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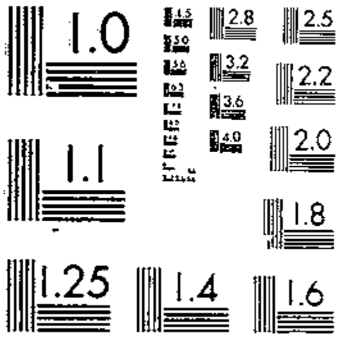

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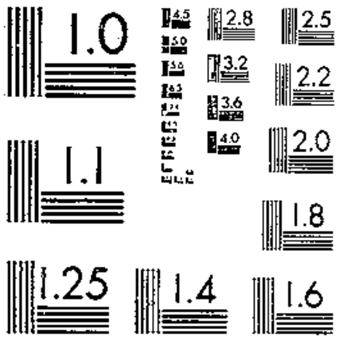

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Water Intake On Midcontinental Rangelands As Influenced By Soil And Plant Cover

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In Cooperation With
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CONTENTS

	Page
Introduction	1
Related investigations	2
Objectives	3
Time and locations of tests	4
Description of general area	5
Mixed prairie	5
True prairie	6
Terminology	6
Methods and procedures	8
Water application and runoff measurements	8
Soil and plant cover measurements	12
Results	14
Soil groups and precipitation zones	14
Soil structure, total herbage, and range management	33
Discussion	35
Summary	39
Literature cited	41
Appendix	43
Common and botanical names of plants	43
Plant species composition for the various range-soil-groups	44
Soil profile descriptions	49

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WATER INTAKE ON MIDCONTINENTAL RANGELANDS AS INFLUENCED BY SOIL AND PLANT COVER

By FRANK RAUZI and C. L. FLY, soil scientist and formerly soil scientist, respectively, Soil and Water Conservation Research Division, Agricultural Research Service, and E. J. DYKSTERHUIS, formerly range conservationist, Soil Conservation Service[1]

INTRODUCTION

Soil moisture is a major factor limiting herbage production on rangelands. Storage of soil moisture is dependent on the water intake rates and storage capacities of soils and on precipitation. Increased storage is possible on most ranges and is accompanied by reductions in both flooding and soil erosion. The amount of precipitation entering the soil can be influenced, within wide limits, by management of grazing.

It long has been known that retention of rainfall on rangelands generally is increased with an increase in the amount of vegetal cover present. Also, the amount of new and old plant growth together determine the degree of protection against soil erosion.

Most early research on water intake or infiltration rates stressed influences of soil properties on intake and downward percolation of water. Specific soil properties such as structure, texture, and thickness of the upper horizons were found to influence the rate of water intake. Parr and Bertrand (*19*) [2] in a comprehensive review of the literature noted that, of the factors influencing water intake rates, soil properties had been intensively investigated.

The equipment commonly used to measure rates of infiltration employed nozzles, which produced misty sprays, or consisted of tubes or rings inserted into the soil with clear water ponded under constant head on the soil surface. This minimized effect of plant cover in reducing turbidity from natural rainfall and it effects on water intake.

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[1] O. K. Barnes, now Extension Specialist, University of Wyoming, was fir responsible for field operations in this project. His work in adapting th splash-measuring features of the equipment (*18*) for better measurement o runoff and his council during transfer of responsibilities for the project a gratefully acknowledged.

[2] Italic numbers in parentheses refer to Literature Cited, p. 41.

Ellison (*10*) in stressing the need to include consideration of effects of splash erosion, stated:

> Raindrops working through the splash process . . . break down clods and crumbs of soil and compact these broken materials. The inflow of surface water made muddy by splash further seals surface cracks and pores and tends to waterproof the land. Tests on open ranges . . . showed that with good grass cover . . . only about a ton of soil per acre was splashed, and the water intake was 2.36 inches during a 15-minute period. On other areas where there was less forage, the splash tended to increase and water intake to decrease with each reduction in vegetal cover. Finally, on bare areas where there was no cover at all, 70 tons of soil were splashed . . . and water intake was reduced to 0.10 inch in 15 minutes.

For these reasons the present study was designed to include raindrop splash in tests of water intake. All tests were made under natural rangeland conditions, and rates of artificial rainfall application were sufficient to produce runoff.

RELATED INVESTIGATIONS

Aspects of water infiltration into soils were probably given some thought beginning at the time of the first irrigated agriculture. In a recent review of the literature, Parr and Bertrand (*19*) cited almost 200 items of modern research. Among five major types of infiltration studies they subdivided the type using artificial rainfall into those applying water directly by spray nozzles and those applying water by drip screens from towers.

The latter method most nearly approximates natural rainfall, with attendant turbidity of infiltrating water wherever rainfall strikes bare soil. Recognition of need for, and development of means of, incorporating raindrop effects in studies of infiltration are recent developments. Only the literature believed especially pertinent to or paralleling this type of research is reviewed here.

Lowdermilk (*16*) discovered that a fine-textured layer at the surface of a bare soil was the result of filtering suspended soil particles from muddy water and that this was a decisive factor influencing the rate of water intake.

Baver (*2*) noted that the rate of water intake increased as: (1) texture of the soil became coarser, (2) degree of granulation increased, (3) content of organic matter and time increased, and (4) the soil became looser.

Water intake studies on Nebraska grassland by Duley and Kelly (*5*) revealed that when grass was clipped to ground level and all old growth was removed, the rate of water intake dropped almost as low as that on cultivated land. Working on cultivated soils, these authors later (*6*) found that a straw mulch prevented the formation of a fine-textured layer at the surface of bare soils and that presence or absence of this layer could have more effect on infiltration than a combination of several other factors commonly recorded in similar studies of that time. Studies by Duley and Domingo (*7*) on ranges and tame pasture of Nebraska showed that total plant cover (live material and mulch) was more significant in determining water intake than species of forage plants or soil type.

Osborn (*17*) tested splash and water intake on over 200 cover conditions on 14 range sites of Texas and Oklahoma. He concluded that for maximum intake of water, two conditions must be met: (1) Surface cover must be adequate to cushion the impact of the falling raindrops, and (2) soil conditions must be favorable, as associated with a relatively advanced stage of ecological succession for the site, typical of one of the higher range condition classes. Osborn (*18*) quantified soil splash for a wide range of rangeland soils and cover conditions.

