Continuous vs. Specialized Grazing Systems: A Review and Application to the California Annual Type

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Rotation of grazing among separate pastures was advocated as a range improvement practice before the turn of the century (Smith, 1895). Following intensive ecological studies in the Wallowa Mountains in Oregon, Sampson (1913, 1914) recommended that deferred-rotation grazing should be a general practice on national forests. Jardine (1915) and Jardine and Anderson (1919) presented the deferred-rotation scheme in diagram form. Numerous grazing experiments were conducted between 1920 and 1950 to test the value of grazing systems and much experience was gained in the application of rotated rest and grazing on range lands. Part of the experimentation showed that continuous grazing gave more animal production than various rotational systems and the conflicting results were briefly reviewed by Sampson (1951, 1952) and by Stoddart and Smith (1955).

Additional information is available from recent work in the United States and in range areas throughout the world. One objective of this paper is to analyze the facts and beliefs about grazing systems in an attempt to determine the reasons for conflicting results. The second objective is to propose the hypothesis that continuous grazing will give more animal production from the California annual type of vegetation than will rotational systems. This will be done by an interpretation of vegetational and animal data from several studies, a minimum field trial, and without a thorough experimental test.

Many people have unknowingly contributed to this report through most helpful oral discussions. Opinions about grazing systems have differed so widely that separate acknowledgement to each person would be inadvisable, besides I find impossible the listing of who said what. I graciously acknowledge the contribution by Mr. Donald T. Torell who helped greatly in the development of the hypothesis and who furnished the data from animals. Messrs. F. A. Branson, A. Heerwagen, and A. M. Schultz improved the manuscript with many worthwhile suggestions.

Definitions

Continuous grazing is used in this paper to include yearlong and seasonal grazing where animals are on a range unit for at least the whole of the growing period. Usually they graze a unit as long as the weather permits. The specialized systems include rotation, deferred, rest-rotation, and deferred-rotation grazing. Distinctions among these systems are easily made by definition (Stoddart and Smith, 1955) but are difficult in application. In practice, rotation and deferment are frequently combined to meet the operator's particular management problems. In experimentation, seldom have two different studies tested the same systems. Grazing and rest periods have been different in length, vegetational types are different in the various experiments, and the animals used have been of different kinds, ages, and sexes. Therefore, meaningful detailed comparisons of the specialized systems are all but impossible. On the other hand, continuous grazing has been compared with one to several of the specialized systems in numerous tests and that is the basis of this review.

Rotation grazing has been intensively studied on cultivated pastures, but that large body of information is used only to establish certain principles.

Advantages of Specialized Grazing Systems

The advantages of a specialized grazing program are generally stated in terms of improved range conditions. The rest from grazing allows the established plants to gain in vigor and to produce more seed. Seedling establishment is encouraged and palatable plants increase. The result is higher herbage yield. The establishment of a grazing system usually requires fencing of additional pastures so better livestock distribution and more uniform grazing are attained. These permit division of the herd and closer supervision. Since every pasture is grazed every year in most systems, it is argued that no forage is lost, that the mature plants are not damaged by grazing and that the animals scatter and cover the seed by trampling. Reseeding and brush control can be done on the rested pasture without interference from livestock. Damage in areas of livestock concentration will be eased. The improved range conditions are supposed to result in greater livestock production through more animals or more gains from the same number of animals.

The above list emphasizes vegetational improvement and control, livestock handling, and more livestock products. Improvement of deteriorated ranges is recommended as the principal use of specialized grazing systems. The kind of grazing system that maintains an excellent range and yields the greatest net return from excellent range is seldom mentioned.

Disadvantages of Specialized Grazing Systems

A specialized grazing system is difficult to establish on many ranges because sufficient water is unavailable and certain pastures must be used at the same season every year. Fencing costs are always high and are especially so on rough topography. Feed values are lost in the rested pastures because forage nutritive values decrease after plant maturity. Livestock production may not be increased enough to pay for the extra costs of developing water and fencing. Numerous experiments have indicated that specialized grazing systems may actually depress livestock gains when equivalent stocking rates to continuous grazing are maintained. No grazing may allow extreme fire hazards to develop. The disadvantages stress the additional costs and the lack of increased animal products to meet them.

Livestock Responses to Grazing Systems

The response of animals in experiments which compare continuous and specialized grazing systems has been varied but mostly in favor of continuous grazing. The experiments where no differences have been found include those in the northern Great Plains (Thomson, 1938; Black and Clark, 1942; Whitman, et al., 1943); in the southern Great Plains (Dickson, Fisher and Marion, 1948; Fisher and Marion, 1951; McIlvain and Savage, 1951); in forested summer range in eastern Oregon (Pacific Northwest For. and Range Expt. Sta., 1959); and in the southeastern United States in switch cane vegetation (Biswell and Foster, 1947; Biswell, 1951). Similar results have been reported from other countries. Among these are a 4-year study by Moore, et al. (1946) and Davies (1946) in Australia and a summary of 13 experiments that were conducted over a 17-year period in New Zealand (McMeekan, 1956). The latter reported that extreme differences in systems had small effect on animal production. After 8 years of work on five experiment stations in different vegetational types in Southern Rhodesia, continuous grazing was recommended as the most productive way to graze the natural vegetation (West, 1958).

In the northern Great Plains, Sarvis (1923) reported steer gains in favor of deferred-rotation grazing but after 25 years with the same experiment he reported moderate continuous grazing as superior (Sarvis, 1941). These results were restated in 1944 and in 1951 by Rogler. Significantly more livestock gains with continuous grazing were reported by Hyder and Sawyer (1951) for the sagebrush-grass type in eastern Oregon; by Smoliak after 9 years in the plains of southern Canada (1960); and by Suckling (1954) for unploughable hill land in northern New Zealand.

In addition to the 1923 paper by Sarvis, in which the results were later reversed the only report found that mentioned more favorable animal gains with deferred-rotation grazing was a 3-year study with lambs in Wyoming (Barnes, 1948).

The preponderance of evidence is that the system of grazing makes little difference in the production of livestock. Four studies showed advantage for continuous grazing and one for deferred-rotation. The results are in terms of animal weight gains and presumably equivalent stocking rates within each study. In view of the additional costs necessary to establish a special grazing system and to move the livestock, there seems little chance that a special system will be economically feasible. However, the picture is not that clear-cut. For example, it is a reasonable assumption that increased animal production will follow range improvement. The animal data must be interpreted in terms of vegetational changes in the same trials.

