several soil conditions are often represented in a pasture and in a mixture plants adapted to each soil condition are likely to be found.

3. Mixtures provide a more uniform seasonal production because the periods of flush growth and dormancy vary in different plants.

4. Mixtures of grasses and legumes provide a better balanced ration since legumes are richer than grasses in both protein and minerals.

Some suggested mixtures for pasture planting in the different sections of the United States are:

For the Northeastern States

On good, well-drained soils				On poor, well-drained soils			
Kentucky bluegrass	5	or	6	Orchard grass	8	or	10
Timothy	4		5	Canada bluegrass	5		6
Orchard grass	4		5	Redtop	4		5
Redtop	2		3	Alsike clover	2		3
Alsike clover	2		2	White clover	1		1
Red clover	2		2		20	or	25
White clover	1		2				
	20	or	25				

In Iowa, Minnesota, and the Dakotas, bromegrass may be substituted for orchard grass in these mixtures and Reed canary grass alone makes a very productive pasture where rainfall conditions are good.

Legumes in pasture mixtures help to maintain the nitrogen content of the soil, add calcium and vitamins to the ration, and reduce the need of nitrogen fertilizers.

On wet, poorly-drained soils

Timothy	4		6		Reed canary	5	8
Redtop	8	or	10	or	Redtop	4	4
Alsike clover	3		4		Alsike clover	1	3
	15	or	20			10	or 15

Reed canary grass may be sown alone at the rate of 8 to 12 pounds per acre on land likely to be submerged for a part of the year, and excellent pasture obtained thus from land otherwise unproductive.

For the East Central States

Good, well-drained soil

Kentucky bluegrass	5	or	6
Orchard grass	4		5
Timothy	2		3
Redtop	2		2
Lespedeza	6		7
White clover	1		2
	20	or	25

Poor, well-drained soil

Orchard grass	5	or	6
Redtop	4		5
Alsike clover	4		5
Lespedeza	7		9
	20		25

Wet, Poorly-drained soils

Timothy	5	or	6		Meadow foxtail	4	or 5
Redtop	8		10	or	Redtop	8	10
Alsike clover	3		4		Alsike	4	5
	16		20			16	or 20

In the northern part of this section the Korean lespedeza should be used; in the southern part, common, Kobe, Tennessee 76 are best; the latter two varieties are usually more productive than the common. However, good results are obtained from a mixture of common and Korean in Tennessee and North Carolina.

For the Southeastern States

On Moist Sandy Soils

Carpet grass	5	or	6
Dallis grass	3		4
Lespedeza	12		15
	20	or	25

Clay, loam, or clay loam, or silt loam

Dallis grass	3	or	4
Bermuda grass	5		6
Lespedeza	10		12
White clover	2		3
	20	or	25

Common, Kobe, and Tennessee 76 lespedezas are the varieties to use in this region.

Great Plains and Intermountain Region

Here native grasses are used for the most part. Crested wheatgrass, bromegrass, slender wheatgrass, and sweet clover mixtures are good for the northern part while for the high mountain valleys, Kentucky bluegrass, or Canada bluegrass, timothy, redtop, meadow foxtail, red, alsike, and white clover alone or in combination are best. Crested wheatgrass, bromegrass, and slender wheatgrass are also used in the latter region.

Northern part or the Northern Great Plains

Irrigated Lands		Other Areas			
Smooth bromegrass	9	Smooth bromegrass	3	or	4
Orchard grass	9	Kentucky bluegrass	4		6
Timothy	4	Orchard grass	4		6
Meadow fescue	5	Meadow fescue	3		4
Yellow sweet clover	3	Alsike clover	1		2
	30	White clover	1		2
			16		24

Alfalfa or sweet clover alone may be sown at the rate of 12 to 15 pounds per acre.

On wet poorly-drained soils a mixture of Redtop 10 is good.
Timothy 6
Alsike clover 4
20 pounds

Southern Part or the Southern Great Plains

Bermuda or alfalfa on irrigated lands or Dallis grass may replace Bermuda.

North Pacific Slope

Moist bottom land		Fertile uplands		Land which is subject to flooding for short periods	
Italian ryegrass	3	Italian ryegrass	4		
Perennial ryegrass	3	Tall oatgrass	4		
Meadow fescue	4	Orchard grass	4		
Kentucky bluegrass	4	Kentucky bluegrass	4	Seaside bent	5
White clover	2	White clover	2	Meadow foxtail	5
Red clover	2	Red clover	2	Italian ryegrass	4
Alsike clover	2	Alsike clover	2	Alsike clover	4
	20		22		18

Land which is subject to flooding for long periods

Reed canary grass 8 or 10
or
Seaside bentgrass 8 or 10

On irrigated lands in this section the mixture recommended for moist bottomland is perhaps the best pasture mixture. Both alfalfa and ladino clover seeded alone have been found to make unusually productive pastures for dairy cattle. There is however, grave danger of loosing some of the animals from bloating when either of these legumes are grazed.

In the southern part of the Pacific slope the summers are quite dry and the rainfall during the winter is light so that natural pastures consist largely of winter annuals which reseed every year. On the irrigated lands a large part of the pasturage is obtained from alfalfa fields. Ladino clover, Bermuda grass, and Dallis grass, also, do well here.

South Pacific Slope

Irrigated lands

Dallis grass	5	Harding grass, sweet clover and orchard grass are sometimes added, but do not make the mixture more satisfactory.[2]
Italian ryegrass	5	
Alfalfa	5	
Ladino clover	6	
	21	

2. Semple, A. T., United States Department of Agriculture Miscellaneous Publication 194, 1934.

CHAPTER IV

Drought Survival

The adaptability of any forage plant to a certain section or region is determined by how well that plant grows under the general conditions found there and, also, how well it stands the adverse conditions which may at times exist. In many sections of the United States moisture is a limiting factor of production and those plants which can withstand drought are valuable to such sections.

The following work was done by D. A. Savage in the drier sections of the United States.

A total of 643 quadrats, each one meter square, representatively located, were charted with pantographs to show ground cover of all native grasses and other perennial or turf-forming vegetation on ungrazed, moderately grazed, and heavily grazed areas on all the major textures of soil in the vicinity of North Platte, Nebraska; Akron, Colorado; Colby, Hays, Tribune, and Garden City, Kansas; Woodward, Oklahoma; and Dalhart, Texas. These quadrats were considered sufficient to include all species occuring regularly and abundantly in the different areas.

The pantograph-chart method of measuring vegetation, which is described later in this paper, was used because it is considered the most acurate.

An average of about 10 quadrats were charted in each grazed or ungrazed area included in the study which is considered sufficient to obtain a reliable representation of conditions.

Each chart was reduced to an area 1/25 of a square meter or by a lineal ratio of 5 to 1. Planimeters were used to assist in measuring the different characters shown on the charts. The resultant data were computed to determine the actual percentage of ground cover occupied by every species of grass, sedge, and important forb present and the percent of total vegetation contributed by each species. Forbe include all herbaceous species other than grasses and sedges. Ground cover or basal cover represents that part of the ground occupied by the basal cross section of crowns, stolons, or stems of true plants. When two or more such plant portions were closer than 1 cm. apart they were considered as fully occupying an area.