Rauzi and Zingg (*21*), utilizing rangeland water intake data from many soil and climatic conditions within the Great Plains, showed that intake rates could be roughly correlated with surface textures where all had cover in comparable ecological condition, and that intake could be approximately doubled on most textural groups through improvement in range cover conditions. Hanks and Anderson (*12*) found that burning the mulch of old growth substantially decreased water intake rates on native bluestem ranges in Kansas.

Dortignac and Love (*4*) found that on a pine-savannah range of Colorado, dead organic materials on the soil surface were more consistently associated with water intake rates than any of the other vegetative factors measured.

Johnston (*14*), utilizing equipment patterned after that described here, showed that on rangeland of Alberta, Canada, the rate of water intake increased with increasing amounts of standing vegetation and natural mulch (old growth). On silty upland ranges of North Dakota, Rauzi (*20*) showed that amounts of standing vegetation and mulch accounted for 88 percent of observed variation in water intake. Rhoades, Locke, and Taylor (*22*), working on sandy experimental ranges in Oklahoma that had been grazed at different intensities for 20 years, found that water intake was inversely proportional to long-term grazing intensity.

OBJECTIVES

When this study was begun, a vast area of the central and northern Great Plains lacked data of the type reported here.

Primary objectives were: (1) to determine the effect of different kinds and amounts of range cover on the ability of extensive groups of range soils to absorb simulated rainfall, (2) to determine the effect of specific soil properties, taken from standard soil survey descriptions, on water intake, and (3) to obtain a relative rating of water intake for major range-soil-groups as related to vegetal cover.

A secondary objective was to provide data for projecting water intake of range areas in the development of hydrographs for watersheds. Water intake data, as related to soils and amounts of vegetal cover on rangelands, should make possible considerable refinement in interpolations and extrapolations currently being made by hydrologists and sedimentationists for planning of watershed yields and water control structures in such areas.

Some tests were repeated at a single location to determine possible differences in water intake between autumn and early spring. But differences in intake during the second 30 minutes of water application were believed to be too small to warrant this line of investigation. Therefore, tests were made throughout periods when the soil was unaffected by frost and not wet from recent rains or snowmelt.

TIME AND LOCATIONS OF TESTS

During the period 1952 to 1964, water intake studies were conducted on rangelands in the six Northern and Central Plains States of Montana, Wyoming, North Dakota, South Dakota, Nebraska and Kansas (fig. 1).

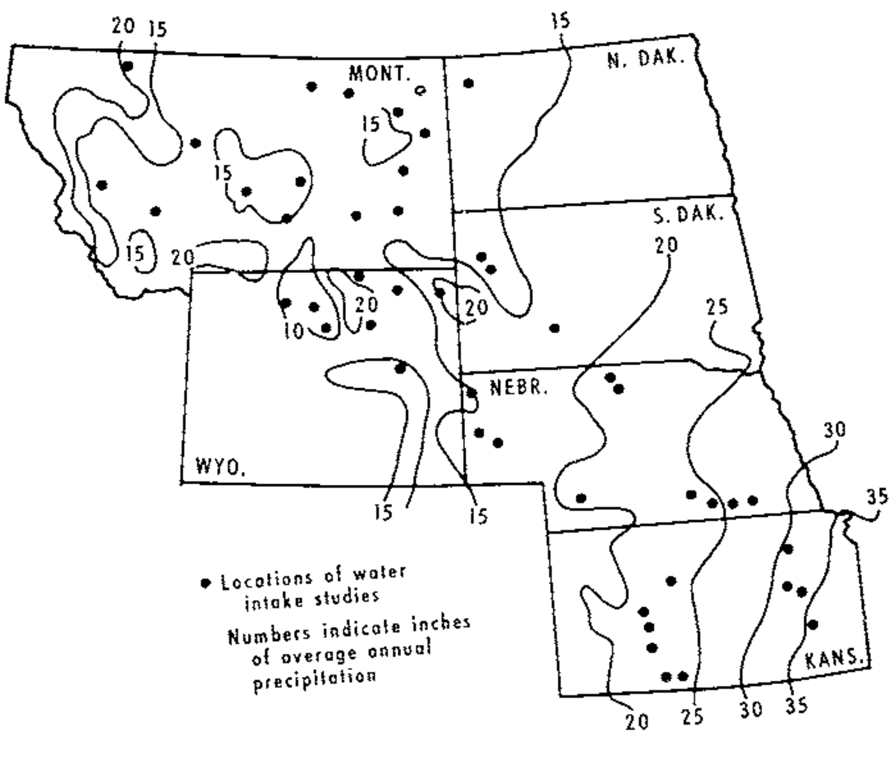

FIGURE 1.—Lines of average annual precipitation and approximate location of water intake studies in the six Northern and Central Plains covered in this report.

Within this area, test locations were selected to represent as wide a range as possible of differences in soils and covers. All tests included evaluations of climate and soil with designation of the type of range site and measurements of plant cover with designation of the range condition class.

To minimize soil heterogeneity, a series of tests at a location consisted of six closely spaced plots; three on each side of a range fence which separates apparent differences in range vegetation. Such fenceline contrasts were selected by professional range conservationists of the Soil Conservation Service. Tests also were made at State and Federal experimental ranges where different stocking rates long had been maintained on adjacent range pastures.

DESCRIPTION OF GENERAL AREA

In studies made in six States, two extensive climatic grassland types were sampled—the mixed prairie in the drier western area and the true prairie eastward. These types grade into each other and frequently are referred to as the shortgrass plains and the tallgrass prairie, respectively.

Borchert (*3*) monographed the effect of climate on the plant cover of central North American grasslands.

Mixed Prairie

The mixed prairie plains area is currently characterized by short grasses (species with culms ordinarily not taller than 18 inches). Taller grass species of the original mixture are now infrequent as a result of decades of close grazing. The shortgrass plains occupies about 200 million acres in the six States. Physiography of the area is extremely diverse, ranging from nearly level to rough broken. The weather is highly variable from year to year. Hot, drying winds and droughts occur frequently. The average annual precipitation ranges from 12 to 20 inches, and the average growing season varies over the area from as little as 60 days to more than 180 days.

The characteristic grasses in the current vegetation are buffalograss,[3] blue grama, western wheatgrass, sand dropseed, ring muhly, needle-and-thread, and junegrass. Weaver and Albertson (*25*) have devoted a book to the description of mixed prairies and their use.

The soils of the shortgrass plains, according to the most recent system of soil classification of the U.S Department of Agriculture (*23*), consist of: (1) Mollisols, 62.5 percent; (2) Aridisols, 33.8 percent; (3) Inceptisols, 3.5 percent; and (4) Vertisols, 0.2 percent. Soils are considered in more detail as range sites.