Vegetational Responses to Grazing Systems

The experiments which indicate either no advantage in livestock gains with specialized grazing systems or more gains with continuous grazing also report no significant differences in the vegetation under the various systems. For example, Moore, et al. (1946) in Australia found that sheep in different rotations did not change the composition of harding grass and subclover pastures. Smoliak (1960) described numerous vegetational changes during 9 years of cattle grazing on short grass ranges at Manyberries, Alberta, Canada and concluded that the total change was the same in the deferred-rotation and continuously grazed pastures. The Intermountain Forest and Range Experiment Station (1959) reported the same forage production in four grazing systems after 11 years on crested wheatgrass pastures near Benmore, Utah.

Several papers have presented vegetational data only and concluded that deferred-rotation grazing was superior to continuous. They include Hanson, Love, and Morris (1931) and Morris (1932) after 9 years of work in Colorado; Aldous (1938) and Anderson (1940) in an experiment started about 1919 in the bluestem type in Kansas; Canfield (1938, 1940) after 21 years of experience and experiments on black grama and tobosa grass in the Southwest; and Merrill (1954) after 4 years of work on the Edwards Plateau of Texas. The last study is still in progress and it includes measurement of animal responses. The Intermountain Forest and Range Experiment Station (1959) reports in a preliminary analysis of a 16-year study of spring grazing on sagebrush-grass range that rotational grazing permits heavier use than continuous grazing. They confuse the picture with data that the pastures used at different intensities within this study had similar herbage production at the end of the trial.

The value of specialized grazing systems for the restoration of depleted ranges has been emphasized by Clarke, Tisdale and Skoglund (1943) and Hubbard (1951) for short grass ranges in southern Canada and by Sarvis (1923, 1941) and Rogler (1951) in North Dakota. The work at Dubois, Idaho, (Intermountain Forest and Range Expt. Sta., 1959) mentions restoration. Frandsen (1950a, 1950b) recommended the deferred-rotation system as the easiest one to use to maintain range condition with bunch grasses, to reduce damage in areas where livestock naturally congregate, and to give protection during the establishment stage of other improvement practices.

Hormay (1955) has obtained remarkable improvement in range condition with a rest-rotation system in northeastern California. In this same study, Woolfolk (1960) shows that drought effects were minimized in a dry year by good management and that animal performance was best on the pasture grazed season-long. Reid and Pickford (1946) suggest fencing and deferred-rotation grazing for improvement of mountain meadows in eastern Oregon and eastern Washington. Observations with the once-over and twice-over systems in a mountain sheep allotment in Montana indicated that the once-over system was better because grazing was timed with forage development at different elevations, that less trampling damage occurred, and that the sheep were easier to manage. The range improved under both systems because of moderate use, open herding and 1-night bedgrounds (Heady, Clark, and Lommasson, 1947).

Although experiences such as these do not always give valid comparisons between systems, there is no doubt that improvements in range condition have been attained with grazing systems. How much improvement is due to the system of grazing and how much to other aspects of better overall management is not always clear. It is logical to believe that better ranges will increase animal production. The fact that many of the experiments did not show increased animal production may be because they were placed on good or excellent ranges or that range improvement occurred in all treatments. This indicates that other items such as stocking rate and distribution of animals are as important or even more important than the grazing system. On the other hand, the use of a specialized system as a part of a better management program is an important consideration.

Factors Influencing the Results

One finds evidence in these experiments to support either contention that continuous grazing or a specialized system is best. Of more importance than defense of one system or another is to understand the operation of the factors which influence the results. Such factors include stocking rate, relative resistance of plants to grazing at different seasons, uniformity of pastures, frequency of grazing, time between deferment periods, emergencies in managing livestock, weather, vegetational differences from one area to another, topography, and unrecognized conditions. Few specific data are available on these points. Experiments that determine the effects of these factors singly and in combination are extremely expensive. A full understanding will be difficult to attain.

Some authors have suggested reasons why their experiments failed to show an advantage for the specialized system. Anderson (1940) mentioned that livestock were moved at the wrong dates. Black, et al. (1937) wrote that the same stocking rate on pastures of different grazing capacities influenced the results. Hubbard (1951) and Hyder and Sawyer (1951) believed that heavy use in the spring grazed pasture in one year out of three caused more damage than was repaired by rest from spring grazing in the other two years.

Stocking rate is frequently discussed as an important factor determining the outcome of grazing trials and two or more rates have been included in part of the experiments. The range of results is illustrated as follows: The Pacific Northwest Forest and Range Experiment Station (1959) found no interaction between system of grazing and stocking rate; another found no difference in systems at heavy stocking rates but an advantage for deferred-rotation at moderate rates (Clarke, Tisdale, and Skoglund, 1943); a third mentions that climate is more important in causing fluctuations in production than intensities of grazing at light and moderate rates (Intermountain Forest and Range Expt. Sta., 1959); and a fourth indicated that stocking rate was the most important factor in determining the results of grazing trials (McMeekan, 1956). Few, if any, studies have included adequate measurements and controls of all the variables so that the main effects of system of grazing could be determined.

The relative resistance of plants to grazing at different seasons has been studied by subjecting them to different clipping frequencies. This information is used to suggest the periods of rest and grazing. But grazing on range land is neither as severe nor as sudden and it is more selective than clipping treatments. If the period between clippings is short, the implication is that all the herbage is consumed at near the same rate that it is grown. A constant adjustment of grazing pressure is required to accomplish this—a condition which is possible in a single pasture but next to impossible on a ranch basis. If the period between clippings is long, lengthy rest periods and short grazing periods are implied. This requires large groups of animals or a large number of pastures and animals moved frequently—again conditions of questionable practicality on ranges. Clipping treatments, except those on pure stands ignore the selectivity factor which is important to animal health and to range condition. A review of the large body of information on the effects of clipping is not needed to make the point that plant response to clipping is not the same as response to grazing on a ranch basis.

Certain characteristics of range herbage and animal production influence the results obtained by different grazing systems. Range animals are run for the most part on a long-time basis and they must receive about the same amount of feed every day with slight changes due to weather, pregnancy, fattening, etc. The demand for feed on a ranch varies somewhat during a year. As young animals grow, demand gradually increases and there is a sudden decease in demand when animals are sold. Thus, a cycle of high and low demand exists on most ranches.

A second cycle is present in the herbage supply. Herbage increments are small at the beginning of growth, increase rapidly in the short flush growth period to a peak at plant maturity, and then cease. During a dry period there is a decrease in herbage by shattering, insects, rodents and other causes not controllable by the manager. Grazing continues so there is a gradual decrease in available feed. In contrast to cultivated pastures where a considerable control of the cycle can be exerted with fertilization, irrigation, mowing, and choice of species, the herbage supply cycle in range vegetation is largely determined by factors beyond the operator's control. Certain exceptions exist where range fertilization and seeding can be done economically.

