RANGE MANAGEMENT RESEARCH METHODS IN THE WESTERN UNITED STATES

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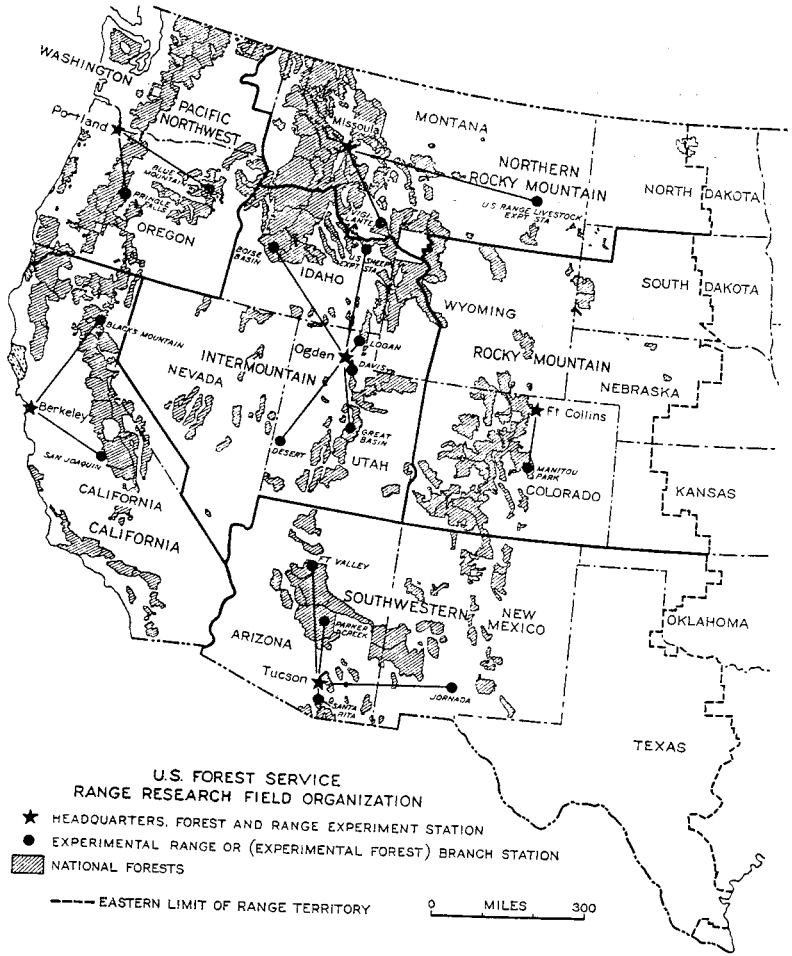
THE great range land in the western half of the United States of America covers a territory approximately 1,000 miles wide and 1,200 miles long, within which some 728 million acres of mountains, foothills, plains, and semi-desert are grazed at various seasons of the year by millions of cattle, horses, sheep, and goats, as well as big game and other wild animals.

The range research problem is to determine how the continued productivity and use of this vast native forage resource can be maintained at the highest level in harmony with economic livestock production and the conservation of other resources on the range, such as timber, and water for irrigation ; and with the feed production of the associated lands in cultivation. This means working out the proper utilization and management of the rather sparse vegetation growing under usually low rainfall and easily damaged by too heavy grazing, especially during recurrent severe drought periods.

In planning a comprehensive research attack, allowance must be made for the distinct differences of vegetation, topography, climate, and the character of grazing and agricultural use in different portions of the huge range area. Accordingly, within this western domain the Forest Service has organized six regional forest and range experiment stations, each fully equipped and staffed and in charge of a director who co-ordinates the research on forest and range lands, involving timber management, range management, watershed management, and related studies. Within each region have been developed several experimental forests or ranges, representative of major types of vegetation, or of use conditions, on which range research is being conducted under four main phases : range management, artificial revegetation, range forage investigations, and range watershed protection. The organization and scope of the research under each of these phases have been outlined in detail in *Herbage Reviews* (**3**) by W. R. Chapline, Chief of the Division of Range Research, and recently in *Bull.* 26 of the Herbage Publication Series (**22**).

The range management phase of Forest Service research is covered in this paper, which indicates some of the more important experimental methods employed. These methods will be illustrated with problems of outstanding importance, since it is the



problem and the available facilities that determine the experimental methodology. Space does not permit detailed description of specific methods as applied on each of the twenty experimental range areas in the western United States, nor is this necessary to a general understanding of the main approach to problems. A rather full discussion of the research approach at the Jornada Experimental Range in southern New Mexico will illustrate application of many methods now in use. This range is representative of semi-desert grasslands of southern Arizona, New Mexico and western Texas, and has been under experimental management for 25 years. Briefer consideration of the approach to several other problems of major importance on different experimental ranges will illustrate certain necessary modifications and differences in methodology.

1. Comprehensive Management Studies on Semi-Desert Ranges

The fortunes of the range livestock business on semi-desert ranges fluctuate considerably, being governed mainly by climatic vicissitudes. Prosperity accompanies years with higher rainfall and good forage production, while adversity comes in dry years with limited forage growth and scanty water supplies. The vegetation is naturally sparse, usually covering only 0.1 to 0.3 of the ground, with a delicate balance frequently disrupted by severe drought. The average annual rainfall on the Jornada Experimental Range is only 9 inches, more than half of which comes during the months of July, August and September. The tuft-forming perennial grass forage, which makes up 80 per cent of the vegetation, is grown during this summer period, and is the principal basis of the yearlong grazing by cattle. Only in occasional years of unusually favourable rainfall is there appreciable forage growth during the spring. Forage production is so uncertain that large areas, thousands of acres in size, are necessary for a practical ranch unit. Since this yearlong range is better suited to grazing by cattle-breeding herds than to fattening young animals, the livestock industry in this section is mainly one of calf production.