[3] Scientific and common names of all species of plants mentioned in this report and species composition as determined from the test plots are given in the Appendix.

True Prairie

The tallgrass prairie (true prairie) occupies nearly 117 million acres of the six-State area. The major portion lies east of the 100th meridian. On arable lands, the original vegetation of the tallgrass prairie has been almost entirely replaced by cultivated crops. The physiography of this area is level to broken. The climate (*3*) is generally not as harsh as that of the shortgrass plains. The summers are generally hot and humid and the winters are cold, with more snow accumulation than on the shortgrass plains. Average annual precipitation ranges from 15 inches on the western edge to 35 inches along the eastern border. Droughts are neither as frequent nor as severe as in the shortgrass plains.

Characteristic grass species of the tallgrass prairie are big bluestem, little bluestem, indiangrass, and needle-and-thread. Weaver (*24*) has described the ecology of this grassland.

In the tallgrass prairie region the four main soil orders are as follows: (1) Mollisols, 85.0 percent; (2) Aridisols, 2.9 percent; (3) Vertisols, 8.5 percent; and (4) Inceptisols, 3.6 percent.

TERMINOLOGY

RANGELAND here designates land with edaphic and climatic factors, including natural fires. The vegetation on rangeland usually develops into natural pasturage rather than natural forest. RANGE is native pasture on such lands, as distinguished from cultured or tame pasture.

RANGE-SOIL-GROUPS are groupings of soil mapping units for purposes of range and watershed management. Mapping units are composed of soil classification units.

RANGE SITES, as simply defined by the Soil Conservation Service, are distinctive kinds of rangeland with different potentials for producing native plants. Each range site has its own combination of environmental conditions, the ultimate expression for which is a characteristic plant community found only on that site. Furthermore, the range site retains its ability to reproduce this potential plant community unless materially altered by physical deterioration.

In this study, physical environments were designated by (1) range-soil-group, (2) precipitation zone (p.z.), and (3) geographic area. Thus silty, 15 to 19 in. p.z., North Dakota, or clayey, 20 to 24 in. p.z., foothills west Montana designate a type of physical environment.

RANGE-SOIL-GROUPS are named from a highly relevant soil feature.

The following are names and descriptions of the range-soil-groups from which water intake data were obtained:

1. Soil groups that can produce more herbage than ordinary upland rangelands because of plainly superior soil moisture availability.

OVERFLOW.—Areas regularly receiving more than normal soil moisture because of run-in from higher land. Not subirrigated or wetland.

SANDS.—Deep, loose, fine sands and medium sands on nearly level to undulating (rolling) relief. Not compact, dark, nearly level loamy fine sands. Not loose, coarse sands.

2. Soil groups of ordinary (normal) uplands with gentle relief and no obvious soil inhibitory factors. The vegetation can make a normal response to climate, reflecting regional climax.

SANDY.—All normal sandy loams (not true sands or cemented kinds) plus dark, nearly level loamy fine sands.

SILTY.—All normal silt loams, loams, silts, and very fine sandy loams.

CLAYEY.—All normally granular, relatively pervious, sandy to silty clay loams and clays.

3. Soil groups of uplands with soil factors that prevent development of the regional climax.

THIN-SILTY.—Thin but deep silty soils of hills with smooth-surfaced slopes, generally over 15 percent.

THIN-CLAYEY.—Thin but deep clayey soils of hills with smooth-surfaced slopes, generally over 15 percent.

PANSPOTS.—Areas where compacted clays or other impervious materials lie close to or at the surface in shallow depressions which occupy 20 to 50 percent of the area. (Solodized-solonetz soils where B horizon is exposed in numerous depressions).

DENSE CLAY.—Relatively impervious deep but dispersed clays. These may be overlain by a thin but ineffectual layer (does not modify water intake) of other materials. The dispersed layer is very hard to extremely hard when dry and very sticky when wet.

SHALLOW TO GRAVEL.—Shallow soils 10 to 20 inches deep resting on clean gravelly or cobbly materials.

SHALLOW NONLIMY.—Shallow neutral to acid soils 10 to 20 inches deep underlain by rock virtually impenetrable by roots.

SHALLOW LIMY.—Shallow, limy soils 10 to 20 inches deep underlain by rock virtually impenetrable by roots.

SHALLOW CLAY.—Shallow, normally granular clays 10 to 20 inches deep underlain by fragmented shale.

VERY SHALLOW POROUS.—Soils less than 10 inches deep over open clean gravel, stones, or fragmented rock with rapid and deep water storage.

VERY SHALLOW LIMY.—Very shallow limy soils where few roots can penetrate deeper than 10 inches and with gravel and rock outcrops common, but bedrock may be jointed and deep soil pockets may develop.

SALINE-ALKALI UPLAND.—Soils of ordinary depth for the climate but with apparent salt or alkali accumulations on or near the surface and with salt-tolerant plants in evidence.

RANGE CONDITION is the state of the vegetation in relation to climax condition. In each range site, vegetation may be found in all gradations from the ecological potential for the range site to the seriously depleted range conditions resulting from decades of close grazing. All such conditions are grouped into four classes—excellent, good, fair, and poor. Such range condition classes are specific for the range site and are quantitatively derived. The background of research and procedure in establishing range sites and range condition classes, as used here, were described by Dyksterhuis (*8, 9*).

INFILTRATION (the downward entry of water into the soil) is distinguished from PERCOLATION (the downward movement of water through a soil). The rate of water intake ordinarily is limited by the infiltration rate. Nonetheless, percolation can be the limiting factor if a soil becomes saturated down to a layer with slower permeability than the surface. PERMEABILITY is defined quantitatively as the rate at which a porous medium transmits air or fluids under specified conditions. The permeability of a soil, particularly at its surface, can be a major factor determining infiltration rates.

WATER INTAKE RATE and INFILTRATION RATE as used in this report are essentially synonymous and are expressed in inches per unit of time at which water passes into the soil. However, when the infiltration rate is used with simulated rainfall for practical field experimentation, it must be qualified to mean water held against runoff. This is because some water is intercepted and held by plant cover and some water may remain on the surface in microdepressions of plots. Buffer areas are essential to avoid losses of water at borders of plots from which runoff is collected and are to be assumed in stated rates unless qualified. RUNOFF here refers to that portion of the simulated rainfall discharged from the plot in surface flow.