When the cycles of demand and supply are superimposed, four periods are evident: (1) Consumption of forage is more than the green increment in the early growing period and animals must eat old or conserved forages along with the green. (2) Consumption and increment are equal. This is a very short period on range land and may be no longer than a day or a week. (3) Increment exceeds the demand for a short period during the time of flush growth. (4) A dry period without forage increment but with continuing demand on the increment unused in period 3.

Probably the very highest livestock production would come with adjusting stocking rate to herbage growth so that all allowable forage is used by the end of the green season. The forage would be used when it is most palatable and when it has the highest nutritive content. But, as mentioned earlier, this is impossible with relatively constant stocking in a year-long ranch operation. Therefore, grazing use tends to reduce the supply of forage in all but period 3.

Specialized systems concentrate animals so that some pastures get eaten down. If this is in period one, the new growth is rapidly diminished and the capacity of the plants to recuperate is endangered. The second period is too short and elusive of determination on range lands to permit consideration in the grazing program. The third period gives more than adequate forage so the system of grazing probably makes little difference to either plant vigor or animal production unless animals are concentrated to a degree that prevents plant development. Unfavorable grazing consequences are minimized in the fourth period because the above ground plant parts are mature.

Specialized grazing systems on range lands tend to be rotations in growing period grazings where decreases of forage in the grazed pastures are counter-balanced by increases in the rested pastures. The problem is to prevent overuse on the grazed pastures during the first period. Where overuse occurs, even for a few days, livestock gains will be lowered. Herein may lie a reason for lower gains with specialized grazing systems than with continuous grazing in some of the experiments.

Of interest is a point made by Willoughby (1958, 1959) that whenever there was less than 1,400 pounds per acre of herbage on the ground sheep were not gaining at their maximum rate. He found this to be an asymptotic relationship with increasing availability above zero on the one hand and increasing quality on the other resulting in increasing animal production to a maximum imposed by the animals. If there was always 1,400 pounds per acre available, the animals gained at their maximum rate regardless of the actual amount of forage or the grazing system. As it seems more likely that available forage is below this limit when animals are congregated in a rotation system than when they are allowed continuous use, especially in period one, herein may lie another explanation of less animal products from deferred-rotation grazing than with continuous grazing in many experiments.

The figure of 1,400 pounds is unimportant to this discussion. The important point is that a relationship exists between the amount of feed available and animal performance. Many factors of animal type, age, weight condition, and health; and pasture type, quality, species, etc. will change the actual values of the asymptotic curve. These are still largely unknown and the form of the relationship needs to be determined for various combinations of factors. Of interest is that other workers (Johnstone-Wallace and Kennedy, 1944) arrived at a similarly shaped curve with an asymptote near 1,000 pounds per acre for dairy cows.

In grazing experiments, factors which are primarily vegetational or primarily animal or both may be limiting. If pastures are not limiting, as with light or moderate stocking rates, the capacity of the animals limits production. Under such conditions, no matter what the pasture treatment, animal responses reflect their ability only. On the other hand the pastures must be limiting the capacity of the animals to produce if the animals are to give a valid measure of pasture differences. It would seem that heavy stocking rates and high producing animals would be more likely to show differences in grazing systems than low or moderate stocking rates and low producing animals. Many experiments have been intentionally started with an effort to achieve moderate stocking. Results from them can give little more than animal differences.

What System for a California Annual Range?

In the absence of a thorough study of grazing systems in the California annual type the question of which one would give most efficient production must be answered on a basis of related information. The arguments presented above indicate that continuous grazing should be the choice. Results from several ecological and grazing experiments presented below substantiate that conclusion. The studies were concerned with description of vegetation as it changed under the influence of weather, grazing and other treatments. The range manager can manipulate some aspects of the California annual vegetation but over others he has little control. Most of the work was conducted on the Hopland Field Station of the University of California. The Station is located in the coastal mountains about 100 miles north of San Francisco and 40 miles inland

The California Annual Type

The annual plants germinate in the fall with the first rains, grow slowly until about the first of April, grow rapidly for six weeks and are usually mature and dry by June first. Changes in relative and absolute amounts of the different forage species are to a large extent correlated with weather fluctuations.

The annual type is a complex one composed of many species. For example, in one study area that was 100 feet square, about 50 species were found. Annuals make up at least 97 percent of the foliage cover and 80 percent or more of the species are introduced from the borders of the Mediterranean.

Fluctuations in Species Composition

The proportion of the different species that comprise the annual vegetation varies to such extent that some years are known as good clover years, some as filaree *(Erodium botrys)* years, and some as grass years. The magnitude of these differences is shown by data from a series of plots which were sampled from 1953 to 1960 (Table 1). Grasses constituted 87 percent of the cover in 1958 but only 22 percent in 1960. Filaree varied between 6 and 45 percent and legumes from 1 to 17 percent. Rainfall was heavy at Hopland in 1958 (60.4 inches) and well distributed throughout the growing season. In 1960 rainfall was 28 inches and there were two dry periods, one of 94 days, which greatly favored the filaree. Extensive vegetational differences which are largely beyond the control of the land manager result from the various weather pattern in the California annual type.

Fluctuations in Time of Maturity of Major Species

The period of rapid plant growth in the spring is one of a progression of different species (Heady, 1958). Observations at Hopland indicate that desirable and undesirable species mature throughout the season. Legumes *(Trifolium* spp., *Lotus* spp., *Lupinus* spp.) and undesirable weeds *(Agoseris heterophylla, Baeria chrysostoma, Hypochoeris*

Table 1. Percentage species composition based on herbage cover in 64 ungrazed plots at the end of the growing season, 1953-1960.

	1953	1954	1955	1956	1957	1958	1959	1960
Bromus mollis	11.5	14.1	10.5	15.0	14.2	21.2	17.1	4.6
Other grasses	36.3	44.7	18.4	26.0	23.0	65.9	37.6	17.8
Legumes	6.1	2.6	16.8	6.1	5.0	0.9	2.1	12.7
Erodium botrys	20.1	18.7	34.7	31.5	26.2	6.1	29.4	44.9
Other broad-leaved plants	26.0	19.9	19.6	21.4	31.6	5.9	13.8	20.0

glabra, Orthocarpus, etc.) seed early and at the same time. Little quaking grass *(Briza minor)* and silver hairgrass *(Aira caryophyllea)* mature early, the fescues *(Festuca* spp.) intermediate, and soft chess *(Bromus mollis)* and ripgut *(Bromus rigidus)* mature near the end of the season and slightly later than bur clover *(Medicago hispida)*. Filaree and wildoat *(Avena barbata)* set seed all spring. The last plants to mature are mostly undesirables; medusa head *(Elymus caput-medusae)*, nit grass *(Gastridium ventricosum)*, tarweed *(Madia* spp.), turkey mullein *(Eremocarpus setigerus)*, and prairie three-awn *(Aristida oligantha)*. These relative times of flush growth and maturity for the many species are within a two-month period, except for the summer species. A certain amount of telescoping in response to weather is evident in years with low spring precipitation. In 1956 all the species set seed and turned dry in a 3-week period. Two points are important; the short and variable time when species mature, and desirable and undesirable species mature both early and late.