A large percentage of the native grasses in the central and southern Great Plains was killed by the sever drought of 1933-34. The ground cover on sandy soils being originally less than that on heavier soils was correspondingly less after the drought, except on certain areas at Dalhart, Texas.

Buffalo and blue gramma together constitute more than 90% of the total vegetation on all except very sandy soils. On the heavier soils only a few scattering plants of the tall grasses survived, principally bluestem (western wheatgrasses), sand dropseed, and red three-awn (wire grass).

Bluegramma is adapted to a much wider range of soil textures than buffalo grass, and was an important species on all soil textures in all localities studied.

Soil blowing and overgrazing contributed materially to the damage, but climatic extremes caused much more injury than that traceable directly to grazing.

The grass cover on closely clipped areas was consistently better than on lightly clipped areas in all comparisons at Hays, Kansas and at Dalhart, Texas.

As grazing was intensified the actual ground cover of buffalo grass declined in all areas where the drought was severe, however, the relative proportion of ground cover represented by buffalo grass increased with each successive increase in the degree of grazing.

Buffalo grass was more abundant than any other grass in pastures of the heavier soils, and grazing, when not extreme, appeared to be indirectly beneficial to this grass probably in reducing the competition of taller grasses.

Blue gramma was less resistant to clipping, heavy grazing, and perhaps drought than buffalo grass, but was superior to all other grasses in these respects.

The ground cover of practically all tall grasses was consistently and successively reduced as grazing was intensified.

Most of the perennial and biannual forbs decreased under grazing and drought in about the same proportion as the tall grasses.

Annual grasses represented only a small part of the total vegetation. These grasses as well as the annual forbs were most numerous on heavily grazed and severely damaged

pastures where the perennial grasses were covered by wind-deposited soil.

Savage states that although, much of the grass is dead, the surviving plants are rather uniformly distributed and may be expected to recover rapidly under favorable climatic conditions.[1]

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1. Savage, D. A., United States Department of Agriculture Technical Bulletin 549, 1937.

CHAPTER V

Revegetation

In general, it may be said that revegetation is either natural or artificial.

Natural revegetation

The natural revegetation of native pasture and range plants is dependent first upon the production of a fertile seed crop. If such a crop is produced, the requirements for vigorous growth must be met. The more vigorous the plant the earlier it will send up flower stalks, thus having a better chance to mature its seed and the more viable these seed will be. Grazing will of necessity be regulated so that the plants can mature normally.

Usually when plants mature seed they are dropped to the ground. This is significant in revegetation because livestock consumes few of the mature seed. If after the seeds are dropped the land is not grazed, the seeds of many of the desirable plants will not find their way into the soil because they are light and chaffy while those of weeds and other undesirable plants will usually be buried in a good seedbed by natural agencies since they are round and heavy. An adequate litter cover is not so likely to exist unless the area is grazed. In view of these facts, it is desirable to graze the area which has been allowed to mature seed reasonably heavy before the following spring.

After the seeds have been produced, planted, germinated, and emerged as seedlings, they must have special care if they

are to continue to develop. Dry areas or hard-packed areas are undesirable for seedling growth and often cause the death of many. The root system is so poorly developed until the end of the first growing season that moisture conditions must be optimum for seedling survival. They can, also, be easily pulled from the soil by grazing during their first year.

Artificial Reseeding

To be successful, artificial range and pasture reseeding will require conditions above the average in soil, rainfall, and growing. On the range such conditions may be found in mountain meadows, moist parks, alluvial bottoms along streams, the more favorable slopes, where the annual precipitation is 17" or more, and where restoration of the native vegetation by range management is not practical.

If the area is favorable to reseeding, then the adaptability of the plants should be considered. The probability of restoring the native vegetation whould be kept in mind and if grazing cannot be restricted until the reseeded area has become well established, it might as well not be done.

If the species in mind is not native and there is any doubt about its adaptability, it should be tried in small areas first.

Near the timber line on inland mountain ranges common bromegrass, Kentucky bluegrass, Canada bluegrass, and redtop are desirable.

Medium to high elevations below the timber line of inland mountain ranges the same can be used as near the timber

line, but other plants may be added. Some of these are: timothy, orchard grass, slender wheatgrass, red clover, white clover, alsike clover, Italian ryegrass, sheep fescue, meadow fescue, and bur clover.

In revegetating a pasture the methods may be the same as those for establishing a pasture. Under range conditions it is somewhat different. The seeds may be broadcast and tramped in by sheep or with cattle, they may be drug in with a harrow or a brush drag. In some instances furrows are made on the contour every three or four feet apart, and rain washes the seeds into these and covers them. On limited areas it may be possible and advisable to do a complete job of plowing and harrowing to plant the seed.

The same care and precautions must be taken with the seedlings as when they are naturally reseeded.

There is very little use to reseed if judicious grazing practices are not followed afterwards, but if such grazing is done the increased effeciency of the pasture or range will soon repay all expenses involved.[1]

Because of their growth habits, some grasses reproduce more readily by sodding than by seeding.

Occuring in varying degrees of abundance from southeastern Montana and southwestern North Dakota to southcentral Texas and from the foothills of the Rocky Mountains to the 97th degree of longitude on the Great Plains, buffalo grass is a very important range and pasture grass.

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1. Forsling, C. L., United States Department of Agriculture Circular 178, 1931.

From 20 to 50 years are required for buffalo grass to become reestablished naturally on abandoned farm land. It is not practical to establish it by seeding because seed is difficult and expensive to collect. It is, also, of very low germination.

Buffalo grass may be propogated by setting out the runners or stolens in moist soil, but this method is not successful on strictly dry land. The most practical method, where watering is not possible, is to set small pieces of sod in well-prepared soil at intervals of 3 to 4 feet.

An acre of cultivated land when set out with 4-inch cubes spaced three feet apart requires about two square rods of sod or a strip 12" wide and 538 feet long.

Buffalo grass has been successfully transplanted every month from March to August inclusive, but the best time appears to be in March and April before spring growth has started and following a heavy rain. A 4-inch cube is the most convenient size to handle and the most effecient in spread.

Four-inch cubes of sod when spaced 1 foot apart covered all intervening spaces the first season, two feet apart the second season, and when spaced three feet apart they covered the ground before the end of the third season. Similar sods spaced six feet apart made a total cover at the end of the fifth season.

An effecient way of planting large areas is to slide pieces of sod in sheet iron chutes from wagons to the surface of deeply cultivated land and pack them into the ground with

the wheels of the wagon or a heavily-weighted surface packer. Packing the land after the sods are set is essential to success.

Buffalo grass spreads largely by surface runners which should not be disturbed by hoeing or cultivating. Cultivation, also, encourages erosion.

Clipping at the height of two inches or moderate pasturing at intervals throughout the sason to control other growth and admit sunlight is beneficial to the spread of buffalo grass.

Sweet clover, if properly grazed, may be grown continously or areas being resoded with buffalo grass, thus providing additional pasturage while the grass is becoming established.

Buffalo grass will not withstand protracted excess of water on low land.[2]

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2. Savage, D. A., United States Department of Agriculture Circular 328, 1934.