The distinctness of horizon boundaries was characterized as follows:

4. DIFFUSE.—A boundary that is more than 5 inches thick with gradual changes and horizon characteristics with no tendency for temporary perching of the moving waterfront.

3. GRADUAL.—A boundary that is 2½ to 5 inches thick with no tendency to perch water unless the lower horizons are of slow or very slow permeability.

2. CLEAR BOUNDARY.—A boundary or transition layer that is 1 to 1½ inches thick, which may or may not tend to perch water depending on permeability of the horizon below.

1. ABRUPT.—A boundary or transition layer that is generally less than 1 inch thick and represents a sharp change in structural and textural characteristics with a tendency for water movement to be impeded at the transition point.

METHODS AND PROCEDURES

Water Application and Runoff Measurements

Water intake measurements were made with a mobile raindrop applicator (fig. 2), which was developed in the former Research Division of the Soil Conservation Service. Ellison and Pomerene (*11*) designed a rainfall applicator, which utilized a drip-screen that produced drops of uniform size and velocity. This was later

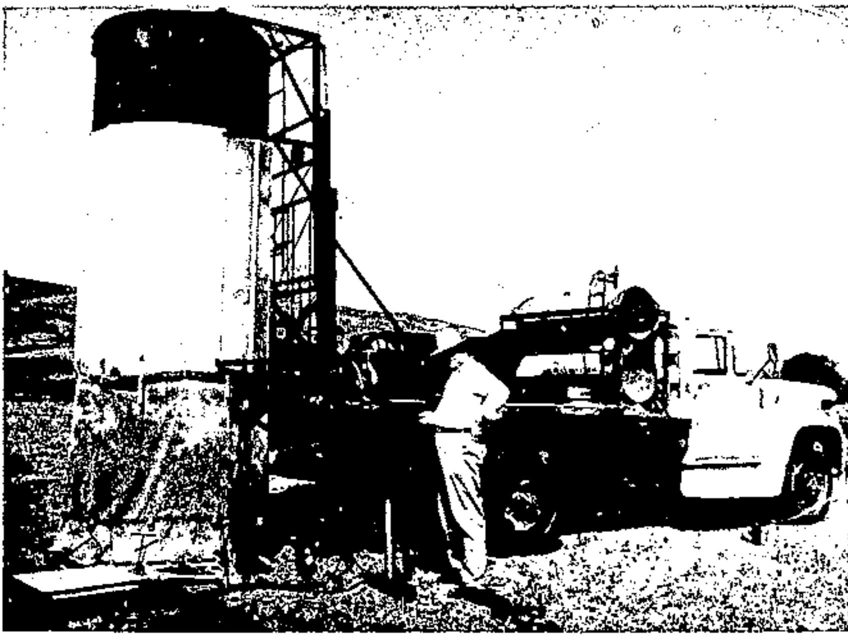

FIGURE 2.—Mobile raindrop applicator used to determine water intake rates on rangelands.

incorporated in a mobile unit with facilities to elevate the screen to a height where falling drops approximated 80 percent of terminal velocity of natural raindrops in quiet air. The raindrop applicator used for conducting the water intake studies reported herein was a modified version of the Ellison-Pomerene unit. Barnes and Costel (*1*) made further modifications for use on a pickup truck.

The raindrop applicator, used for conducting the water intake studies reported in this bulletin, applies simulated rainfall to a circular area of approximately 13 square feet on a selected area (fig. 3). An interchangeable full-cone nozzle is at the top and center of the tower of the raindrop applicator. Intensity of application can be varied from 2 to 6 inches per hour by changing nozzles. A drip screen located 4 feet below the nozzle consists of a tubular hoop 4 feet in diameter covered with 1-inch mesh chicken wire. Over the chicken wire is placed one layer of unbleached muslin. This material is pushed into each mesh opening to form a pocket approximately 1 inch deep. A cotton-rayon yarn is pulled through each pocket, knotted at the top, and cut to a 2-inch length. With this arrangement, uniform drop size is maintained over the area receiving the simulated rainfall. The drop size is controlled by the diameter of the yarn. Drops formed by the raindrop applicator average 5.1 mm. in diameter.

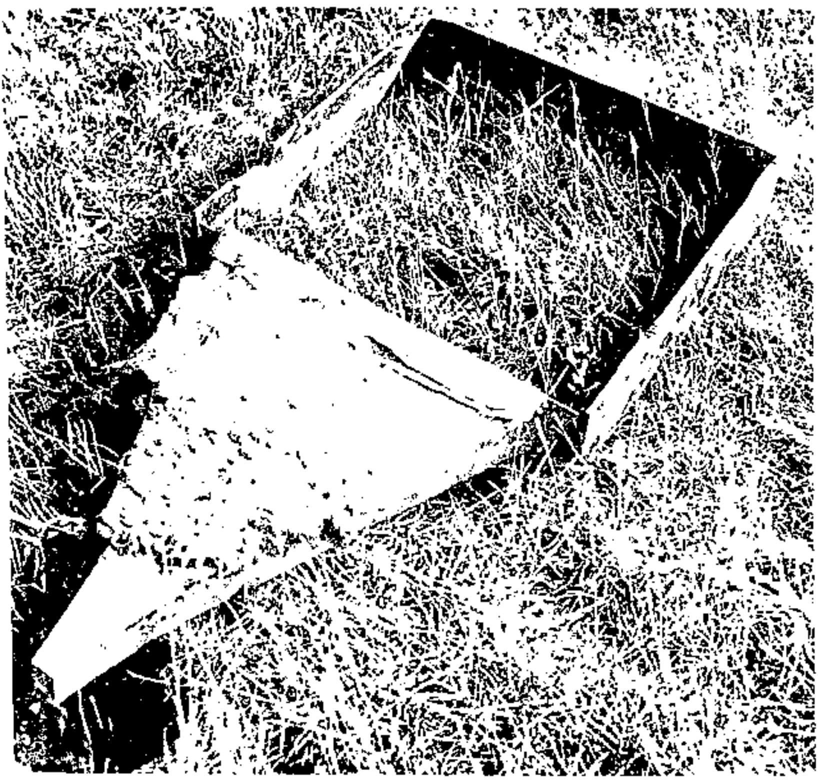

FIGURE 3. Runoff spout attached to the 2-foot-square plot frame used to measure the difference between water applied and runoff.

These are large drops and similar in size to large drops occurring during a heavy thundershower. On level ground the distance of drop fall is 8½ feet. On sloping ground the drop-fall distance would be slightly more in the front of the plot area. Impact velocity of drops this size, falling 8½ feet, would be 21 feet per second. Velocity without the added forces of wind reach 65 percent of terminal velocity.