Unless the grazing pressure is extremely heavy, sufficient seed will be produced for the next crop and rest from grazing during the fast growth period is not needed. Pechanec and Stewart (1949) have shown the same relationship for the annual cheatgrass ranges in southern Idaho.

Fluctuations in Herbage Production

Weight of herbage production at the end of the growing season may differ over 100 percent between years (Table 2). From 1954 through 1960 production varied from less than 1,000 pounds per acre to about 2,000 pounds in one set of plots on the Hopland Field Station. Although the amount of production may be different for other areas, yearly differences of similar magnitude have been reported by Talbot, Biswell, and Hormay (1939) and Bentley and Talbot (1951).

The amount of green herbage available during the winter wet period may be almost nil in some years and abundant in others. In a six-year period, 1955-1960, the herbage varied from about 200 pounds to over 1300 pounds per acre on March 1 in ungrazed conditions. Small amounts of winter forage can be expected in the years with late or scanty fall rains and low temperatures.

Fluctuations in Nutritive Content of Annual Herbage

Young herbage has a high moisture content which reduces its value as livestock feed. Not many data are available but percentages between 70 and 87 have been reported by Gordon and Sampson (1939); Luick, Torell, and Siri (1959); and Torell (1954). The first authors report moisture contents of 62 to 86 percent for plants in the flowering stage. Moisture content in herbage is high immediately after a rain and in the morning. It decreases during the day and with increasing days after a rain.

Table 2. Average oven-dry weight of herbage in grams per square foot on 63 ungrazed areas in a 200-acre pasture, 1954-1960.

	March	June
1954	......	18.41
1955	6.24	9.66
1956	2.33	12.86
1957	3.29	15.67
1958	12.31	19.01
1959	3.31	13.79
1960	2.25	7.77

A decrease in percentage of crude protein and an increase in crude fiber with advancing stage of plant maturity are well established relationships (Gordon and Sampson, 1939; Hart, Guilbert, and Goss, 1932). It is also commonly known that rains on mature herbage leach the nutrients and the result is poor feed with crude protein contents less than 5 percent.

If a mature sheep requires 4 pounds of dry matter per day, then it must eat 20 pounds of green material at 80 percent moisture, nearly 27 pounds at 85 percent moisture, and 40 pounds at 90 percent moisture. Although data are not available, animals are likely to be improperly nourished during periods of wet weather when the forage is young because the high moisture content in the feed prevents them from consuming enough bulk to get the daily requirements of total digestible nutrients. In the dry season sufficient bulk will be consumed but it may not contain adequate nutrients.

Fluctuations Related to Site

Maturity of the annual plants occurs over the whole ranch in the California annual type during a relatively short period. The elevational range is usually less than 3,000 feet and does not influence the speed of maturity as much as local soil conditions. Some soils are deep while others are shallow. On deep moist soil in the swales vegetation stays green longer than that on the hillsides where the soils are often shallow. North slopes stay green longer than south slopes. Thus, soil and moisture conditions result in more seasonal variation in plant maturity than elevation on most ranches. Fencing the range sites separately is seldom practical and every pasture will include areas with different forage potentials. Management of livestock on a basis of sites is difficult.

Influence of Degree of Use on Annual Vegetation

Too light utilization results in an increase of the tall annual grasses and less filaree and clover. Close grazing delays fall growth and reduces winter growth of the annual forage plants (Bentley and Talbot, 1951).

A study of the effects of mulch on the composition and production of annual vegetation has been conducted since 1952 (Heady, 1956). After removing the yearly changes due to weather by experimental design, the proportions of the different species were shown to be a function of the amount of mulch on the ground when the growing season begins (Table 3). Mulch is here defined as the total dry plant material above the soil surface regardless of its position or state of decomposition. With amounts of mulch in excess of about 700 pounds per acre the tallest grasses such as soft chess and ripgut were favored. With no mulch at all the vegetation was composed of small, unpalatable broadleaved plants such as *Baeria chrysostoma*, *Hypochoeris glabra*, *Orthocarpus erianthus*, and many others. Grasses of low forage value such as little quaking grass and silver hairgrass were associated with small amounts of mulch and others like the annual fescues and nit grass with intermediate amounts. More grass resulted in fewer legumes. Filaree did well regardless of the mulch.

Table 3. Percentage species composition in 1952 and two years later as a result of removing and leaving all dry plant material on the ground.

	All mulch removed		All mulch left in place	
	1952	1954	1952	1954
Bromus mollis	0.9	1.9	2.7	37.3
Other grasses	43.6	47.4	36.4	31.3
Legumes	6.8	2.8	12.7	1.5
Erodium botrys	14.5	22.3	22.7	17.0
Other broad-leaved plants	34.2	25.6	25.5	12.9
	100.0	100.0	100.0	100.0

Not only did manipulation of mulch change the composition but it also changed the herbage production (Table 4). Roughly twice as much herbage was produced with all the plant-material left in place than when all was removed. Intermediate amounts of mulch resulted in intermediate herbage production. The study suggests that mulch or dry plant material standing upright is more effective than the same amount lying on the soil surface. These results indicate that degree of herbage removal, or degree of utilization, is an important factor in determining the characteristics of the next crop, within the limits set by weather. Also it would seem wise to leave the least nutritious plant material as mulch and to encourage as much animal selectivity of the better plant parts as possible. Animals should be widely spread and allowed to graze for long periods to accomplish these conditions most efficiently.

Influence of Seasonal Use on Annual Vegetation

Almost no data are available on the effect of season of use in the annual type when other factors such as stocking rate and improvement practices are held constant. Significant differences in total production and species composition at the end of the growing season due to seasonal grazing by sheep or deer are not apparent in the studies at the Hopland Field Station. It stands to reason that heavy use early in the season will change the composition and much data are available on this point with seeded grasses and legumes (Love, 1944; Jones and Love, 1945; Love, 1952; Williams, Love, and Conrad, 1956). A commonly heard suggestion is to concentrate grazing animals in the early spring to discourage the undesirable annuals and to encourage the more desirable species. This is true where the desirable species are seeded legumes and perennial grasses and the undesirable species are the resident annuals. However, within the annual type the desirable and undesirable species mature throughout the spring season and grazing to reduce one group and to favor the other on a permanent basis is difficult.