The problem is how to produce cattle economically on this semi-desert yearlong range with its wide fluctuations in forage production. The Jornada Experimental Range is an area of 185,000 acres, forming a single cattle ranch suitable for experimental purposes, adaptable as a demonstration area, and easily administered. With such a large area, the experimental approach is a combination of empirical experiments in large pastures, practical tests of cattle management on the range, and detailed studies of the important forage plants and range types. The entire range is fenced into several large pastures, separating the main forage types and providing four main seasons of grazing, which research to date indicates furnish best practical management or justify further tests :

1. Summer grazing in pastures supporting predominantly tobosa grass (*Hilaria mutica*) and its associated species.
2. Yearlong grazing in a pasture in which all the vegetative types on the experimental range, both perennial grass and shrub types, are represented and stocking is rather uniform throughout the year.
3. Semi-deferred grazing in a pasture containing mainly black grama (*Bouteloua eriopoda*) and mesquite (*Prosopis glandulosa*)—sand dune types, grazed very lightly in summer and sufficiently heavily during the rest of the year to utilize the year's forage.
4. Deferred grazing in a pasture of black grama grass, with utilization deferred mainly until winter and spring.

The entire experimental range is stocked in conformity with the general aim of providing sufficient range forage to support the cattle in all except the most severe

drought years, although practical considerations occasionally interfere with the literal execution of the plan for season and degree of use in each pasture. A breeding herd of some 1,200 Herefords is grazed on the range, with seasonal movements of animals between pastures as indicated above.

Studies Aimed at Maintaining Forage Production

Studies to determine potential forage production and methods of attaining such production are conducted simultaneously. Both involve: (1) general relation of grazing and climate to range maintenance; (2) determination of relative forage values of various plants on the range; (3) life histories of the more important or abundant species to determine how and when they grow and reproduce; and (4) plant succession and change from year to year as to both species and forage production. It is particularly important to determine the factors responsible for plant change, such as climate, soil, grazing, and plant competition. These features may be arranged along ecological lines of research, aimed at the threefold problem of maintaining forage production on the better grass types, of increasing production on the poorer shrub types, and of holding up production in good years and bad.

The combination of the seasonal grazing between the pastures, and the location of permanent study plots within the pastures has made it possible to evaluate the effect of season and intensity of grazing upon forage growth and maintenance. Results are observed both in extensive surveys and in more detailed measurements on plots. For the most part, grazed quadrats are located at 0.5 mile and 1 mile intervals along lines radiating from permanent watering places, as grazing is heaviest near these watering places, and gradually diminishes at greater distances. A few plots contain certain types of vegetation without relation to degree of grazing. In the perennial grass types, the quadrats are 1 meter square, but plots 10 meters square are used to follow changes of the large shrubs in the mesquite (*Prosopis glandulosa*) sand dunes.

The quadrats are charted each fall near the end of the normal growing season, since it was early determined that fall charting best furnished comparable data from year to year. The boundary of each perennial grass tuft at 1 inch above the soil surface is mapped on a quadrat sheet, and the area computed in square centimeters. Other perennial herbaceous plants are located on the sheet and the number totalled by species. The annual plants are merely counted and recorded on the quadrat sheet by decimeter strips. Full notes are made of all conditions influencing each quadrat and of such features as height growth, flower stalk production, and related matters for the more important plants.

The greatest importance is attached to accuracy and completeness of records and detailed instructions for handling quadrats have been worked out by McGinnies (**10**). Mapping of the plots is greatly facilitated by the chartograph. This instrument, developed by Hill (**7**), consists of a low table and a set of pantograph arms which permit the plant clumps to be traced on a quadrat sheet reduced to one-fifth. Substantial mechanical improvements have been made in the chartograph by Pearse et al. (**12**).

The chart quadrat method was decided upon for detailed records of vegetation on the Jornada Range for several reasons: (1) it reflects the change in black grama (*Bouteloua eriopoda*), the most important perennial grass, from year to year, both as to size and shape of individual tufts, in such a way as to trace effects of weather and grazing and to reveal the character and amount of reproduction; (2) it furnishes similar information for numerous other plant species, varying in growth form and habit, including broad-leaved herbs and small shrubs, many of which are aggressive, low value plants; (3) it measures the vegetation and its changes under several degrees of grazing; (4) it indicates the competition between plants on the same area, and furnishes accurate data as to the outcome of such competition; (5) through combined tuft areas and height measurements it gives some measure of forage volume production by species from year to year; and (6) it furnishes the data in definite quantitative form so that plant change can be correlated with concurrent measurements of climatic and physiographic factors.

Adequate sampling with quadrats of the entire vegetation in each of the large pastures on the Jornada Range has not been attempted. However, sufficient quadrats are recorded to furnish a reasonably sound check of the main vegetative and grazing conditions and management features.

Determining Relative Forage Values

Relative forage values of plants on the Jornada Range were first estimated from ocular observations of the degree to which the species were utilized when the various parts and types of range were suitably grazed. Such percentages, based upon the current year's growth, represent the proper use factors employed for individual species in range surveys, as described more fully by Pickford (**15**), although they were formerly defined as the palatability or palatable forage of each plant. The preliminary figures for species on the Jornada Range were improved and refined over the years from data obtained in a number of ways:

1. Supplemental notes on quadrats, which record separately the vegetation on the quadrat itself, and for the adjoining area, the estimated proportion of each species in the stand and the degree to which it has been grazed. Utilization observations are made both in fall when the quadrats are charted and again in June. The records of use are checked against the ability of plants to maintain their productivity over the years.

2. Utilization inspections of the pastures are made in October, December and June each year, when estimates are made of the percentage of herbage that has been grazed on each species within each type of vegetation and each recognizable class of grazing intensity.