PART III

TECHNIQUE IN MEASURING RESPONSE

CHAPTER I

Methods of Measuring Response

The technique of grazing management can be studied best by careful observation of the habits of grazing animals. However, there is need for very technical measurement in many instances and the methods of measuring response of plants to different treatments and methods of management are many and varied. Some of them follow:

1. Gain or loss in live weight of cattle or sheep.
2. Clipping and dry weight yields.
3. Grazing with steers and calculating maintenance and gains into therms and total digestable nutrients.
4. Profits or losses.
5. Hay weights.
6. Combinations of grazing and clipping.
7. Analyzing herbage for total nitrogen.
8. Surveys.
9. Observation with or without grazing.
10. Field cured hay weights.
11. Palatability.
12. Unit days of grazing.
13. Observation of the growth behavior of plants.
14. Duration of grasses.
15. Leafiness, spreading ability, hardiness, and seed production.
16. Milk and butterfat production and cow pasture days.
17. Effect on health of animals.
18. Hours of grazing.
19. Botanical analysis (species and their frequency).

Of these mentioned the first and the last namely gain or loss in weight of animals and botanical analysis are of most importance and will be chiefly the ones considered here.

A. Grazing Versus Harvesting

In determining yields or response, grazing animals may be used and the yield thus determined indirectly, or it may be measured more directly by clipping and weighing the vegetation. The answer to the exact difference of grazing and harvesting by mechanical means is not known, but some interesting facts may be noted.

Animals exercise preference both, for kinds and parts of plants in their grazing. Because of this, the herbage of grazed and mowed plats may, in time, differ markedly in botanical composition. The importance of these differences would depend on many factors including the type of sward and animal, the time and rate of stocking, and soil fertility or fertilization.

Animals void a large proportion of the fertilizer elements consumed in their feed. This is particularly true of nitrogen and phosphorus. That the previous use of the land may have a very important bearing on its response to fertilizers may be illustrated by some observations made at the Storrs Agricultural Experiment Station. There a meadow runout by the mowing and removal of hay crops responded markedly to potash while an adjacent pasture, runout by grazing shows little, if any, more growth of herbage when the nutrient is included in the fertilizer.

Different classes of livestock remove varying amounts of fertilizer elements from the soil. For instance fattening animals require less nitrogen, phosphorus, and calcium, than

milking or growing stock. Milking cows are usually removed from the pasture for several hours, frequently for all night and other parts of the farm benefit from the voidings at the expense of the pasture. Milking cows usually receive more or less supplemental feed and indirectly the pastures receive elements not derived from the fertilizers. The relative effects of the manure may be expected to vary inversaly with the adequacy of the direct fertilization. With optimum fertilization no beneficial effects could be expected from manure. As these varying effects cannot be evaluated it appears to be good experimental procedure to reduce supplemental feeding to the lowest possible minimum.[1]

The Pennsylvania Experiment Station recorded between 70 and 80% as many digestible nutrients for grazing as for clipping, and the data had a high positive correlation. However, as the mowed enclosures were changed to previously grazed areas every two or three years, this experiment does not afford a comparison between continously mowed and continuously grazed land.[2]

The West Virginia Experiment Station found that yields of total digestible nutirents from continuously mowed plots have gradually decreased, and were only 56% of the grazed plats after five years.[3]

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1. Brown, B. A., Journal American Society of Agronomy 29, p. 468, 1937.

2. Gardner, F. D., Pennsylvania Agricultural Experiment Station Bulletin 323, 1935.

3. Robinson, R. R., Journal American Society of Agronomy 29, pp. 349-359, 1937.

At the Storrs Station in Connecticut, the relative yields of dry matter from continuously caged areas were greater in most cases than the corresponding yields as determined by grazing with dairy heifers without supplemental feed. The yield of the differently fertilized pastures were in the same order by either method.[4]

These results seem to lead us to the conclusion that like results may be secured from either method, but that there is a difference when the two are used together.

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4. Brown, B. A., Journal American Society of Agronomy 29, p. 468, 1937.

B. Determining Yields By The Use Of Grazing Animals

There is much room for error when grazing animals are used for determining yields because animals are subject to considerable variation. The breed, age, size, hereditary complex, physiological makeup, sex, and stage of pregnancy must all be considered in selecting animals for measuring experiments.

The use of sheep in pasture experiments will permit the use of a larger number of animals and will thereby reduce the error of random sampling. However, the data obtained are not readily applicable to cattle grazing. The tramping effect and grazing habits of the two animals are entirely different and produce different effects upon the pasture.[5]

While total gains of cattle for the grazing period or season are of ultimate interest and importance, the gains for various periods are, also, highly significant. Weighing should be at regular intervals throughout any experiment. Over reasonably long periods a 30-day interval is desirable. At the beginning and close of the grazing period the cattle should be weighed on three consecutive days and the average for the three weighings determined for the initial and final weights.

It is usually highly desirable to weigh cattle individually rather than as a group. If during the season some

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5. Schuster, G. L., Journal American Society of Agronomy, XXI, pp. 666-673, 1929.

individual has an abnormal weight, that animal should be checked the following day.

Serial numbers may be branded on the hoofs of each animal in order that an individual record may be kept.

In so far as possible, weights should be taken at the same time of day each time, and the cattle should be in the same condition as regarding water and grass.

When using more than one group of cattle in the same experiment, it is desirable to have them as nearly equal as possible in weight, age, breed, and in previous care and handling.

One method of weighing on the first and last weighings of an experiment is to weigh after keeping without food or water from the afternoon of the day previous to weighing and additional weights are taken until the animals cease to lose weight. It is seldom desirable to be this technical, however.

In more technical work one may, in addition to determining the growth increase of cattle (especially young cattle) by weight, take measurements of the chest girth when turned on and off the pasture. Certain studies in Germany showed that young cattle making the greatest weight gains but the least girth increases fell back three years later to the lowest place in weight. The increase in weight was finally in proportion to the increase in girth the first year.[6]

This, however, is more closely connected with response of different individual cattle than with grazing methods.

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6. Lanew, Deut., Tierzucht 18, pp. 185-187, 1914.

Clipping is one of the most accurate methods of determining yields.

C. Determining Yields By Clipping

In clipping plots of forage grass shears, lawnmowers, sickles, or mowing machines may be used. Of these, the lawnmower most nearly approaches actual grazing conditions but, of course, the instrument to be used will depend upon several factors such as topography, plants to be harvested, size or area, and others. Grass shears are useful mainly for clipping very small areas, such as in cages, quadrats, nursery rows, etc. A mowing machine is used when the area is large and hay cuts are made because if the forage is over six inches high, a lawnmower will not harvest it effeciently.

It is often desirable to measure the height of plants whether they are to be clipped or not. For this purpose a stick with the following descriptions is a desirable one. Measurements are in feet and in tenths of feet. The stick is a planed one of light pine about 1.5" wide and .75" thick, and as long as is needed for the vegetation to be studied. Spaces between certain much-used points may be variously colored so as to facilitate rapid recognition.[7]

After clipping, the vegetation should be weighed and the weights recorded. Then, after weighing some of the forage should be saved for the determination of dry matter because it has been found that different species on adjacent plots have varied from 12 to 39% dry matter during a single month.[8]

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7. Pearse, Kenneth, Ecology 16, pp. 529-530.