Table 4. Average oven-dry weight of herbage in grams per square foot resulting from mulch manipulation.

	All mulch removed	All mulch left in place
1954	11.31	25.99
1955	11.85	21.39
1956	7.94	16.43
1957	18.00	29.63
1958	11.53	33.78
1959	8.22	20.76
1960	17.94	42.45

Speed of Vegetational Changes

Response of the annual vegetation to manipulation and to weather patterns is very rapid. The major responses of vegetation to mulch manipulation were attained in a year or two and maintained by continued treatment. Additional evidence of rapid response is available from a study of burning in the annual grass type (Hervey, 1949). The resulting vegetation due to various treatments is permanent only so long as the treatments continue. For example, by a combination of mulch manipula-

Table 5. Percentage species composition at end of the first and second growing seasons after seeding and mulch manipulation.

Plot	Species	July 9, 1957	June 3, 1958
Soft chess broadcast	*Bromus mollis*	35.0	76.0
seeded and half	*Erodium botrys*	48.0	7.0
of mulch removed	*Medicago hispida*	6.5	2.5
	Bromus rigidus	2.5	12.0
Filaree seeded	*Bromus mollis*	24.8	79.0
and all mulch	*Erodium botrys*	52.5	6.0
removed	*Medicago hispida*	4.2	2.5
	Bromus rigidus	3.0	9.0
Bur clover	*Bromus mollis*	32.0	85.5
seeded and half	*Erodium botrys*	35.7	2.0
of mulch removed	*Medicago hispida*	16.3	0
	Bromus rigidus	3.5	7.0
Resident	*Bromus mollis*	43.8	85.0
annual	*Erodium botrys*	39.3	4.5
no mulch	*Medicago hispida*	2.5	0
removed	*Bromus rigidus*	10.2	9.5

tion and seeding, four plots were obtained with percentages of soft chess between 25 and 44, filaree between 36 and 52, and bur clover between 2.5 and 16 (Table 5). These plots were left ungrazed and untreated. The next year, soft chess percentages were between 76 and 85, filaree between 2 and 7 and bur clover from zero to 2.5 percent. There seems little doubt that composition of the annual type can be changed, but the results are temporary and last only as long as the particular intensity and pattern of treatment, or grazing, are maintained. The over-riding influence of annual weather in causing vegetational changes on annual ranges is illustrated. Systems of grazing which give pastures a growing season rest every three or four years in order to allow range improvement would seem to be ineffective on annual ranges because any gain in one year can be wiped out the next by weather alone.

Grazing Habits of Sheep

The fact that animals prefer different forages at different times of the year and that they select different forages in relation to the amount available is well known. In a study of grazing preference, as determined by sheep with esophageal fistulas (Heady and Torell, 1958), results indicate that the animals avoided bur clover in the winter, ate it in large amounts in May and ate stems and burs in July. Grass appeared in the sheep's diet in the winter in greater proportion than it occurred on the ground. Filaree composed a high proportion of the diet when the animals were on dry forage even though that plant was shorter than the grasses, and many of the leaves had shattered. Much of the filaree eaten in July was fruits (Table 6). Various plants and plant parts, therefore, are selected at different times of the year.

If livestock are congregated, the palatable species get heavy use while the same species in rested pastures are unused. The same may be true for the less palatable species and the result is uniform grazing. Even grazing is often given as a desirable condition that is easily obtained by concentrating animals in a pasture and rotating the use among pastures. There is a difference of opinion on this point for range grazing. One suggestion is that the animals should be given free choice of as large an area as possible when the feed values are high. No access to plants with a high value for a short period is a loss of forage. Potential gains cannot be made up later when the feed values are low (Sarvis, 1941; McIlvain and Savage, 1951; Rogler, 1951).

Sheep select material of high nutritive value (Weir and Torell 1958). Chemical composition of material collected by fistulas was universally higher in crude protein and lower in crude fiber than material collected by clipping plots (Figures 1 and 2). These preliminary data indicate that sheep will select plants and parts of plants which are higher in nutritive value than the average of the herbage available to them. The opportunity for the selection of high quality feed is especially important during the dry season when feed values are low.

Digestive upsets have been observed in animals on the Hopland Station when they were shifted to ungrazed forage during the growing season. This may be due to the shift from a feed high in coarse material to one high in leaves, or from one low in crude protein to one with a higher protein content (Torell and Weir, 1959), or from one low to one high in total digestible nu-

Table 6. Percentage of three species in herbage available to sheep with esophageal fistulas and the percentage in the diet at five different dates in 1957.

Date	In herbage	In diet
Bromus mollis		
Feb. 1	41.3	56.5
Mar. 5	47.1	47.4
Apr. 1	42.5	52.9
May 2	48.0	37.5
July 9	48.2	11.2
Erodium botrys		
Feb. 1	38.2	38.0
Mar. 5	39.9	45.6
Apr. 1	36.2	36.3
May 2	37.5	28.2
July 9	35.9	76.1
Medicago hispida		
Feb. 1	9.6	2.0
Mar. 5	8.0	4.2
Apr. 1	13.1	10.6
May 2	9.1	34.4
July 9	6.0	11.4

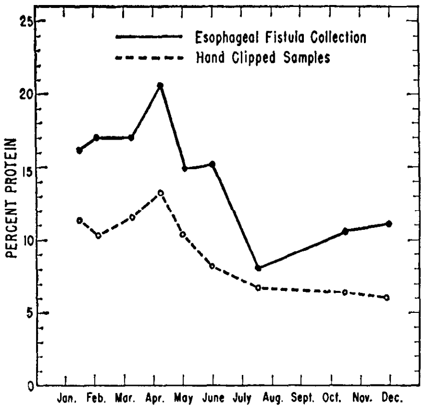

FIGURE 1. Percent protein in forage collected by sheep with esophageal fistulas and by hand clipping of square foot plots at different times (graph furnished by D. T. Torell).

trients. When animals are moved suddenly from one feed to another in a fattening operation, digestive upsets often occur. These have been attributed to the sudden change in nutrition. Therefore it is reasonable to suspect that digestive upsets apparent after sheep have been moved from one pasture to another are also due to change in nutrition.

Two recent papers (Brundage, 1960; Blaser, et al. 1960) show that the digestibility of pasture herbage increased for the first day or two when animals entered a fresh pasture and declined as the supply of available herbage diminished toward the end of the grazing period. Digestibility values were positively correlated with the degree of selective grazing in a repeating cycle that correspond to the rotation pattern. Milk production also exhibited similar cyclic fluctuations (Brundage, 1960; Kennedy, et al. 1960).