3. Special studies, including (a) actual observations of cattle grazing, through field glasses if necessary, to note species and amount eaten, and (b) permanent plots, 1 rod square, on grazed range, observed at 2 weeks' or monthly intervals to measure or estimate and record the percentage of herbage grazed on each species, especially to establish livestock preferences at different seasons of the year.

Analysis of these data show directly the dominant plants that furnish the feed on the range, but the establishment of proper use factors rests upon careful determination of proper utilization of the range through all of the methods here indicated. This includes study of the resistance of the important forage species to grazing, to provide for their maintenance and reproduction. Clipping provides a direct attack and close control in studying the effect of different frequencies and intensities of harvesting upon forage production and plant density. Although it is impossible to reproduce the actual effects of range grazing by artificial harvesting, the results of clipping *Bouteloua eriopoda* and *Hilaria mutica* on the Jornada (**2**) have been of value in supplementing grazing studies.

Plant Life Histories

Much of the information on life histories is obtained from phenological records on selected plots. Stem height and leaf length are measured on permanently marked specimens of the important forage plants at weekly or 10-day intervals during the growing season, and stages of development, such as flowering, seed maturity, and seed dissemination, are clearly indicated.

Ocular examinations indicate which species reproduce vegetatively by means of stolons or rhizomes, both frequent methods of propagation among grasses in the Southwest. Detailed records on the chart quadrats show how and when such vegetative reproduction takes place, and how it is affected in the various species by weather and grazing. The quadrat records also show tillering of grasses, and the extent to which individual tufts solidify and spread, or break up over the years (**11**).

Special studies are made of reproduction by seed. Plant growth records indicate the formation, maturity, and dissemination of seed, but in addition, seed collections are made of the important grasses, weeds, and shrubs each year. Florets of grasses with small seed are carefully examined with a hand lens to establish the approximate proportion of seed actually matured. Germination tests are then made to determine seed viability, both in the year of collection and in subsequent years as a check on longevity. These germination tests are made mainly in the laboratory, with due precautions to scarify impermeable seed coats and to allow for after-ripening where necessary. Other tests are made in the nursery under more nearly actual range conditions. Finally, both general observations and chart quadrats with supplemental notes are employed to follow the natural reseeding and establishment of the various species in the several range pastures.

Plant Cover Change

Changes in plant cover are followed not only to bring out the principal relationships between vegetation, grazing and weather, but to determine potential range productivity through studies of plant succession and competition. Plant succession is worked out from close study of representative areas on comparable soil types and also from chart quadrats. For example, on clay soils on the Jornada, stages of succession were found from practically bare soil with only scattered lichens to a dense cover of tobosa on more moist sites. Quadrat records demonstrated the actual

invasion of bare areas by burrograss (*Scleropogon brevifolius*), and the competition between burrograss and tobosa grass (**1**). Other successional series have been worked out similarly on sandy soils, the more advanced stages appearing as distance from livestock watering places increased, or in successive years as deteriorated range recuperated from severe drought and overgrazing.

Competition, as a special phase of plant succession, is studied not only by careful observations of number and condition of different species over extensive areas, but also on plots. The behaviour of *Bouteloua eriopoda* and snakeweed (*Gutierrezia sarothrae*), an aggressive low woody perennial, together on compact sandy soils, for example, was studied on three quadrats, each 1 × 3 meters. The plots were established in a fairly dense stand of snakeweed and charted each year, with special records of diameter and height of each snakeweed plant. Supplemental information was obtained from annual records of density and species composition on the surrounding area and on certain other portions of the experimental range. Bisects were made to determine the root habits of both species and the zones of competition for available soil moisture. Altogether sufficient different sets of conditions were compared to indicate the influence which competition, other biotic factors and weather had on survival and reproduction for both species.

Chart quadrats in ungrazed enclosures are used as a check on results obtained on range grazed to various degrees. In laying out enclosures large enough to furnish ample experimental vegetation of the type desired, due allowance must be made for border effects of the fence. In the semi-desert Southwest, enclosures are subject to considerable deposition from drifting windblown sand, especially with rodent-proof fences. It is now a standard practice to build permanent enclosures at least 1 acre in size and, for some studies, considerably larger. The purpose of the enclosure, of course, guides the choice of fence. Barbed wire alone is used to exclude cattle, whereas a mesh wire is necessary to exclude utilization by the smaller rodents such as rabbits and kangaroo rats.

Studies of plant change are amplified with observations and measurements of climatic and edaphic factors. Standard U.S. Weather Bureau instruments are maintained at the Jornada headquarters for measuring precipitation, air temperatures, wind movement, evaporation, and relative humidity. Precipitation varies so greatly between local areas that it is sampled with about eighteen rain gauges located systematically over the experimental range, in addition to several other gauges employed for special studies.

Soil factors are also taken into account in relation to plant change, both as influencing the vegetation and as reflecting the effect of grazing treatment. A soil survey made on the Jornada in 1918 gives a knowledge of general soil-vegetation relationships. Soil conditions are observed, including such features as texture, structure, perceptible moisture, and evidences of wind or water erosion, and recorded every year in the supplemental notes accompanying the charting of each quadrat. Limited detailed studies of soil moisture, physical properties, and chemical analyses of mineral and organic constituents are made as required to explain specific phases of plant behavior.

Grazing Capacity in Large Pastures

With the accumulation of fairly detailed information concerning the important forage plants, the degree of grazing they will withstand, and the seasons of use, there still remains the important task of fitting this information into practical cattle management, especially of working out through grazing-capacity tests the principles for determining proper numbers of livestock to graze on a range unit during suitable seasons or yearlong. Grazing capacity is defined as the number of livestock that can be run successfully on the range year after year during the designated season without injury to the forage or other resources.

The essentials underlying grazing capacity recorded and studied in the Jornada pastures include : (1) the number and condition of livestock ; (2) the annual forage crop ; (3) utilization of the forage crop ; (4) the trend of range condition under the various treatments, and (5) correlation of the preceding items to determine proper stocking in (a) each individual year, and (b) over the period of years, including provision for drought.