8. Brown, B. A., Journal American Society of Agronomy 29, p. 471.

Where it is desirable to know the dry matter content of a large number of samples, it may be best to dry all samples quickly in a heated room, remove them to unheated storage where they are kept for a few days to permit them to reach equilibrium, and finally weighing a large number of similar samples in one day, taking two or three for complete drying in an oven. This eleminates a great deal of work and under this set up all samples so treated will contain practically the same amount of moisture on any given day.

D. Botanical Analysis

The methods of obtaining a botanical analysis of any area are many, but in general they may be said to be directed at determining the number of plants of the various species or at finding the area covered by a certain plant or group of plants.

Although no rule can be laid down which will be most satisfactory for all regions, it may be said that counts are desirable on bunch grasses and that the percentage of area covered is best for mat grasses. Where exact counts are not practical, some such method as the point quadrat method which gets an approximate is good to use.

Because of the variableness of composition within a small range, it is desirable to have several counts. An apparently homogenous award may be extremely variable. In the analysis of such a sward at least 10 readings per plot are necessary. While variation becomes less pronounced as the size of plot is decreased, still the curves do not tend to become smooth until about the 8th or 10th reading. The size of the area counted is an important item. A study of an acre by the quadrat method and with 20 mesh readings or counts taken on each plot showed that at least five plots, each one itself properly samplet, are required to obtain an average of reasonable accuracy. In plot work there should be at least five replications.

Plots of pure species were studied for relative establishment and ability to produce tillers, and again it was found

that at least 10 readings should be made per plot. Similar work on the analysis of a hay sample led to the conclusion that the equivalent of about one pound of green mature hay should be about the minimum sized sample of young pasturage of a single species or a simple mixture.[9]

1. Mapped Quadrats:

Carefully selected areas are established and charted at the beginning of an experiment. These areas are then mapped and this permanent record kept. Maps may be made for individual species or several species may be mapped together. The relationship of different species and the effect of the type of grazing or clipping can be noted by later maps.

2. Isolation Transects:

To determine the effects of grazing or non-grazing, isolation transects may be used. In this a transect is fenced off and divided into series. These series are in turn divided into units or blocks. One of the units in the first series is opened to grazing each year, while one of the units in another series which is open at first is closed each year. One series should be provided which is not grazed at all.

A good example is a transect 200 feet long and 60 feet wide divided longitudionally into three series A, B, and C. The middle series is not divided into units nor even grazed. The outside series are each divided into 10 20-foot square units. Series A being open and C closed at the beginning of the experiment have one opened and one closed respectively each year.

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9. Welsh Plant Breeding Station Report 1, 1931.

A	Closed at beginning---one opened each year
B	Continually closed
C	Open at beginning---one closed each year

3. List Quadrats:

Areas of definite size in which plants are counted and the numbers recorded are of value in keeping a record of the number of plants of individual species as affected by the grazing system in use. Such quadrats may be used in open pastures or ranges or in isolation transects as described above. They may be permanently located by means of a single stake or by several stakes.

4. Clipped Quadrats:

Clipping quadrats may be done to determine

1. The effect on subsequent growth of different frequencies of clipping.

2. The period of most active growth of the species studied.

3. The effect different frequencies has upon various species in the association if more than one species is represented.

4. Yields under various clipping frequencies.

Frequencies may be from 10 days to semi-annually or annually. The annual clippings usually give greatest production, but most economical clippings have been from 30 to 40 days on most species. Some plants are benefited by frequent clippings.

5. Percentage Composition

Rods one meter long and marked in centimeters are used in what is essentially a quadrat method. Plants are noted in five groups--forage grasses, legumes, forage herbs, sour grasses, and weeds. The percentage area for each group is estimated on a scale of 100 and later the percentages of the more important plants in each group are also estimated. The relative abundance is denoted by F. F. for the most, F. for the less, and f for the least abundant species.

6. Braun-Blanquets

The species present receive from one to five points according to the area covered; 5 points for covers more than 3/4 of the whole area, 4 points for covers of $\frac{1}{2}$ to 3/4 of the area, 3 points for covers of $\frac{1}{4}$ to $\frac{1}{2}$ of the area, 2 points for a frequent species covering small areas (1/20), and 1 point for a species covering very little. When studying a large area several (at least 10) standard plots (1sq. meter) are analyzed.

V. Kosik of Czechoslovakia used the above and expressed the points in percentages. The term "species aspect" and "group aspect" are introduced for the following main groups: good meadow grasses, clovers, other good meadow plants, "sour" grasses, valueless and noxious plants, etc. The sums of points obtained in 10 analyses according to Braun-Blanquets' method for each species are divided by the total number of points (received by all species in the respective areas) divided by 100. Thus the occurence and covering ability of the single species and their groups are expressed. When the sum of the

percentages of the first three groups (good meadow plants) makes from 75 to 100% of the growth, it is according to Klecka first quality, 50 to 75% second quality, 25 to 50% third quality, and 0 to 25% fourth quality. Thus after the analytic numbers the quality may be more or less accurately expressed.

7. Percentage Estimation Method

Where a homogenious mixture of species occurs, this method may be significantly less accurate than the method of separation but where, as is usually the case, the various component species are grouped the method is accurate and rapid. The "percentage estimation" method of botanical analysis is synonomous with the "percentage productivity" method to be discussed later.

8. Percentage Productivity Method

In this method sample covers are taken, the vegetation separated into graminae, leguminosae, all other phanerogams and cryptogams, and each is reduced to dry weight. The results are presented as percentages by weight of the total herbage. The method is laborious, but gives yield results which most of the other methods do not.

9. Rating of Composition

In this method the area covered by bare areas, those covered by legumes and grasses, and those covered by weeds are estimated. It is noted whether species are occassional, very occassional, very few, few, rather few, rather many, many, very many, dominant, or exclusively present.

10. Percentage Tiller Estimation

A six by six inch frame is dropped and the number of tillers of each species noted. The results are recorded on a scale of 0 to 10. This is repeated 10 times and the sum of these 10 readings gives the percentage number of tillers of each species present in the plot.

11. Percentage Area

A frame of one-foot square is divided into square inch areas and dropped on the ground cover. The percentage ground cover occupied by each species is recorded as well as the percentage of bare ground. Where the vegetation is homogenous 10 readings suffice, but in other cases many more may have to be taken. When all readings have been taken, each species is totaled and divided by the number of readings.

The advantage of this method is speed, but it gives no information as to yields and cannot be used in long grass.

12. Point Quadrat

The method consists in taking a series of readings in each of which 10 points, each 2 inches apart touch some part of a herbage as the points are lowered toward the vegetation.

A frame is used in which there are 10 movable wires. These are pushed down and whenever a wire strikes a plant the species is recorded. This method is said to give results very similar to those secured by the percentage area method.

13. Specific Frequency

In this method a frame usually six inches square is thrown at random 100 times on the area to be examined, and the

various species occuring within the frame are recorded for each throw without regard to the abundance or scarcity of the individual plants within the frame. The specific frequency of any one species is the number of times its presence is recorded out of 100 casts. This method is not quantative.