The rate of application was determined before and after the test periods by placing a measuring pan over the plot and measuring the amount received during three successive 5-minute periods. Splash boards were placed around the plot while rate of application was being determined to prevent wetting and lateral movement during measurement of application rate (fig. 4).

The desired rate of application was that which produced runoff after a very few minutes of application. The average rate of application used for these studies was approximately 3 inches per hour. The test plot for water measurements was 2 feet square and in the center of the area receiving rainfall (fig. 3). The 2-foot-square plot frame used to outline the plot was constructed from cold-rolled iron one-quarter inch thick. The plot frame was 6 inches high on three sides and 1½ inches high on the side to which the runoff spout was attached. The bottom edge of the plot frame was sharpened to enter the soil with a minimum of disturbance. The frame was forced into the soil approximately 1½ inches by use of a hydraulic jack pushing against the weight of the truck and by light blows from a sledge hammer. Thus, soil disturbance along the edge of the plot frame was minimized; and, this, as well as water applied to an area much larger than the plot, negated lateral water movement from water applied to the test plot (border effect).

The 2-foot-square plot frame was centered by hanging a lightweight chain from a small hook in the center of the drip screen, attaching a light wire 2-foot-square frame to the lower end of the chain, and then alining the 2-foot-square plot frame.

Runoff water entering the runoff spout from the plot was transferred to a measuring container by a suction pump. Runoff was measured every 5 minutes during the 1-hour test. A piece of burlap was placed on the runoff spout to absorb the rain falling on the spout. This prevented splash into the plot area.

Water intake was measured as the difference between applied rainfall and measured runoff. Surface storage in microdepressions and interception by vegetation and mulch material are included in the measured water intake.

Because of the microrelief, and detention storage and interception by the vegetal cover, water intake data obtained during

FIGURE 4.—Measuring pan and splash boards over the 2-foot-square plot for protection during test to determine the rate of application.

the first 30 minutes of the 1-hour test were more variable than measurements made during the second 30 minutes. Interception and surface detention were extremely variable but were usually satisfied during the first 15- to 30-minute period of a test. Consequently, the analysis was based on the second 30-minute period of the 1-hour test.

Soil and Plant Cover Measurements

The condition of the vegetation of a type of range site was determined by quantitatively comparing present vegetation with the successionally potential plant community for that type of site. In this method the components of the vegetation were segregated as decreasers, increasers, and invaders in accordance with their response to grazing as determined by comparison with the potential plant community (*8*).

Species composition of the vegetation was determined by the vertical point method (*15*). In each plot 100 equidistant points were taken, and only the first hit of each point was recorded. All standing vegetation in the test plot, including previous years' growth, was clipped at ground level 1 or 2 days after the water intake measurement was made. For weight determinations, the standing vegetation was separated into four categories: midgrasses, shortgrasses, annual grasses, and forbs. These were air-dried and weighed. Midgrasses included perennial grass species that normally flower at a height greater than 18 inches; shortgrasses included all shorter perennial grasses.

All mulch material on the test plot was collected, and soil particles were removed by screening and blowing. The mulch was air-dried and weighed. At each fenceline contrast three samples of both coverage by species and air-dry weights of the several classes of materials were obtained for each test. Description of range site, condition class, and soils for each set of samples was provided by personnel of the Soil Conservation Service.

Sixteen of the twenty-eight major range-soil-groups described by the Soil Conservation Service in the northern Great Plains States were studied. Steepness of slope, stones, or base rock near the surface limited the number of groups that could be sampled with this equipment.

Most of the test sites designated as "saline uplands" were considerably affected by high alkalinity (or high dispersability) so that there was a rapid drop in the intake rate for each succeeding 15-minute interval. The same was true on the more exposed or barren areas of "panspot" sites. Several similarly responding test sites were found scattered through some of the dense clay and clayey sites. In arranging the data for analyses, all sites that exhibited the behavior of an alkali or saline-alkali soil were grouped together and the panspot designation was used only for the panspot interareas. This was done because the panspot interareas were so widely different in their intake characteristics from the actual panspots themselves. It was felt that a total "panspot" site could not be characterized in a single analysis. The percentage distribution of the panspots themselves as compared with the interareas was necessary in characterizing a site of this type.

Similarly, it was more practical to combine silty with thin silty and clayey with thin clayey sites. Because of an insufficient number of tests for the various types of shallow soils, all the shallow sites were combined into a single group called "shallow soils site complex." This gave, for the final analyses, nine major soil groups with an average of about 75 observations per group. The actual number of observations per group ranged from 11 to 218.

By a careful scanning and evaluation of the soil descriptions and water intake behavior for each site, data on soils were compiled by significant horizons from the surface downward to the depth of wetting or to approximately 18 inches. The data were broken down by natural horizons where the descriptions were adequate for this purpose. Soil properties used in the analyses included structure of the first, second, and third significant horizons divided into seven major structural groups arranged in numerical order with the highest number corresponding to the probable highest intake as follows:

(7) Crumb or granular structure with no obstructing surface layer or crusting.

(6) Structureless and single grains with soft, loose consistency.

(5) Weak or moderate prismatic to weak or moderate subangular blocky structure with vertical cleavage more dominant than horizontal.

(4) Structureless or massive structure with slightly hard to hard consistency when dry.

(3) Structureless or massive structure with hard to extremely hard consistency when dry and generally few large, continuous pores.

(2) Platy or laminar structure with 25 percent or greater overlap of peds.

(1) Coarse blocky or angular blocky structure with greater horizontal than vertical cleavage and considerable overlap. Also included in this group is strong columnar structure associated with solodized soils.

Boundaries of the horizons were differentiated as to distinctness. (See section on "Terminology.") The micro- and macrotopography of the boundary were omitted since with a 2- by 2-foot test plot a relatively smooth plane could be assumed.

Textures of the first three significant horizons were classified according to standard terminology from sands to clays in 17 textural grades, with sand being given the highest numerical designation and clay the lowest. The thickness of the separate horizons was designated in inches.

Other factors in the analysis included the location by States and range condition classes with excellent 4, good 3, fair 2, and poor 1. All four condition classes may be present within a range site. Thus, to describe an overall condition an average condition class is obtained from the numerical ratings. The condition class is then described as "high, low, or in between." Seven precipitation zones were recognized, and the midpoint of the precipitation zone was used in the analysis. These zones ranged from 5- to 9-inch desert type of rainfall with a midpoint of 7 inches to the subhumid prairie type with a range of 35 to 39 inches and a midpoint of 37 inches.