Records of numbers of animals in each pasture at all times are of special importance on yearlong ranges where transfers between pastures occur, since they are the basis for calculating the number of animal days of grazing in each pasture. Different classes of animals, such as cows, bulls, steers, and calves, are recorded separately. Condition of the cattle is indicated each month from ocular observations which are supported by actual weights of calves or adult animals sold each year. These livestock records furnish a convincing measure of the results of management, both in the different pasture treatments and on the entire Jornada Range as a practical ranch unit.

The forage crop is the volume of herbage produced that is available to livestock and which can be grazed when the range is properly utilized. It may be expressed on either a relative or absolute basis. On the Jornada Experimental Range the relative percentage of forage produced has been estimated ocularly each fall through a systematic field survey of each type and pasture, and checked against actual measurements of plant area on quadrats and against height growth of important species. It is a present practice to clip and weigh the forage on a number of plots as a check ; there is not at present the available manpower adequately to sample by clipping pastures several thousand acres in size.

Degree of utilization or the amount of herbage grazed is also estimated each year and, as with forage crops, may be expressed on either a relative or absolute basis. On the Jornada Range, utilization is estimated in percentage of the available forage. Ocular estimates are made by species and by types within each pasture during a systematic inspection. The observer practises carefully by estimating utilization on individual tufts of plants and by actual measurements on the quadrats. Utilization inspections are made at first in the autumn when grazing of the matured forage crop is being planned, in December to check range feed available for the next six months, and again late in June just before new growth starts. In a small check pasture of 160 acres, utilization has been estimated recently in absolute terms of pounds per acre by clipping and weighing plants on pairs of plots, one before and one after grazing.

The trend of range condition, including plant succession and forage production under the various grazing treatments, is obtained from annual inspections, by periodic range surveys, and from the permanent quadrat records. Careful inspection makes use of all the readily available evidence developed by the intensive studies previously described.

The information gathered each year under each of the preceding headings is correlated to determine for that year the suitable stocking or the forage production in terms of animal units for each pasture. It is impossible to stock large yearlong pastures so as to utilize the range exactly to a predetermined degree under widely varying forage production conditions when annual rainfall varies from 3.5 inches to 18 inches, as it has over the last 25 years on the Jornada Range. Moreover, it would have been impracticable to maintain a uniform number of animals in each pasture from year to year. Records of 25 years of grazing, however, closely checked against the several factors of production and use, have given a very good indication of grazing capacity on semi-desert range. With recurrent drought so important a factor, conservative grazing has been shown to be the most stable and productive method of utilizing the best forage, as in the case of the valuable black grama, and furnishing the most economic cattle production. True grazing capacity and proper stocking must be placed at a level considerably below average forage production ; on semi-desert range, about 25 per cent below average production.

The application of such conservative grazing and other good management practices on the experimental range has given calf crops half again greater than those on comparable poorly managed range in the same locality, and losses of only one-third as much. The growth of calves and their sale value have also been considerably greater on the Jornada Experimental Range, with correspondingly greater opportunity for profitable beef production.

2. Intensive Pasture Studies on Northern Shortgrass Plains

In contrast to the low grazing capacity of the Jornada Experimental Range is the relatively greater grazing capacity on shortgrass ranges of the Northern Great Plains requiring appreciably smaller areas for ranch operations or experimental work. The range is grazed yearlong by cattle, primarily as a breeding ground as in the Southwest ; but winters are very severe and drought is not uncommon. Although average rainfall is only 4 inches greater than at the Jornada, evaporation is less and the rainfall, coming primarily in spring and summer, is more effective for plant growth. Experiments to determine the best utilization for such ranges and its relation to calf production are being conducted at the United States Range Livestock Experiment Station near Miles City, Montana, by the Forest Service in co-operation with the U. S. Bureau of Animal Industry and the Montana State Agricultural Experiment Station.

Twelve pastures are grazed so as to test the value of three intensities of grazing throughout the year. Degrees of use are provided by difference in size of the pastures

to accommodate ten breeding cows and their calves in each lot, duplicated, with 23.1 acres per head in the heavily grazed, 30.5 in the moderately grazed, and 38.8 acres in the lightly grazed group. In the field layout, six pastures were built around one well for summer grazing and a similar group of six pastures at a second well for winter grazing.

Results are measured in terms of both livestock and vegetation. Calf crop in percentage, weights of calves at birth and at weaning, and amount and cost of supplemental feeding, all have clearly indicated the superiority of conservative grazing during the 8 years the experiment has been in progress (**8**). Response of the vegetation to grazing treatment and to climatic factors is followed in the pastures by means of permanent chart quadrats. The point-analysis method, developed in New Zealand, has been used here by Ellison (**6**), employing a mechanically spaced array of needle points projected vertically to the soil surface, and the number of hits on vegetation and ground tallied. These results are supplemented by measurements of height growth and estimates of forage production, utilization, and range trend, throughout the pastures as on the Jornada Range.

The principal difference between the methods applied at this Northern Plains area and the Jornada Range lies in more restricted studies and in carrying the same breeding animals in a uniform number under the same intensity of grazing over a series of years in relatively small pastures set aside for each specific degree of use. Losses in breeding animals are replaced with comparable animals held on other range land grazed to a suitable degree. A similar pasture arrangement adapted to the needs of the central plains area has been established in Northeastern Colorado by the Rocky Mountain Forest and Range Experiment Station, in co-operation with the Soil Conservation Service.