14. Transect

In this method a line is laid down and appropriate distances marked. Along this line readings are taken with a frame laid edge to edge, with the line and tiller counts are made. This method is especially valuable for noting changes from year to year as points on the line may be marked and the same areas be examined at later times.

15. Estimated Productivity

A frame one foot square and divided into ten parts is placed on the grass and the percentage green weight is estimated by the eye. The beginner or one who starts on a new cover should check results with a few determinations according to the percentage productivity method. The mean percentage of each species is calculated together with its probable error.

16. Percentage By Weight

The pasture yield of each species is grouped from all the samples per plot, clipped off where the chlorophyll disappears, and having the root systems discarded. The samples are weighed and the percentage composition calculated on the basis of weight of yield for each species.

17. Percentage Frequency

This method aims at giving the number of units of each species contributing to the sward, expressed as a percentage of the whole. A frame six by six inches is cast a number of times on the area, the sod removed and the plant units counted in the laboratory.

This method gives the botanical composition rather than the productive value of the area.

18. Estimation of Stand

Estimation of relative ground area occupied by each species.

19. Weight and Count

Samples are cut, separated into the species or into groups, weighed or the number of plants in each sample may be counted.

20. Order of Rank

The relative abundance of grass, clovers, and other plants is estimated in terms of the order of importance in abundance; as 1-G (grass), 2-K (clovers), 3-O (weeds). If details are desired the grasses, clovers, or weeds present may be noted in order of their importance.

21. Top and Bottom Counts

Samples are taken by cutting an area to ground level, at every ten paces along a diagonal line from one corner to another of a pasture. This procedure is repeated along three parallel lines on each side of the diagonal. (In pastures of short grass, sod samples are taken).

The samples are separted into top and bottom grasses and then separated into species. Each is then weighed. Since the separation of bottom grasses is laborious, about 1/8 of the entire quantity is so treated.

This method may, also, be used to determine the relative proportions of grasses, legumes, and weeds.

22. Area List

This method is based upon the determination, by actual measurement, with an especially marked scale, of the area of the vertical projection of the foliage of each perennial plant on every plot or major quadrat under study. The foliage of each plant is compressed by hand to circular formation through which the ground cannot be seen. The area of this clump is then read directly on the special scale which is laid across or inserted through the compressed plant. The scale is graduated so as to show the area of circles of various diameters. The figures of area, used on the scale were chosen so as to provide an interval which increases as the diameters of the plants increase in order to keep the error in measurement at a nearly constant value, and, also, to provide numbers which could be conveniently handled in compilation. The intervals on the scale are small enough to measure the areas of plants as accurately as the nature of the subject will permit.

Because of their short life cycle, annual plants are not measured individually. Instead, the examiner estimates the total area of all the plants of a species by mentally passing them into a circle of unit density, and measuring the circle

with the scale.

The details of this method are:

(a) All perennial plants shall be compressed until the foliage make up 10/10 density. If the plant does not grow in a circular clump, it will be rounded off until the average diameter can be determined. The area scale will then be laid across this diameter and the projection area of the plant thus obtained will be recorded.

(b) Perennial plants, the centers of which have died, shall be given two measurements. In addition to the projection area of the entire clump, the area of the dead portion shall be determined in the same manner. This shall be entered on the form as being subtracted from the total area, e.g. 20 - 4, or in the case of a plant all of which has recently died, 20 - 20. On compilation only the living portion of the plant will be considered as making up density.

(c) Seedlings will not be measured, but counted. Before leaving the plot, the examiner will arrive at an average figure for the area of seedlings of each species, which will be used in determining the density of seedlings on the plot.

(d) Annual species will not be measured individually, but the total area of ground covered by the species shall be estimated with the aid of the scale, and this figure is recorded.

Plots five by five meters are used. These are divided by tapes into strips one by five meters, the plants in each strip being measured and recorded separately. This division affords

data on the distribution of species within the plot and insures against sacrifice of the entire plot if one to four of the strips are unduly damaged by unforseen circumstances. The division is, also, helpful to the examiner, since a strip one meter wide is the most convenient for progress over the plot. The data are recorded on a special form on which the number of plants of each species is tallied by area classes with the ten-point tally system. Records of the presence of an area covered by rodent mounds, fecal matter, alluvial deposits, stumps, logs, rocks, and other noteworthy features of the plot are made on the same sheet. In addition adequate supplemental notes concerning condition of the vegetation, slope, aspect, soil erosion, utilization by stock, and other biotic influences are made for each plot or area.

The area of each species is determined by totaling the area made up by each sized class record. This is then converted into species density by expressing it as a decimal fraction of the total area of the plot. The total density of the plot is the sum of the individual species densities.

These areas are expressed next in terms of decimal fractions of the total area of the strip. The average density of each species for the five by five meter plot is determined by averaging the species density of the five strips. The sum of the average species density gives the total density for the plot.

23. Pantograph Charting

A pantograph is an instrument that records the outline of vegetation on a reduced scale, on paper as an arm is moved around such outline. The reduction may be from one to five times.

Two men are required to run a pantograph. One of these is to trace outlines and call out symbols, while the other lifts the pencil from each outline and records symbols. The work of charting or mapping is facilitated considerably by this method.

Some advantages of using a pantograph over most methods are:

1. Results are fully as accurate; the pantograph will record as accurately as the skill of the operator in following the outline of plants will permit.

2. The pantograph can be used with entire disregard of the presence of rocks or impenetrable soils (these factors are very important in the use of straps).

3. The rank growth of vegetation is even less of an obstacle to accuracy with the pantograph than it is with the strap method because the foliage can readily be held with one hand while the outline of the plant is traced with the other.

4. The work can be done more rapidly and with much less tedium with the pantograph (two persons, only one of whom need be skilled, can chart three times as many quadrats with this instrument as one skilled person can chart with straps).

5. The pantograph is especially effecient in locating individual seedlings or one-stemmed plants and in tracing the outline of crowns of low bushes.

24. Proportion by Weight of Species

(Simplified)

A sample of 100 grams is divided into five or ten approximately equal sub-samples, each of which is roughly divided further into two or three groups (grasses, clovers, weeds, etc.), their relation to the sub-sample is eye-estimated in percentage or marks. The groups are then classified into constituent species and the percentage contribution of each species within its group is eye-estimated. This method has been found to be about as accurate as the common method and the time required is in the ratio of common method 75, simplified method 13.

25. Permanent Sample Plot

Plots should be located so fires, grazing, and other ordinary destructive factors will not hamper the relocation of the area.

Mapping of the vegetation and the summarizing of the map date should be done in such a way that comparisons may readily be made, and in such detail that future relationships may be insured.

If the study is intensive, the plot need not be over a few square feet or a meter square in size but if a more general work is to be carried out, it may be several acres in size. The shape is most conveniently square.

When only general mapping of large areas is done, then it

is well to have small areas inside for more detailed mapping.

The general mapping should include:

1. Dominant and sub-dominant species.
2. All species found on the selected plot.
3. Density of the cover.
4. Grazing capacity of the plot expressed on an acre or section tract basis of animal-unit capacity.