In moving a large band of ewes and lambs from one pasture to another, lambs have been observed to become separated from their mothers and, thereby, weaned prematurely. This happents most frequently when the sheep are driven a considerable distance between pastures. South Dakota (1958) reported that, "when ewes are moved frequently under a rotation system, the disturbance of their routine may also have an effect on their production."

The available information on the effects of moving animals on selectivity of forage by animals and on forage digestibility indicates that changing animals from one pasture to another upsets their normal physiological processes. This may not be serious in terms of animal production if sufficient high quality feed is always available. On the other hand if they are forced to eat herbages of low value near the end of each rotation period, it will lower their production. Rotation grazing congregates animals and frequently forces them to eat less nutritive materials than are available in ungrazed pastures.

One Test of Continuous vs. Deferred-Rotation Grazing

Since 1955 two 40-acre pastures on the Hopland Field Station have been used to test the effects of continuous and deferred-rotation grazing on the vegetation and animals. Both pastures have been essentially without deer and the same sheep have been in the pastures for the five years. They have lambed on the range and grazed without supplements since 1956. One pasture is divided into three parts.

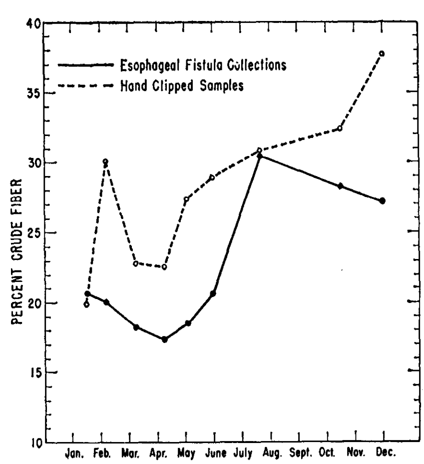

FIGURE 2. Percent crude fiber in forage collected by sheep with esophageal fistulas and by hand clipping of square foot plots at different times (graph furnished by D. T. Torell).

One division is grazed in the early part of the growing season, one in the middle, and the third near the end of the growing season. These have been rotated on a yearly basis so that each division is grazed at each time once in three years. The sheep are allowed free access to all three divisions during the dry season. The other pasture is without divisions.

The vegetation has not shown different trends in species composition, density, and herbage production under the two treatments. Differences between

Table 7. Average 120-day weight of single lambs under two systems of grazing (data collected by D. T. Torell).

	Continuous grazing	Deferred-rotation grazing
	— — (Pounds)	— —
1956	78.6	74.1
1957	80.9	70.9
1958	81.0	72.4
1959	74.4	62.9
1960	77.1	74.6

years have completely masked any differences due to grazing system. The average weaning weight of lambs has been consistently higher in the pasture with continuous yearlong grazing (Table 7). These are preliminary results because the experiment is still in operation. The treatments have been reversed to determine the influence of inherent pasture differences upon the results.

Discussion and Summary

The results of experimentation with grazing systems, such as continuous and the more specialized systems (rotation and deferred-rotation), are reviewed. None of these experiments have been comparable because they have employed different combinations of grazing and rest periods; they have been conducted on different types of vegetation; and they have used different kinds and combinations of animals. Continuous grazing has commonly been one of the treatments. For this review emphasis is given to the comparison of continuous grazing with other systems.

Weight gains of livestock have generally shown no difference due to grazing system or more gains have been obtained with continuous grazing. Changes in vegetation in those experiments reporting livestock responses have shown little differential effect of grazing system on range condition. When improvement or deterioration has occurred, it has been generally the same in all treatments.

On the other hand, there have been numerous reports where range improvement has been obtained with a specialized grazing system. These are largely based on application of grazing systems on range units and ranches. They pose a question of why, for example, does deferred-rotation grazing show significant results in the management of land while it has not been proved superior under experimental test? The answer probably lies in other features of management. When a rancher begins a deferred-rotation system, he usually changes the stocking rate, improves the distribution of animals, controls brush, reseeds, etc. In experiments these factors are held constant. The difference in results between grazing experiments and general application may be due to these practices and not to the grazing system.

Several authors have mentioned that the primary value of a specialized grazing system is in the restoration of depleted ranges. However, many of the experiments were started on ranges in good or excellent condition, where the restoration aspect has little chance to become evident. Practical application frequently begins with deteriorated ranges where range improvement can be evident immediately. How much improvement can be attributed to the system of grazing and how much to change in the other management practices is unknown.

An evaluation of this evidence indicates two major conclusions. One is that a specialized grazing system has no advantage in livestock production over continuous grazing, at least with good or excellent ranges under comparable stocking rates and degree of care in other management practices. The second is that other management factors are more important in the production of livestock than system of grazing. Evidence in support of these conclusions has been reviewed in the paper and is briefly summarized below along with some suggestions for conducting tests of grazing systems.

When the demand cycle for forage on a ranch basis is superimposed on the supply cycle of herbage growth, it is evident that during the relatively short period of rapid growth preceding plant maturity, herbage is growing faster than it is consumed. Except for that period the more animals are concentrated, as with rotation systems, the more some pastures get eaten down. A positive correlation exists between the amount and quality of forage available and animal performance below a certain level. Rotation systems are designed to force animals to graze closely before they are moved to fresh feed. This cycling of available feed from large amounts to very little through a grazing period materially affects the diet. Studies on animal preference for plant species and parts of plants in the California annual type and digestibility studies elsewhere are cited as evidence on this point.

A positive correlation exists among the degree of forage selectivity by livestock, the dry matter intake, and the quality of feed consumed. Selectivity decreases with an increase in stocking rate and an increase in proportion of herbage removed from a pasture. In the comparison of grazing systems, animal output is often confounded with stocking rate and the concurrent effects of differential selective grazing. Even though two pastures of the same size are grazed with the same number of animals, stocking rates and selectivity are not constant unless herbage production is also constant from day to day and between pastures. Since animal output is correlated with dry matter intake and quality of feed consumed, it is also correlated with the animal's opportunity to select forage. This suggests that for grazing pressures to be equal on two pastures the degree of selectivity, amount of dry matter intake, and quality of feed consumed should also be equal. Given animals with the same productive capacity, they should give equal response under these conditions. To equalize grazing pressure in different pastures, the stocking rates should be adjusted under one system of grazing until the animals give the same production at a level below their inherent capacity. This is suggested as the procedure to calibrate the pastures before different grazing treatments are tested.

In order to measure different pasture treatments the stocking rates should be simultaneously and equally increased until production is reduced to a greater degree on one treatment than another. Such a procedure eliminates the inherent productive capacity of the animals from determining the pasture results. The fact that different pastures have different numbers of animals and that all pastures are heavily used should cause no concern in experimentation.