3. Cattle Pasture Experiment in the Annual Plant Type

The problem of grazing breeding cattle on the annual plant type of the California foothills has many different aspects and requires different sampling methods from other western ranges. Introduced annuals now predominate and make their growth mainly in spring after the winter rains. The study aims to determine the time and intensity of grazing that will allow production of the greatest amount of usable range forage each year, especially to furnish a longer season of native grazing than at present, because the annual plants become parched and of low value during the hot dry summer. These and related problems are studied on the San Joaquin Experimental Range, an area of 4,700 acres, in co-operation with the Animal Husbandry Division of the University of California. Duplicate pastures furnish three intensities of grazing, with 160, 240 and 320 acres respectively for heavy, moderate, and light grazing, from the time green feed is available, usually in January, until it dries and loses most of its nutritive value in July or August. Equal numbers of cattle are grazed in each pasture as in the Northern Great Plains experiments, but a special trial is made on supplemental feeding, because of the low nutritive level of the annual plants during the summer and fall. Half the animals in each pasture

are given supplemental feeds only in emergency; the other half are regularly fed in summer, but also at any other time of year if necessary to keep them in thrifty condition. The cattle are kept in a separate pasture during the months they are not in the six experimental pastures.

Samples of forage representing as closely as possible that utilized by the cattle are collected and analysed for nutritive value for each two weeks' period. The cattle are weighed fortnightly while in the experimental pastures, and results of the various degrees of grazing and supplemental feeding are measured in livestock gains or losses, calf crops, calf weights, and amount of supplemental feed used.

The response of the range itself is unusually difficult to measure because the composition and volume production of the annual plants vary so greatly from year to year, and even from month to month during the growing season (**20**). Inventories are made of the six experimental pastures each year in early summer at the height of forage growth. The individual plants are far too abundant and ephemeral to permit use of the chart quadrat, as with the predominantly perennial grasses of the Northern Great Plains and the Jornada Range in the Southwest. The vegetation is sampled with plots only 1 foot square, randomly located at the rate of one to 2 acres, or preferably one per acre. The forage on each plot is clipped, segregated by main species, and weighed. The trend of the vegetation on the rest of the experimental range is followed with a less intensive sampling by estimate plots. Special enclosures and detailed sampling methods are employed to measure the effect on vegetation of complete protection from grazing and the forage utilization by the more abundant rodent species on the range, such as ground squirrels, pocket gophers, and kangaroo rats.

4. Sheep Grazing Experiments

The sheep grazing experiments of the Intermountain Forest and Range Experiment Station illustrate the need for careful co-ordination of range management research on areas often widely separated. Reflecting the different seasonal sources of forage for range sheep grazing in this region, the Intermountain Station is studying problems of management on high-mountain summer ranges in central Utah, on spring-fall ranges in the high plains of southern Idaho, and on winter ranges in the deserts of western Utah and Nevada. On the pastures of the two latter areas experimental approaches are employed which are rather different from those described for cattle.

Two general differences between range management of sheep and cattle affect the experimental procedure. First is the greater number of animals needed, reflecting the ratio of about three sheep to one cow in range forage requirement, the larger number of animals necessary in an economic outfit, and the greater individual variation encountered over a period of years due to the shorter productive life span of sheep. Second is the strict control exercised over sheep on the open range through constant herding, leading to a more uniform and well managed utilization of the forage than is usually possible with cattle. Because of this, any advantages of improved manage-

ment recorded on small experimental pastures without herding must be carefully checked on herded range. These and other contrasts with cattle experiments are shown in the following examples:

Management of Spring-Fall Ranges

Methods of managing sagebrush-wheatgrass ranges grazed in spring and fall are studied by the Forest Service in co-operation with the Bureau of Animal Industry at the U. S. Sheep Experiment Station in southern Idaho. The purpose is to determine the best seasonal management and intensity of stocking consistent with maximum production of usable forage and of mutton and wool.

Specifically, the rotation system is tested against the rotation-deferred system and continuous grazing in moderately grazed 80-acre paddocks. In the rotation system the 2 months spring grazing is so rotated among a series of four paddocks that each is grazed during the same 15-day period only once in 4 years; and the fall grazing is similarly rotated. In the rotation-deferred system each paddock in the series is completely deferred until fall once in 4 years.

In addition to the tests of moderate use, the rotation system is tested under light and heavy grazing in 40-acre paddocks. The different intensities are attained by stocking at 8, 12 and 16 sheep-days per acre in spring and again in fall. The animals grazed in the experimental paddocks are run with the regular Sheep Station herds during the rest of the year, on mountain range in summer, and in winter either run on desert range or fed. The dual season of grazing and the complexity of the management systems being tested in this experiment show a sharp contrast from the year-long and winter-spring cattle grazing arrangements previously described.

Results of treatments are measured both in terms of the livestock and of the vegetation. Sheep records include body weights of mature ewes before and after both spring and fall grazing, the number of lambs born, and the weights of lambs at birth and weaning. The weights of fleeces at shearing furnish an additional consideration not available in the cattle experiments.

The measurement of results on the vegetation is made difficult by the fact that the main growth occurs during the spring grazing season. Furthermore, the forage crop is so heterogeneous in growth form, with approximately 14 per cent shrubs, 58 per cent grasses, and 28 per cent weeds, that the sampling problem is different from that of the predominantly perennial grasses of the Northern Plains and the Jornada and the annual plants of the California foothills. Chart quadrats and general estimates of forage production and use, checked by sheep-days feed obtained, were employed to follow the vegetative response in early studies (**5**). In studying shrubs too large for meter quadrats, such as sagebrush (*Artemisia* spp.), Pickford and Stewart (**16**) mapped plots 5 by 20 feet in size with the co-ordinate method. A crossbar was suspended from two parallel steel tapes located on the sides of the plots; the mapper recorded the intersection of the bar with each shrub, then moved to the next interval on the steel tapes.