26. Chart Plot

This method is good to use in detailed charting of vegetation.

Usually all the vegetation within the plot is charted in situ, or in less intensive studies, the maps may show only the species of primary importance.

The meter-square area is usually used for detailed mapping. This is very tedious and laborious, and thus is not a popular method.

In mapping the chart plot, it is divided into convenient blocks and all the vegetation is located on the map to correspond with its position on the selected area. A legend is made in connection with the map, which is drawn to a convenient scale, to show what species are denoted by such symbols as are used on the maps.

Symbols may be placed on the map each time that a certain plant occurs or the percentage of the whole which occurs in that block may follow the symbols of all plants occuring in that block. The density of cover for each division may, also,

be stated.

On the reverse side of the map should be stated the object, location, size of plots, the character of the vegetation, history of the range or pasture as to use, present usage and condition, a record of the vigor and life history of plants present, and a summary of the quadrat data.

The divisions of the map are numbered from left to right and from top to bottom.

The permanent location is established by corner posts. When mapping is done "boundry tapes" are laid down and securely fixed. Cross tapes are then laid down and held in position by surveyors pins placed through the holes in the ends and through the division holes on the boundry tapes. The cross tapes are moved as each division is mapped until the entire quadrat has been mapped.

27. Photographs

During the course of an experiment photographs may be taken regularly each year. The same views should be taken each time, so that certain photographs will be directly comparable for a number of years. It is well to take a general and a close-up view.

Photographs can be taken at different growth periods to show plant conditions and relations during such periods.

Points may be brought out by photographs which do not lend themselves well to description or measurement, they are a permanent record and may be taken more readily this way than any other way.

28. General Field Notes

Regardless of what method is used in getting field data, it is desirable to have notes of a general type.

Points which should usually be recorded are:

1. The time of starting spring growth.
2. The period of maximum growth.
3. The time of flower stalk production.
4. Time of fruiting.
5. Time of seed maturity.

Other facts which may need to be noted are droughts or other abnormalities which have a bearing upon the results received from an experiment.

CHAPTER II

Identifying Species

The best stage for identifying a plant is while it is flowering but if it is not in that stage when it is identified, then the determination must be made on (a) morphological characters and (b) anatomical characters, or (c) a combination of both. These characters will vary somewhat with growing conditions so a key might not work under all pasture or range conditions, but keys are available and are invaluable for such work. The "Manual of The Grasses of the United States" by A. S. Hitchcock is an ideal one for grass identification.

Often times it is desirable to take a sod into the greenhouse or laboratory for future identification of the species present. When this is done it is best to take long narrow strips rather than square ones.

CHAPTER III

Carrying Capacity

The carrying capacity of a pasture or range is the number of animals of a particular kind that a unit of area will support for a definite period. To this may be added, without permanent injury to the forage crop. On permanent pastures and on range lands this is usually stated in terms of animals to the acre for the grazing season. In some cases carrying capacity may be stated in terms of the whole year.

Factors entering into the determination of carrying capacity are:

1. Density
2. Composition
3. Palatability

A. Density

Density or percent of ground cover is very important when carrying capacity is considered. In order to determine the exact cover it is necessary to take into consideration the spread of vegetation and determinations should be made from directly above, so open spaces within the body of the vegetation can be noted. If the vegetation is spreading, it should be pressed together just enough to close all gaps when making determinations. When vegetation is dense enough or compact enough to completely cover the ground, it is known to have 10/10 density.

Only that browse which is in reach of grazing animals should be calculated in density. It is generally accepted that browse 30 inches or less from the ground is accessable to sheep, while browse as high as 60 inches is accessable to cattle.

The method of determining density just described is known as the reconnaissance method. Another method "The square-foot density method" is described below.

In this method of determining density, vegetation is sampled by randomized and replicated plots.

The plot used is a circle 100 feet in area. Two systems of describing the boundry of this circle are the compass and the radius rod systems. In the first two stakes they are connected with a chain 5.64 feet long. One of these is set, and the other marks the boundry at the end of the chain. In

the second system a rod 5.64 feet long is held at one end while the other end marks the boundry.

In using the square-foot density method, the density of each species is measured or estimated individually and no attempt is made to estimate the percentage each species comprises of the total plot density.

A square foot covered as described under the reconnaissance method is the standard for estimation of density, and though it is usually estimated the estimator should check his estimates often with a wire square foot frame.

The number of square feet of any species appearing in a plot will be the percent of ground cover given by that species, since the plot contains 100 square feet. It is well to check the sum of the total densities of the several species against the total estimated density.

B. Composition

Type composition estimates are based on the relative density abundance of each available vegetation species in the type. Usually the most abundant species is rated first then on down the line as to abundance. The total composition, of course, equals 100 percent.

Several types are recognized in range and pasture work. In some instances many of these types may be used in a single area determination, whereas in others only one or two will be needed because the vegetation is more or less homozygous. Some of the types used follow, but it should be remembered that many types are only local and thus the number of such types is numerous.

1. Grassland
2. Meadow
3. Weeds
4. Browse
5. Forest
6. Waste
7. Rocks
8. Shrub
9. Abandoned

These and others like them may be subdivided into subtypes.

C. Palatability

Grazing animals exhibit preferences for certain types of forage over other types. Those types which are most desired by animals are said to be the most palatable and other things being equal these desirable plants will be grazed in preference to less palatable ones. As used in range surveys and in pasture work, palatability is spoken of a little more generally and is used to express the percent of the total year's growth of a species within reach of stock which is utilized when the range or pasture is properly grazed under good management.

Palatability varies with type, intensity of grazing, season of grazing, mechanical features such as awns, and to a certain extent on the familiarity of the stock with the plants grazed.

By comparing the percentage of each species before and after grazing, the species preferences of the animals used may be determined. This is much the same as the percent of utilization of different species which was used to make up the accompanying table.

Rabbits are used to some extent in determining relative palatability, but the conclusions drawn may not always be applicable to livestock.

The following of an animal for an entire 24 hour period of feeding and the recording of the grazing activities of that animal would lead to some conclusion on palatability.

While the preferences in forage plants shown by grazing

animals may be determined rather accurately, the same is not true concerning the amount of feedstuff furnished by the various species of forage plants, because of the great difference in what may be termed the rate of feeding. Thus, a cow may feed half an hour or longer upon one plant of prickly pear, and obtain less feedstuff than she would in a minute or two of grazing. The difference in amount of feed taken by animals in feeding for a given time upon the various plants is not so great in sheep and goats as it is in cattle and considering all classes of stock as a whole, the amount of time devoted to feeding upon the various constituents of the range vegetation is a fair measure of their value to the range under the conditions existing at the time of observation.

Making determinations on palatability by counts made both, before and after grazing can be done over a short period of time or over a reasonably long period of time. If it is to be over a long period of time, a good plan is to map the area, locating thickets, trees and other plants that may be of special interest. Individual plants should be counted by species in so far as possible. The ground space occupied by each species should be measured or estimated.

Laying out of the quadrats and the reading made should follow the instructions given under the discussion on taking botanical analysis. Subsequent resurveys of these quadrats at convenient intervals of years will reveal the trend of the vegetation and the preferences of the grazing animals for those species present.