Specifically for the California annual type, production fluctuates widely in terms of total amount, season of growth, species composition, time of maturity, moisture content, nutrient content, and on different habitats. The major causes for these fluctuations are weather and soil. Evidence was presented that the degree of use is an important grazing factor causing vegetational change and that it is superimposed on natural fluctuations. Changes in the California annual type are rapid and the over-riding influence of annual climate in causing these changes was emphasized.

With rotation systems the usual objective is to force the animals to consume all or most of the available forage in a short time. The fallacy of this system in terms of livestock responses is evident in the work which indicates that animal production decreases with a decrease in quantity and quality of feed available and degree of forage selectivity. On the other hand yearlong grazing allows the animals to choose the feed they prefer. Under ranch conditions in the California annual type ample amounts of feed are more likely available in the winter season with the animals widely scattered than when they are bunched. In the deferred-rotation system the objective is often to graze at a time or to a degree that will favor certain plants but not others. In the California annual type the changes are so rapid that any improvement to one pasture is lost before the cycle of a deferred-rotation system can be repeated.

Yearlong grazing at reasonable stocking rates, is the best way to manage the California annual type because it pays primary attention to the day by day animal needs and because yearlong grazing amounts to a partial deferment every year. Enough forage must remain at the end of the forage growth period so that the animals have ample feed to last them until the new crop is produced several months later. This amounts to a very light grazing on all the range during the growing season every year. At the same time, it should be realized that animals must be congregated occasionally for purposes of protecting new range developments and for certain animal husbandry practices. These do not destroy the hypothesis that continuous grazing should be practiced on the California annual type.

LITERATURE CITED

Aldous, A. E. 1938. Management of Kansas bluestem pastures. Jour. Am. Soc. Agron. 30: 244-253.

Anderson, K. L. 1940. Deferred grazing of bluestem pastures. Kansas Agr. Exp. Sta. Bull. 291, 27 p.

Barnes, O. K. 1948. Slightly more lamb on a rotated pasture. Wyoming Agr. Exp. Sta. 58th Annual Rept.: 7

Bentley, J. R. and M. W. Talbot. 1951. Efficient use of annual plants on cattle ranges in the California foothills. U. S. Dept. Agr. Circ. 870, 52 p.

Biswell, H. H. 1951. Studies of rotation grazing in the Southeast. Jour. Range Mangt. 4: 52-55.

Biswell, H. H. and J. E. Foster. 1947. Is rotation grazing on native pasture practical? North Carolina Agr. Exp. Sta. Bull. 360, 17 p.

Black, W. H., A. L. Baker, V. I. Clark, and O. R. Mathews. 1937. Effects of different methods of grazing on native vegetation and gains of steers in northern Great Plains. U. S. Dept. Agr. Tech. Bull. 547, 19 p.

Black, W. H. and V. I. Clark. 1942. Yearlong grazing of steers in the northern Great Plains. U. S. Dept. Agr. Circ. 642, 16 p.

Blaser, R. E. et al. 1960. The effect of selective grazing on animal output. Proc. 8th Intern. Grassland Congr. 601-606.

Brundage, A. L. 1960. The relationship of daily milk production to herbage digestibility and intake. Proc. 8th Intern. Grassland Congr. 450-453.

Canfield, R. H. 1938. Vegetational density and composition of black grama ranges as influenced by semi-deferred grazing. Southwest Forest and Range Expt. Sta. Res. Note 35, 2 p.

Canfield, R. H. 1940. Semi-deferred grazing as a restorative measure for black grama ranges. Southwest Forest and Range Exp. Sta. Res. Note 80, 4 p.

Clarke, S. E., E. W. Tisdale, and N. A. Skoglund. 1943. The effects of climate and grazing practices on short-grass prairie vegetation. Canada Dept. Agr. Tech. Bull. 46, 53 p.

Davies, J. G. 1946. A note on pasture management. Australia Council Sci. and Ind. Res. Bull. 201: 97-104.

Dickson, R. E., C. E. Fisher, and P. T. Marion. 1948. Summer grazing experiments on native grassland at Spur, 1942-47. Texas Agr. Exp. Sta. Progr. Rept. 1123, 10 p.

Fisher, C. E. and P. T. Marion. 1951. Continuous and rotation grazing on buffalo and tobosa grassland. Jour. Range Mangt. 4: 48-51.

Frandsen, W. R. 1950a. Management of reseeded ranges. Jour. Range Mangt. 3: 125-129.

Frandsen, W. R. 1950b. Effects of systems of grazing on livestock production. U. S. Dept. Agr. Soil Cons. Serv., Portland, Ore. 11 p.

Gordon, A. and A. W. Sampson. 1939. Composition of common foothill plants as a factor in range management. Calif. Agr. Exp. Sta. Bull. 627, 95 p.

Hanson, H. C., L. D. Love, and M. S. Morris. 1931. Effects of different systems of grazing by cattle upon western wheatgrass type of range. Colo. Agr. Exp. Sta. Bull. 377, 82 p.

Hart, G. H., H. R. Gilbert, and H. Goss. 1932. Seasonal changes in the chemical composition of range forage and their relation to nutrition of animals. Calif. Agr. Exp. Sta. Bull. 543, 62 p.

Heady, H. F. 1956. Changes in a California annual plant community induced by manipulation of natural mulch. Ecology 37: 798-812.

Heady, H. F. 1958. Vegetational changes in the California annual type. Ecology 39: 402-416.

Heady, H. F., R. T. Clark, and T. Lommasson. 1947. Range management and sheep production in the Bridger Mountains, Montana. Mont. Agr. Exp. Sta. Bull. 444, 30 p.

Heady, H. F. and D. T. Torell. 1958. Forage preferences exhibited by sheep with esophageal fistulas. Jour. Range Mangt. 12: 28-34.

Hervey, D. F. 1949. Reaction of a California annual plant community to fire. Jour. Range Mangt. 2: 116-121.

Hormay, A. L. 1955. The Harvey Valley Demonstration Allotment. Calif. Forest and Range Exp. Sta. 12 p.

HUBBARD, W. A. 1951. Rotational grazing studies in western Canada. Jour. Range Mangt. 4: 25-29.

HYDER, D. N. AND W. A. SAWYER. 1951. Rotation-deferred grazing as compared to season-long grazing on sagebrush-bunchgrass ranges in Oregon. Jour Range Mangt. 4: 30-34.

INTERMOUNTAIN FOREST AND RANGE EXP. STA. 1959. Highlights in Research. U. S. Dept. Agr., Ogden, Utah. 61 p.