More recently, Pechanec and Pickford (**13**) have developed the method of

estimating directly the forage weight on plots, overcoming many of the disadvantages of general estimates of forage production. At the beginning of an experiment to extend through several years, an inventory of productivity is made by estimating forage production by species on temporary plots, either randomized or in a gridiron. A number of plots are marked permanently for annual estimates. In determining forage production, the estimator trains and accurately checks his estimates regularly by clipping and weighing the plants on a few test plots. Particular care is necessary on the sheep range to include only forage available to sheep, eliminating from the estimate forage plants protected from grazing by the abundant sagebrush. Circular plots of 50 and 100 square feet have been used; the smaller plot has proved better suited to this type of range. If forage production is being determined on grazed range, the herbage on the ground is estimated, the utilization percentage recorded, and the weight of forage calculated accordingly. To preserve ungrazed plant material for sampling, small temporary enclosures are erected in the paddocks grazed during the growing season. These enclosures are moved each year to avoid cumulative effects of protection.

The ocular plot-estimate method of determining degree of utilization has also been applied on this range (**14**). Utilization of each species is estimated on plots as indicated above. Training is based on ungrazed plants clipped to simulate grazing; estimates of utilization for each species are made and the residual herbage is clipped so that the observer's estimate of percentage removal is checked against actual weight.

As a final step in the research, the conclusions drawn from the small experimental paddocks are studied under practical range conditions with herding on the entire Sheep Station area of over 12,000 acres, which is grazed conservatively during both spring and fall.

Economic Sheep Grazing on Desert Winter Range

The winter-range phase of sheep raising in the Intermountain Region is being studied at the Desert Experimental Range in western Utah. The purpose is to develop methods of managing winter ranges in as highly productive condition and for as long a winter season as practicable. The studies on the 55,000-acre range aim to determine the effects of late fall, winter, and early spring grazing upon forage productivity under different intensities of grazing. These three seasons and their three two-way combinations are set up in a factorial experiment with light, medium, and heavy intensities of utilization in eighteen pastures, each 320 acres in size. The animals are unherded in the pastures and are selected from two privately owned bands of sheep, each of which alternates between the general herded pastures of the conservatively grazed Desert Experimental Range and the heavily grazed outside range. The two alternating bands provide an excellent basis for comparison of the economic benefits of good management on the experimental range with the results of usual practices on outside range.

There are many points of difference between the desert winter range and the

spring-fall range on the Sheep Station in Idaho. The precipitation on the desert is more uncertain and nearly one-fourth less than the 10 inches received on the spring-fall area. The desert vegetation is more sparse, hence a greater area is required to support an animal. Furthermore, the winter grazing season begins only after forage growth is completed and the sheep usually leave for spring range before new growth begins on the desert. In addition, the forage is made up mainly of perennial grasses and low palatable shrubs. These features permit much more satisfactory records of the vegetation and its changes than at the Sheep Station where spring grazing coincides with the main growing season.

Inventories are made of forage production each year after growth is complete but before grazing starts, both in the herded area and in the smaller pastures. A volume estimate method is used on plots which, because of the sparse vegetation, are 200 square feet in size in contrast to the 50 square feet employed in the weight estimate method on spring-fall range. After the current year's forage production has been removed and has been measured by species in cubic feet on several plots to train the observers, enough additional plots are systematically estimated to furnish a predetermined sampling accuracy. Degree of utilization in each pasture and on the herded range is determined in the same manner in volume after the sheep have moved away from the desert range. The close correlation between volume and weight of this desert forage permits ready conversion of data into weight if desired.

Forage production from year to year is one measure of the effect of grazing treatments in the pastures, supported by permanent chart quadrats to show changes in stand and the response of individual plants. Complete records of livestock—animal days feed obtained, lamb crops, weights, wool clip, and supplemental feeding required—also show the practicability of the grazing treatments in pastures on the herded experimental range, and on the heavily grazed outside range.

5. Ecological Studies on High Mountain Summer Ranges

The research on management of ranges to furnish livestock grazing throughout the year in the Intermountain region is completed by the studies on high mountain summer ranges at the Great Basin Branch Station in central Utah. This historical area, established in 1912 as the first experimental range of the Forest Service, is located on the Manti National Forest, where many different combinations of range vegetation, soil and moisture, altitudinal zone, and degree and season of grazing by cattle and by sheep are available for comparison. The investigations are primarily ecological, aimed at determining the proper time, degree, intensity, and frequency of grazing on these summer ranges, in accordance with the growth requirements and natural revegetation of the important forage plants. These pioneer studies have been the foundation for much of the range ecology work in the West, both as to methods, and as to basic principles.

The problem differs from all those previously discussed in that the grazing is limited to the late spring and summer, coincident with the active growing season of the vegetation; the forage types are intermingled with stands of oakbrush or open forest, often on slopes so steep that satisfactory grazing is very difficult to attain.

Furthermore, the summer range studies are mainly on the open range, with numerous enclosures to furnish ungrazed plants for detailed observation, and with temporary, movable panels to provide plants grazed at definite times and intensities. Certain management systems are been tested in paddocks, and a few small pastures have been grazed in connexion with special studies of artificial revegetation and watershed management.

The research program includes the following phases under range management investigations: (1) the effect of climate on plant growth, (2) range readiness and season of grazing, (3) natural revegetation, and (4) season and degree of grazing as related to range productivity. In addition to these range management phases, there are closely correlated studies of artificial revegetation, watershed protection, and biological influences.

Contributing to the entire ecological work is the series of climatological stations ranging from 7,655 feet in the oakbrush zone through the aspen-fir at 8,850 feet to the spruce-fir zone at 10,100 feet elevation. These weather data, in conjunction with measurements of plant growth and development, have furnished reliable information on grazing periods (**4, 19**).

In order to determine the time when the range is ready for grazing, plant development observations were made on numerous species, including grasses, broad-leaved herbs, shrubs, and aspen. Conditions represented involve several different elevations, exposures or directions of slope, and degrees of slope. Conducted over a period of years, the study has shown the normal trend and fluctuations in seasonal development as influenced by climatic factors under various site conditions, in relation to best seasonal management.