All variables used in the simple regressions were carefully screened and six were selected for statistical analysis of each site. The six selected variables, except for bare ground, were a combination of single vegetative or soil variables best related to rate of water intake. In many instances, as shown by the simple correlation analysis, a single variable was highly correlated with rate of water intake for one range-soil-group but not for another. Thus, certain soil variables and vegetative variables were combined. An equation was developed for each range-soil-group. The following six variables were selected:

X_1 = Total vegetal cover in pounds per acre.
X_2 = Percentage of bare ground.
X_3 = Sum of the structure indices of three horizons.
X_4 = Sum of the thickness indices of three horizons.
X_5 = Sum of the texture indices of three horizons.
X_6 = Sum of the boundary indices of three horizons.
y = Rate of water intake during the second 30-minute period of the 1-hour test.

RESULTS

Soil Groups and Precipitation Zones

The percentage contribution to R^2 by each of the six variables used in the multiple stepwise regression correlation is shown for each range-soil-group in table 1. In some instances a variable contributed little or nothing to the R^2.

Results for the various range-soil-groups and precipitation zones are shown in table 2.

Saline-Alkali Upland

Saline-alkali upland range sites are more common in the drier areas and occur on the upland and approaches to stream bottoms. These sites are often characterized by solidized, solonetz soils with low permeability.

Saline-alkali upland range sites were studied in the Bighorn Basin of Wyoming, in eastern Montana, and in western South Dakota. Topography varied from nearly level to undulating.

Vegetation on the Wyoming site was chiefly Gardners saltsage. The soil between the saltsage plants was dispersed and nearly impervious to water movement. The larger saltsage plants were surrounded by a deposit of sand, and thus had a higher rate of

TABLE 1.—*Percentage each variable contributed to the total* R^2 *for the various range-soil groups*

Variable	Saline-alkali upland	Dense clay	Panspot	Shallow complex	Clayey	Silty	Sandy	Over-flow	Sand
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
X_1	18.51	11.73	46.03	10.49	46.47	87.09	67.21	----	----
X_2	.95	67.40	.24	68.33	.66	2.54	.90	----	1.73
X_3	16.31	.50	26.15	12.33	29.46	8.25	14.76	70.15	1.63
X_4	49.25	----	24.49	1.65	12.81	.30	5.60	----	5.76
X_5	2.20	2.37	.62	7.15	1.38	.07	5.77	----	14.64
X_6	12.78	18.00	2.47	—.05	9.22	1.75	5.76	29.85	76.24

TABLE 2.—*Pounds herbage and mulch per acre, percent bare ground, range condition, and water intake rate by range-soil-group, site, and precipitation zone*

Range-soil-group, site, and precipitation zone	No. obs.	Vegetal cover		Bare ground	Structure rating	Rate of water intake (second 30 min.)
		Herbage	Mulch			
		Lb./acre	*Lb./acre*	*Percent*		*Inches/hour*
Saline-alkali upland:						
Montana (10- to 14-in.)	24	670	153	69	2.0	0.36
South Dakota (10- to 14-in.)	22	773	227	69	2.0	.26
Wyoming (5- to 9-in.)	13	533	830	83	2.0	.20
Dense clay:						
South Dakota (10- to 14-in.)	40	1,108	445	59	2.6	.50
Panspot:						
South Dakota (10- to 14-in.)	29	1,317	528	48	2.4	.90
Shallow complex:						
5- to 9-in.	4	882	251	71	6.0	1.53
10- to 14-in.	48	1,182	704	54	5.1	1.18
15- to 19-in.	11	1,534	939	32	4.7	1.45
25- to 29-in.	6	3,008	1,975	6	7.0	1.39
Clayey:						
10- to 14-in.	95	1,140	663	38	5.5	1.50
15- to 19-in.	20	1,412	1,047	26	7.0	1.53
20- to 24-in.	17	884	2,322	9	7.0	1.13
30- to 34-in.	6	1,288	2,269	18	3.7	1.35

Silty:						
5- to 9-in.	13	654	643	59	6.4	1.22
10- to 14-in.	84	1,268	1,086	32	4.8	1.26
15- to 19-in.	49	1,716	2,052	25	4.7	1.56
20- to 24-in.	40	1,746	2,881	15	4.7	1.75
25- to 29-in.	9	1,475	1,771	11	5.3	1.03
30- to 34-in.	23	1,720	1,495	15	5.0	1.77
Sandy:						
10- to 14-in.	41	1,330	1,272	30	5.8	1.71
15- to 17-in.	25	1,128	803	54	7.0	1.72
20- to 29-in.	17	1,361	1,125	22	5.3	1.37
Sands:						
5- to 9-in.	4	3,030	1,414	36	6.0	.87
10- to 14-in.	6	1,081	1,262	47	7.0	2.71
15- to 19-in.	4	2,402	3,270	10	6.0	4.83
20- to 25-in.	9	1,374	739	40	6.0	3.65
Overflow:						
20- to 29-in.	11	2,942	2,406	14	4.3	2.31

water intake than the area between the plants. Mulch material and herbage collected consisted of twigs and leaves.

Western wheatgrass, with small amounts of junegrass and blue grama was dominant on the Montana site. Western wheatgrass and a few forbs accounted for the vegetation on the South Dakota site. Greasewood when present was stunted and sparse.

The range conditions for the South Dakota and Montana sites were rated between good and excellent. On these sites tumblegrass accounted for 54 percent of the annual grasses and plains plantain, and stickseed accounted for over 50 percent of the forbs.

Average total air-dry weight of the vegetal cover for the sites was slightly over 1,000 pounds per acre with 38 percent of the total being mulch material. Bare ground averaged 74 percent.

The smallest amount of total herbage and the greatest amount of bare ground were associated with the lowest water intake rate (table 2). The seemingly greater amount of mulch material for the Wyoming sites is accounted for by the fact that small twigs made up the bulk of the mulch material. Differences in rate of water intake between the Montana and Wyoming sites were significantly different at the 5-percent level of probability, but there was no significant difference between the Montana and South Dakota sites or between the South Dakota and Wyoming sites.

Simple correlations between the rate of water intake during the second 30-minute period of the 1-hour test and 14 other soil and vegetative variables are shown in table 3.

The amounts of total herbage and Gardners saltsage present were significantly correlated with the rate of water intake at the 1-percent level of probability. Soil characteristics that were significantly correlated with rate of water intake were thickness of the first and second natural horizons, texture of the first horizon, and soil boundary.