Piper quotes results of a Cornell experiment giving Kentucky bluegrass as preferable to timothy, and states that Kentucky bluegrass is very palatable to all classes of livestock, much more so than any other grass so capable of maintaining itself. It is distinctly exceeded in palatability only by smooth bromegrass.[1]

On the Preswick pasture at Cornell, White summarized observations as follows:

> The order of palatability of the various grasses used in this pasture seems to be as follows: smooth brome, timothy, meadow fescue, meadow foxtail, orchard grass (when young), Kentucky bluegrass, and redtop. The cattle have shunned the redtop wherever it grew, whether alone or in mixtures. Grass on plots which received nitrate of soda and lime were quite closely grazed except where redtop was the chief grass.[2]

At Ames, Iowa the palatability of certain pasture grasses was tested. Canada bluegrass, smooth bromegrass and timothy were preferred. Reed canary grass, Kentucky bluegrass, redtop, tall meadow oatgrass, slender wheatgrass, crested wheatgrass, and rough-stalked meadow grass were eaten moderately and about equally. Orchard grass and meadow fescue ranked low in palatability and sheep's chewings and red fescue were scarcely touched.[3]

At the Massachusetts Agricultural Experiment Station, cattle ate fertilized grass in preference to unfertilized grass on upland pastures, and preferred grass on land which

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1. Piper, C. V., Forage Plants and Their Culture, 1924.
2. White, Paul J., New York Agricultural Experiment Station Bulletin 280, 1910.
3. Wilkins, J. S., Journal American Society of Agronomy 24, pp. 18-20, 1932.

received lime in addition to fertilizer over that receiving fertilizer alone. It was, also, shown that grass from the limed plants was richer in Calcium than that from unlimed plots.[4]

Montgomery states that no relation has been found between chemical composition and palatability. He further states that generally the better grasses have softer and more pliable stems and leaves.[5]

Stage of growth is a factor which affects palatability. A definite order of choice could be determined for plants used when the plants were 4 to 6 inches tall, but when they were only 2 to 4 inches tall there was very little choice shown.

The first year after seeding practically no difference in palatability could be referred to difference in fertilizer applications at the Massachusetts Agricultural Experiment Station, but the second year grass which received nitrogen and minerals was grazed more than that which had received only minerals or no fertilizer. Grass which received high nitrogen appeared to be slightly more palatable than that which received medium or low amounts.[6]

The following table gives the relative palatability, in percent, of several Oklahoma grasses.

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4. Beaumont, A. B., Massachusetts Agricultural Experiment Station Bulletin 281, 1932.

5. Montgomery, E. G., Productive Farm Crops, 1918.

6. Beaumont, A. B., Journal American Society of Agronomy 25, pp. 123-128, 1933.

1. Oklahoma Palatability Table[7]

Scientific name	Common name	Areas* and Percent Utilization				
		1	2	3	4	5
Agropyron smithii	Western wheatgrass	60	60	--	--	--
Andropogon furcatus	Big Bluestem	--	70	75	75	75
Andropogon hallii	Sand Bluestem	30	30	--	--	--
Andropogon saccharoides	Silver Beardgrass	10	10	10	10	10
Andropogon scoparius	Little Bluestem	50	65	70	70	70
Andropogon tenarius	Silvery Beardgrass	--	--	5	10	10
Andropogon virginicus	Broomsedge	--	--	5	10	10
Aristida oligantha	Trippleawn	--	--	--	--	--
Bouteloua curtipendula	Side-Oats Grama	60	60	55	50	50
Bouteloua gracilis	Blue Grama	75	75	60	--	--
Bouteloua hirsuta	Hairy Grama	50	50	45	--	--
Bromus commutatus	Hairy Chess	--	--	--	--	--
Buchloe dactyloides	Buffalo Grass	75	75	60	--	--
Chloris verticillata	Windmill Grass	--	--	--	--	--
Cynodon dactylon	Bermuda Grass	--	70	70	75	75
Panicum virgatum	Switch Grass	30	30	30	30	30
Paspalum dlatatum	Dallis Grass	--	--	--	--	75
Poa arachnifera	Texas Bluegrass	50	50	50	50	50
Poa pratensis	Kentucky Bluegrass	--	--	75	75	--
Sorghum halepense	Johnson Grass	--	75	75	75	75
Sorghastum nutans	Indian Grass	50	60	60	60	60
Calamovilfa gigantea	Giant Reed Grass	--	--	--	--	--

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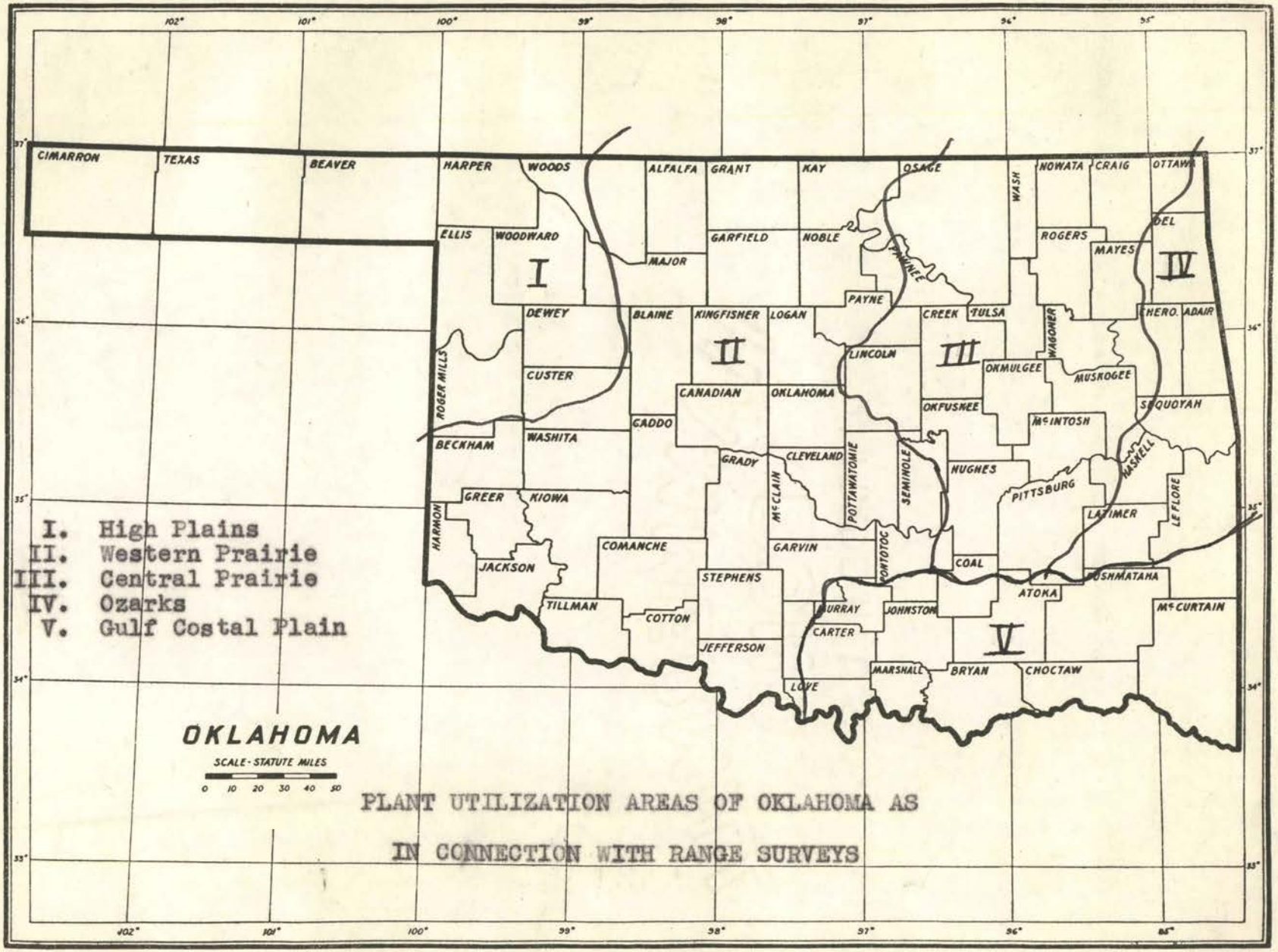
7. Range Utilization Table for Oklahoma.