Studies of range-plant succession and natural revegetation have developed principles of far-reaching importance in management to restore depleted range. Observations of plant and soil conditions over the years on areas ranging from seriously disturbed to highly productive types, supported by chart quadrat records, revealed the stages of plant succession, and the conditions of soil, moisture, slope, exposure, and grazing associated with or responsible for each stage, or for change (**18**). Studies over a long period on permanent chart quadrats are used to show the slow progress of succession on depleted soils. Changes in plant cover under various conditions of habitat and grazing use are also determined from permanent major plots, varying in size from 0.5 rod square to 50 feet square as necessary to include suitable vegetation for observation. The vegetation on these plots is mapped periodically, supplemented by reconnaissance notes of density, composition, forage production, and utilization.

Discussion of range management research on summer ranges is incomplete without a reference to the earlier work of Sampson, dating from 1907 in Oregon, on life histories and forage values of important range plants (**17**). Habitat conditions and growth stages were observed in the field, and ecological requirements such as soil and moisture preferences and drought resistance determined through wilting tests worked out. This type of work is now handled largely under range forage investigations. After a lapse of several years, range research in Oregon and Washing-

ton was revived in 1936, under the Pacific Northwest Forest and Range Experiment Station. Preliminary studies of management on national forest summer ranges have progressed to the point where more intensive work in pastures is being organized.

6. Correlation of Grazing and Timber Reproduction

Some 126 million acres of the western range are on open forest land, which produces both valuable forage for summer grazing and commercial timber. In this type it is important for grazing to be managed with the minimum of damage to the forest resource. A study of the harmonization of cattle grazing with timber growing is conducted by the Southwestern Forest and Range Experiment Station in the ponderosa pine forest of northern Arizona. It aims to determine the susceptibility of pine seedlings of various ages to injury; the relationship to such injury of range forage utilization and of other agents such as insects, small rodents, game animals, fungi, frost and drought; the processes of seedling recovery from injury; and finally the practical range and livestock management needed to reduce grazing injury to a minimum.

The conditions under which grazing damage occurs to ponderosa pine seedlings and the effects of such damage are studied in a large pasture of 24,000 acres grazed by about 1,000 steers, during a five-months' season from June to October inclusive. Observations are made on rectangular plots, varying from 300 to 400 square feet in area, selected to obtain a large number of plants under conditions varying from thin to dense reproduction, different plant types, zones of forage utilization, intensities of injury, and availability of water. Movable panel enclosures are employed to control time and intensity of grazing on selected areas of from 1 to 4 acres. Germinating seedlings are so numerous in some years and die so rapidly from various causes that those less than 2 months old and in the cotyledon stage are simply counted on each plot. Older, well-established seedlings are tagged and indicated on plot maps. Damage from other agencies is carefully recorded before grazing begins each year, and insofar as possible while grazing prevails. Repeated observations are made on the plots during the grazing season to note the kind, amount, and cause of damage to individual seedlings, along with possible correlated factors such as stage of development, succulence, and utilization of the forage plants, precipitation and other climatic factors, and physical conditions of soil and vegetation. Recovery of damaged seedlings is followed both on the plots and on especially selected individual seedlings. Method of recovery and growth are worked out both from gross observation in the field and morphological studies of prepared material in the laboratory.

Finally, the plot data, supplemented by careful observations throughout the pasture, permit determination of the management features that reduce grazing damage to the pine seedlings, such as location of water and salt, and fencing.

A somewhat similar study is conducted in the Sierra Nevada by the California Forest and Range Experiment Station, in the ponderosa pine—sugar pine type. Emphasis here is mainly on a comparison of forage values obtained from open forest range before and after logging, as grazing damage to tree seedlings is negligible.

7. Importance of Fundamental Research

Many additional types of range problems and research approaches might be cited. The methodology of research on artificial revegetation of range lands, and the study of range watershed management each deserve separate treatment. Underlying the more diverse practical experiments aimed at specific management problems, however, there is the need common to all lines of range research for fundamental ecological and physiological investigations. An example will indicate the necessity and value of basic investigations in explaining some of the more intricate relationships of range plant growth.

The high mountain summer ranges in central Utah are in great demand for as long and intense a grazing season as they will stand. In working out the growth and nutritional requirements of the plant itself as a basis for better planning of the permissible season and degree of grazing on such ranges, McCarty (**9**) determined the relation of growth to the varying carbohydrate content in mountain brome throughout the year at the Great Basin station.

Samples were taken from an area of about one-sixth acre within an enclosure seeded to mountain brome several years before. Collections were made at random in the morning at 10-day intervals during the snow-free period and monthly during the winter. A 40-gram sample of stem bases and roots was obtained from six to ten plants, which yielded an adequate sample of herbage, consisting of stems and leaves. The samples were cleaned and preserved in 95 per cent alcohol in the field. Later, in the laboratory, standard methods of chemical analysis were used in determining reducing and total sugars, starch, and hemicellulose. Along with the collections of plant material were taken growth measurements and dates when important growth stages were reached. McCarty's results over a 3-year period indicated the importance of relatively high concentrations of sugars in the basal organs of mountain brome in resistance to low temperatures and to winter survival.

A subsequent 4-year experiment on meter quadrats tested the effect of various clipping treatments on carbohydrate storage and plant growth.

In the early days of range research there was a great deal of empirical study and considerable valuable information was obtained in that way, but the complex nature of the problems demands a more intensive approach along fundamental lines. The 1939 Range Research Seminar (**21**), with an attendance of sixty members of the Forest Service, attests the growth and interest in the work in the United States. Permanent committees were appointed on methodology and terminology. It has already been proposed to hold another seminar within the next few years open to all range ecologists. The numerous foreign visitors to the United States and the more frequent exchange of methodology between workers on different continents through published channels definitely stimulate better research. Opportunities for improvement in methods are great, especially as ecologists adopt more efficient, modern statistical designs and co-ordinate work with other fields such as physiology, biochemistry, soil science, and similar studies.