Water intake rates on these sites are characteristically slow because of poor cover conditions, a dispersed surface, and a high clay content in the B-horizon of the soil profile.[4]

A multiple stepwise regression analysis of the effect of the vegetative and soil characteristics on the rate of water intake during the second 30-minute period of the 1-hour test showed that soil factors were more important than vegetative factors for the saline-alkali upland range sites (table 1). The constant (y) and the independent variables (X) for the regression equation determined from the six selected variables for this range site are shown in table 4.

Forty-one percent of the variation in rate of water intake for this range site was accounted for by the six variables; four of the six variables were statistically significant.

[4] Typical soil profile descriptions are given in the Appendix.

TABLE 3.—*Simple correlations of vegetation and soil characteristics with water intake rates for the various range-soil-groups*—

Variable	Saline alkali upland	Dense clay	Panspot inter-areas	Shallow complex	Clayey	Silty	Sandy	Overflow	Sands	All range-soil-groups
Total vegetal cover	0.161	0.540**	0.641**	0.560**	0.460**	0.728**	0.405**	0.406	0.143	0.586**
Mulch	.008	.777**	.331	.460**	.286**	.643**	.161	.103	.316	.488**
Total herbage	.286*	.211	.576**	.526**	.488**	.707**	.586**	.623*	.074	.553**
Gardners saltsage	.335**									
Midgrass		.079	.036	.378**	.560**	.679**	.505**	.733**	.649**	.537**
Shortgrass	.092	.614**	.637**	.222*	−.248**	−.172*	.117	---	−.086	−.024
Percent bare ground	.124	−.762**	−.576**	−.561**	−.261**	−641**	−.234*	−.180	−.431*	−.532**
Range condition	.320*	−.102	.119	.268*	.666**	.604**	.669**	.442	.751**	.421**
Soil structure:										
1st horizon	.000	.714**	−.492**	.206	.217*	.552**	−.133	.944**	−.130	.514**
2d horizon	.031	−.453**	−.168	.156	.318**	.166*	.211	.384	.414*	.377**
Soil thickness:										
1st horizon	−.464**	.013	.508**	.356**	−.138	−.061	.071	.384	−.005	.123**
2d horizon	−.363**	−.101	.516**	−.008	−.171*	−.014	−.149	.384	.687**	.200**
Soil texture:										
1st horizon	.250*	.650**	.505**	.304**	.187*	.155*	.164	.384	−.369	.323**
2d horizon	.242	.597**	.517**	.349**	.068	.174**	.236*	.384	.253	.426**
Soil boundary	.258	---	.216	.130	.321**	.083	.111	.390	.818**	.420**
Variable mean	.29	.50	.90	1.26	1.45	1.46	1.67	2.31	3.13	1.35
Standard deviation	.16	.38	.38	.55	.83	.92	.65	1.54	1.57	.96
Number of observations	59	40	29	69	138	218	83	11	23	670

[1] All vegetation measured in pound per acre air-dry. Water intake rate measured during second 30-minute period of 1-hour test.
*Significant at 5-percent level and ** significant at 1-percent level, based on number of observations shown in table 2.

TABLE 4.—*Regression equations relating rate of water intake to a combination of soil and vegetative variables*

Range-soil-groups	No. obs.	R^2	Constant (y)	Independent variables					
				X_1	X_2	X_3	X_4	X_5	X_6
All range-soil-groups	670	0.56	−0.6854	+0.0002*	−0.0031*	+0.0466*	+0.0089*	+0.0076*	+0.1335*
Saline-alkali upland	59	.41	.9431	+.0001*	+.0007	−.0472*	−.0147*	−.0076	−.0611*
Dense clay	40	.80	−.0837	+.0002*	+.0007	+.0986	−.0081	+.0261	−.1152
Panspot	29	.83	−5.7094	+.0003*	+.0017	+.2596*	+.4371	−.1991	+.0848
Shallow complex	69	.46	1.0558	+.0002*	−.0034	−.0433*	+.0102	+.0226*	−.0068
Clayey	138	.46	−.2628	+.0002*	−.0032	+.0983*	−.0395*	−.0161	+.1092*
Silty	218	.60	.1511	+.0002*	−.0060*	+.0444*	−.0075	−.0045	+.0684*
Sandy	83	.24	−1.0505	+.0002*	−.0020	+.1137*	−.0283*	+.0458*	−.0628
Overflow	11	.93	−1.1105	+.0001	−.0076	+.5424*	−.2217		
Sand	23	.86	3.6315	+.0000	−.0164	+.2179	+.0702*	−.1572*	+.1166

*Variables were selected from the regression until the reduction for the total sum of squares were significant at the 5-percent level of probability.

Dense Clay

The dense clay range site is usually found in small depressions, basins of playa lake beds, and along the head of elongated drainageways. Soils that characterize this site are deep, very slowly permeable clays which support a sparse vegetal cover and are susceptible to wind erosion.

The dense clay range site studied was in western South Dakota. Topography varied from nearly level to rolling. Droughts are frequent in the test area, and summer rainfall can occur as torrential showers.

The dominant grass was western wheatgrass. A few annual and perennial forbs and grasses were present. Water intake rates were low on these soils because of inherent soil characteristics and poor cover conditions.

Japanese brome, little barley, and tumblegrass were the annual grasses. Selaginella accounted for 40 percent of the annual and perennial forbs. The range condition for this site was rated low good. Midgrasses accounted for 90 percent of the total herbage. Mulch material was light and accounted for 29 percent of the total cover (table 2).

The amounts of total vegetal cover, mulch, and shortgrasses present were significantly correlated with water intake rate (table 3). A high negative correlation was found between rate of water intake and percentage of bare ground. As percentage of bare ground increases, more soil is exposed to the beating action of the raindrops and water intake decreases. Soil structure and soil texture of the first and second horizon were significantly correlated with rate of water intake.

A multiple stepwise regression analysis showed that the vegetative factors were more important than the soil factors measured for this range site since the herbage production is relatively low. The analysis showed that 80 percent of the variation in rate of water intake for this site was accounted for by the six variables (table 4).

Panspot

The landscape of a panspot range site is undulating and made up of not less than two unlike soils. Soils occupying the panspot have a dispersed surface, and rate of water intake is very low. Soils in the interareas may be moderately deep and have fair to good vegetal cover; thus, the rate of water intake on the interareas may be quite high.