* See Following Map.



PLANT UTILIZATION AREAS OF OKLAHOMA AS

IN CONNECTION WITH RANGE SURVEYS

8. Ibid.

D. Determining Carrying Capacity

The oldest and still most widely used method for determining the number of animals an area will support is an ocular survey based on past experience and comparison. More scientific methods however, are usually based upon an estimate of the percentage of each plant of each species which is consumed by stock, and the percentage of the area in the pasture which is covered by each species. The Forage Acre Method and the Cow Months Method are examples.

1. Cow Months Method

Counts should be made in several places over the pasture or range to determine the number of grazed stalks and the number of ungrazed stalks of the more important species. From these counts the percent of utilization can be determined, and from the number of grazing animals times the number of months they have been grazing can be determined the number of cow months the pasture has furnished.

The formula for finding the cow months is:

> number of stock being grazed X months they have been on this pasture X (100 ÷ % of utilization) = the number of cow months that area will support.

To find the number of cow months per acre:

> cow months ÷ number of acres in the area.

It may be wise in many instances to determine percent of utilization of an area on the percent of utilization of the most important species, and when that species is grazed to the desired percent of utilization the area may be considered fully utilized.

2. Forage Acre

The term forage acre may be defined as an acre having a complete cover of palatable vegetation or the equivalent thereof in density and palatability.

The formula for computing the forage acre is:

> total land area X surface supporting vegetation X density of cover X percentage of palatable forage.

In this formula

1. total land area = the number of acres being considered.

2. surface supporting vegetation = the percent of the above which is covered with vegetation.

3. density of cover = how dense the vegetation is on the ground, or how nearly it covers the ground.

4. percent of palatable forage = the part of the vegetation which is palatable to the animals being used.

When the number of forage acres for any given area has been determined then the number of animals of a given kind which the area will support can be determined by dividing the number of animals which one forage acre will support into the forage acres.

To determine the amount of forage an animal will consume in a certain length of time, a series of pens may be arranged and a number of the animals in question placed in alternate pens and kept for that length of time. The animals may then be removed and the pens all harvested. The difference existing

in the grazed and the alternate plots or pens could be attributed to the consumption of the animals.

If the average consumption of an animal is known, the carrying capacity of an area may be determined by the methods already discussed.

The number of animals which any area will support will vary greatly with the kind of animals, but when stated in terms of animal units it is the same regardless of the kind of animals used.

CHAPTER IV

Animal Units

An animal unit as given by Warren may be any one of the following:[1]

1 cow or horse
2 yearlings
4 calves or colts
5 hogs
10 pigs
7 sheep or goats
14 lambs or kids
100 hens

According to Sampson an animal unit, in practice, may consist of:[2]

A steer
A cow
A cow and her unweaned calf
A ewe
A ewe and her sucking lamb
Any similar individual or pair

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1. Warren, G. F., Farm Management, 1918.
2. Sampson, A. W., Range and Pasture Management, 1923.

CHAPTER V

Studying Root Growth

Since so much of what a plant does above ground is dependent upon its root system, the study of root growth is an important one in range and pasture work. Comparatively little has been done with roots because of the difficulty of it. The following procedure simplifies to a certain extent the securing of soil samples containing plant roots.

A heavy iron wedge-shaped tood resembling a spade having a straight blade 12" long, 7" wide, and $\frac{1}{8}$" thick at the upper end, tapering gradually to the cutting edge is used to make rectangular openings in the sod to the full depth of the bald. Soil prisms approximately 3" x 7" x 12" may be cut and removed from the rectangular opening.

In order to remove the samples with ease and without damaging the surrounding sod and roots, a special tool with a hinge attachment and beceled edges is used. Its principle of operation resembles that of a post-hole digger. It is unhinged, introduced into the rectangular-shaped opening, and rehinged for removing the soil prism. The prisms when removed are placed on boards which are placed in a bod and transferred to the laboratory for washing.

The soil prisms are carefully trimmed with a sharp knife to a width of 4" and a thickness of 1". The ease of trimming the prism is facilitated by a board form 4" wide to cut the prism to the desired width. A wood framework 4" x 12" x 1" is placed around the 4"-wide prism and it is then cut to a

thickness of 1". The prism taken from the field is large enough so that duplicate samples may be cut from it.

The prism after cutting is placed in the open wood form having a screen bottom with cross pieces studed with shingle nails to hold the roots in place. The trimmed prism in the wood form is covered with a coarse wire screen and washed free of soil with a fine, high-pressure spray. After the roots are free of soil, the form is inverted and the roots washed on the wire screen. The roots washed free of soil may be placed on a board and sectioned to correspond with various soil levels to determine relative distribution of the roots at various depths.

Deep-rooted plants cannot be accurately studied by this method, but their roots must be dug up.

CHAPTER VI

Soil Sampling

Ordinary methods of soil sampling may not be suitable for grass lands in many instances. This is particularly true of untilled land where fertilizers are applied on the surface. Nitrogen, phosphorus, potassium, and calcium are frequently added to soils and of the four all except nitrogen penetrate slowly, while phosphorus in the soluble carriers remains very near the surface. Moreover, in humid regions at least, most of the roots of grasses are found in the upper three or four inches of soil. Therefore, it is frequently desirable to obtain samples of soil by one and even one-half inch layers. A soil augur cannot be used for such work. Holes dug with a spade furnish less representative samples, and, also, have the additional disadvantage of disturbing more area.

A steel pipe 2" in diameter and 30" long sharpened and slightly drawn at one end and perforated for a removable cross bar near the other end has been used for grass land sampling at Storrs. If the soil is moist and not too stony or sandy, cores 8" long can be obtained and slid intact from the upper end of the pipe. Such cores can be sliced into the desired number of divisions.

In studying changes in soils over a period of years, it is very important to take the samples at approximately the same dates. For annual or less frequent sampling, a date should be chosen when microbiological activities are at a minimum.

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