References

1. CAMPBELL, R. S. Plant succession and grazing capacity on clay soils in southern New Mexico. *J. agric. Res.* 43. 1027-51. 1931.
2. CANFIELD, R. H. The effect of intensity and frequency of clipping on density and yield of black grama and tobosa grass. U.S. Dept. Agric. Tech. Bull. No. 681. pp. 32. 1939.
3. CHAPLINE, W. R. Range research in the United States. *Herb. Rev.* 5. 1-13. 1937.
4. COSTELLO, D. F., and PRICE, R. Weather and plant-development data as determinants of grazing periods on mountain range. U.S. Dept. Agric. Tech. Bull. No. 686. pp. 30. 1939.
5. CRADDOCK, G. W., and FORSLING, C. L. The influence of climate and grazing on spring-fall sheep range in southern Idaho. U.S. Dept. Agric. Tech. Bull. No. 600. pp. 43. 1938.
6. ELLISON, LINCOLN. Intensive methods of measuring vegetation. [Contained in] Proceedings of Range Research Seminar. U.S. Forest Service. pp. 196-207. (Mimeographed). 1939.
7. HILL, R. R. Charting quadrats with a pantograph. *Ecology.* 1. 270-3. 1920.
8. HURTT, L. C. Overgrazing increases production costs. Northern Rocky Mountain Forest and Range Experiment Station. Applied Forestry Note No. 92. pp. 1-2. (Mimeographed). 1939.
9. MCCARTY, E. C. The relation of growth to the varying carbohydrate content in mountain brome. U. S. Dept. Agric. Tech. Bull. No. 598. pp. 24. 1938.
10. MCGINNIES, W. G. The quadrat. *J. For.* 28. 23-7. 1930.
11. NELSON, ENOCH W. The influence of precipitation and grazing upon black grama grass range. U. S. Dept. Agric. Tech. Bull. No. 409. pp. 32. 1934.
12. PEARSE, K., PECHANEC, J. F., and PICKFORD, G. D. An improved pantograph for mapping vegetation. *Ecology.* 16. 529-30. 1935.
13. PECHANEC, J. F., and PICKFORD, G. D. A weight estimate method for the determination of range or pasture production. *J. Amer. Soc. Agron.* 29. 894-904. 1937.
14. ———————— A comparison of some methods used in determining percentage utilization of range grasses. *J. agric. Res.* 54. 753-65. 1937.
15. PICKFORD, G. D. Range survey methods in western United States. *Herb. Rev.* 8. 1-12. 1940.
16. ———————— and STEWART, G. Co-ordinate method of mapping low shrubs. *Ecology.* 16. 257-61. 1935.
17. SAMPSON, A. W. Important range plants: their life history and forage value. U. S. Dept. Agric. Bull. No. 545. pp. 63. 1917.
18. ———————— Plant succession in relation to range management. U. S. Dept. Agric. Bull. No. 791. pp. 76. 1919.
19. ———————— and MALMSTEN, H. E. Grazing periods and forage production on the national forests. U. S. Dept. Agric. Bull. No. 1405. pp. 55. 1926.
20. TALBOT, M. W., BISWELL, H. H., and HORMAY, A. L. Fluctuations in the annual vegetation of California. *Ecology.* 20. 394-402. 1939.
21. U.S. FOREST SERVICE. Proceedings of Range Research Seminar. pp. 414. (Mimeographed). 1939.
22. WHYTE, R. O. Research on grassland, forage crops and the conservation of vegetation in the United States of America. Herbage Publ. Series. Bull. 26. pp. 113. 1939.

GENUINENESS OF TYPE IN RED CLOVER

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IN Swedish hay leys, red clover occupies a very prominent position. Three different types are distinguished according to the degree of earliness of the plants. The time of flowering and withering of the flower-heads is used as an expression of this. In State sealing from July 1, 1937, after-control cultivation at the State Seed Testing Station to determine genuineness of type of the seed lot has been obligatory. As check varieties for the various types may be mentioned Essi for early red clover, Harrie for medium-late and Göta for late red clover.

In the south of Sweden recently there has been a growing tendency to sow medium-late and early types, as leys of shorter duration are now employed there. In the southerly parts of middle Sweden, for example in Östergötland, both late and medium-late types are cultivated. In the greater part of Middle Sweden and also in Norrland, where the leys are often left down for three or more years, the more hardy late red clover predominates. The medium-late types give in general a good yield in the first year with, as a rule, abundant aftergrowth, but on the other hand a poorer yield the second year, and in the third year ley only a small amount of red clover is present in comparison with leys sown with the more persistent late red clover.

It is consequently of great economic importance for agriculture that red clover of the right type should be used and the guarantee of genuineness of type which is now prescribed for State sealed red clover signifies a great advance. The results of after-control cultivation carried out with the samples which represent sale during the period 1937-8, the first season the new sealing regulation was applied, are briefly reported below.

In the spring of 1938 there were sent in for after-control cultivation 188 samples of type-labelled lots of red clover only. As is seen from the accompanying statement, 43 samples came from firms in south and 145 samples from firms in middle Sweden. No samples were received from Norrland and consequently no State sealing of red clover took place in that part of the country. Twenty-nine samples were labelled early, 22 samples medium late, and 137 samples late red clover. The early and the medium-late red clover derived mainly from south Sweden while the major part, or 94 per cent, of the lots of late clover were sealed in middle Sweden.

Of the 43 lots State-sealed in south Sweden only two proved to be not true to type, namely, one lot of early and one lot of late red clover. Of the 145 samples, mainly late red clover, from middle Sweden, 39 could not be certified as true to type; this amounts to 27 per cent of the total number of samples.

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