JARDINE, J. T. 1915. Improvement and management of native pastures in the west. *In* U. S. Dept. Agr. Yearbook of Agr. 299-310.

JARDINE, J. T. AND M. ANDERSON. 1919. Range management on the national forests. U. S. Dept. Agr. Bull. 790, 98 p.

JOHNSTONE-WALLACE, D. B. AND K. KENNEDY. 1944. Grazing management practices and their relationship to the behavior and grazing habits of cattle. Jour. Agr. Sci. 34: 190-197.

JONES, B. J. AND R. M. LOVE. 1945. Improving California ranges. Calif. Agr. Ext. Serv. Circ. 129, 48 p.

KENNEDY, W. K. ET AL. 1960. Influence of system of grazing on animal and plant performance. Proc. 8th Intern. Grassland Congr. 640-644.

LOVE, R. M. 1944. Preliminary trials on the effects of management on the establishment of perennial grasses and legumes at Davis, California. Jour. Am. Soc. Agron. 36: 699-703.

LOVE, R. M. 1952. Range improvement experiments at the Arthur E. Brown Ranch, California. Jour. Range Mangt. 5: 120-123.

LUICK, J. R., D. T. TORELL, AND W. SIRI. 1959. A method for the determination of water intake of grazing sheep. Intern. Jour. Appl. Radiation and Isotopes 4: 169-172.

MCILVAIN, E. H. AND D. A. SAVAGE. 1951. Eight-year comparisons of continuous and rotational grazing on the Southern Plains Experimental Range. Jour. Range Mangt. 4: 42-47.

MCMEEKAN, C. P. 1956. Grazing management and animal production. Proc. 7th Intern. Grassland Congr. 146-156.

MERRILL, L. B. 1954. A variation of deferred-rotation grazing for use under Southwest range conditions. Jour. Range Mangt. 7: 152-154.

MOORE, R. M., N. BARRIE, AND E. H. KIPPS. 1946. Grazing management: continuous and rotation grazing by merino sheep. Australia Council Sci. and Ind. Res. Bull. 201: 5-69.

MORRIS, M. S. 1932. Can we improve our range? Colo. Agr. Exp. Sta. Bull. 313-A, 12 p.

PACIFIC NORTHWEST FOREST AND RANGE EXP. STA. 1959. Annual report. U. S. Dept. Agr., Portland, Oregon, 90 p.

PECHANEC, J. F. AND G. STEWART. 1949. Grazing spring-fall sheep ranges in southern Idaho. U. S. Dept. Agr. Circ. 808, 34 p.

REID, E. H. AND G. D. PICKFORD. 1946. Judging mountain meadow range condition in eastern Oregon and eastern Washington. U. S. Dept. Agr. Circ. 748, 31 p.

ROGLER, G. A. 1944. Summer gains of yearling Hereford steers on native and cultivated pastures. N. Dak. Agr. Exp. Sta. Bimonthly Bull. 6: 20-27.

ROGLER, G. A. 1951. A twenty-five year comparison of continuous and rotation grazing in the Northern Plains. Jour. Range Mangt. 4: 35-41.

SAMPSON, A. W. 1913. Range improvement by deferred and rotation grazing. U. S. Dept. Agr. Bull. 34, 16 p.

SAMPSON, A. W. 1914. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. Jour. Agr. Res. 3: 93-147.

SAMPSON, A. W. 1951. A symposium on rotation grazing in North America. Jour. Range Mangt. 4: 19-24.

SAMPSON, A. W. 1952. Range management principles and practices. John Wiley and Sons., Inc., N. Y. 570 p.

SARVIS, J. T. 1923. Effects of different systems and intensities of grazing upon native vegetation at the Northern Great Plains Field Station. U. S. Dept. Agr. Bull. 1170, 46 p.

SARVIS, J. T. 1941. Grazing investigations on the northern Great Plains. No. Dak. Agr. Exp. Sta. Bull. 308, 110 p.

SMITH, J. G. 1895. Forage conditions of the prairie region. *In* U. S. Dept. Agr. Yearbook of Agr. 309-324.

SMOLIAK, S. 1960. Effects of deferred-rotation and continuous grazing on yearling steer gains and shortgrass prairie vegetation of southeastern Alberta. Jour. Range Mangt. 13: 239-243.

SOUTH DAKOTA. 1958. Antelope Range Field Station: A progress report. So. Dak. Agr. Exp. Sta. Circ. 140, 30 p.

STODDART, L. A. AND A. D. SMITH. 1955. Range Management. McGraw-Hill Book Co., Inc., N. Y. 433 p.

SUCKLING, F. E. T. 1954. Pasture management trials on unploughable hill country at Te Awa. New Zealand Jour. Sci. and Tech. 36, Sec. A(3): 237-273.

TALBOT, M. W., H. H. BISWELL, AND A. L. HORMAY. 1939. Fluctuations in the annual vegetation of California. Ecology 20: 394-402.

THOMSON, L. B. 1938. Dominion Range Experiment Station: Results of experiments, 1927-1936 inc. Canada Dept. of Agric. 56 p.

TORELL, D. T. 1954. An esophageal fistula for animal nutrition studies. Jour. Animal Sci. 13: 878-884.

TORELL, D. T. AND W. C. WEIR. 1959. The effect of rotational grazing on animal nutrition. Am. Soc. Animal Prod. Proc. Western Section 10: 219-224.

WEIR, W. C. AND D. T. TORELL. 1959. Selective grazing by sheep as shown by a comparison of the chemical composition of range and pasture forage obtained by hand clipping and that collected by esophageal-fistulated sheep. Jour. Animal Sci. 18: 641-649.

WEST, O. 1958. Bush encroachment, veld burning, and grazing management. Rhodesia Agr. Jour. 55: 407-425.

WHITMAN, W., F. W. CHRISTENSEN, AND E. A. HELGESON. 1943. Pasture grasses and pasture mixtures for eastern North Dakota. No. Dak. Agr. Exp. Sta. Bull. 327, 24 p.

WILLIAMS, W. A., R. M. LOVE, AND J. P. CONRAD. 1956. Range improvement in California by seeding annual clovers, fertilization and grazing management. Jour. Range Mangt. 9: 28-33.

WILLOUGHBY, W. M. 1958. A relationship between pasture availability and animal production. Proc. Australia Soc. Animal Prod. 2: 42-45.

WILLOUGHBY, W. M. 1959. Limitations to animal production imposed by seasonal fluctuations in pasture and by management procedures. Australia Jour. Agr. Res. 10: 248-268.

WOOLFOLK, E. J. 1960. Rest-rotation management minimizes effects of drought. Pacific Southwest Forest and Range Expt. Sta. Res. Note 144, 3 p.