The characteristics of the interareas are considerably different than those of the actual panspot. Therefore, the panspot range site as used here is actually the interarea of a panspot range site.

The panspot range site was studied in western South Dakota in the 10- to 14-inch precipitation zone. The topography is nearly level to gently rolling. Surface soil texture varies from a sandy loam to a sandy clay loam.

The dominant grass was blue grama with small amounts of western wheatgrass and Sandberg bluegrass. Mulch material was light and accounted for only 29 percent of the total cover.

The amount of standing vegetation, mulch material, soil depth, and texture of the surface soils varied; thus, the rate of water intake varied.

Total vegetal cover, total herbage, and amount of shortgrass (blue grama) were significantly correlated with rate of water intake (table 3). A fairly high negative correlation existed between the percentage of bare ground and rate of water intake for this range site.

Soil characteristics that were significantly correlated with rate of water intake included structure of the first horizon, although negatively, and thickness and texture of both the first and second horizons.

A multiple regression analysis of the effect of the vegetative and soil factors on rate of water intake showed the vegetative factors to be more important. A regression equation determined from the six selected variables for this range site is shown on table 4.

Eighty-three percent of the variation in the rate of water intake was accounted for by the six variables, but only two of the six variables were statistically significant.

Shallow Complex

Water intake tests on various kinds of shallow range-soil-group were not adequate for differentiation; therefore, all tests from the shallow range-soil-groups were treated as a complex.

Shallow complex range sites were studied in Wyoming, Montana, South Dakota, Nebraska, and Kansas. Precipitation zones included the 5- to 9- through the 25- to 29-inch isohyets, with nearly 70 percent of the tests occurring in the 10- to 14-inch precipitation zone.

Vegetation on these sites varied with precipitation zone and soil characteristics of the various locations. A contrast in vegetation on a shallow shale range-soil-group is shown in figure 5. Indian ricegrass and alkali sacaton were the dominant species in the 5- to 9-inch precipitation zone; blue grama in the 10- to 14-inch and 15- to 19-inch zone; and big and little bluestem in the 20- to 25-inch zone.

The increaser and decreaser species varied with the precipitation zone and the soil group within the shallow complex. Generally western wheatgrass, needle-and-thread, bluebunch wheatgrass, and big and little bluestem were considered to be the dominant decreasers. Blue grama, buffalograss, and Kentucky bluegrass were the dominant increasers. On some sites forbs composed almost 20 percent of the vegetation.

Table 2 shows that as the precipitation increased so did the herbage and mulch but not necessarily the rate of water intake. As previously noted, different components of the shallow complex have various underlying materials and this, as well as the kind of surface, may influence water intake rate.

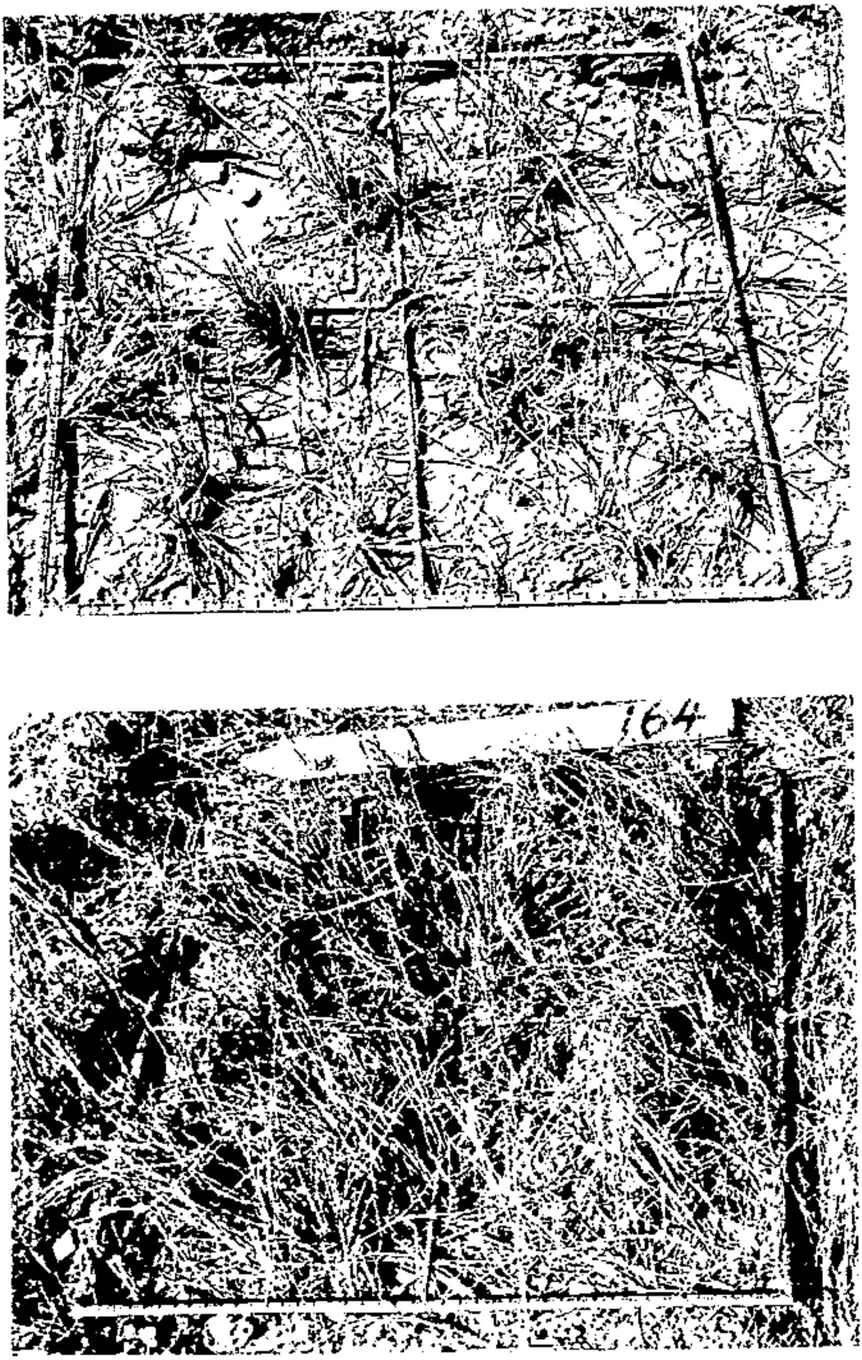

FIGURE 5.—Contrast of a shallow shale range site with less than 500 pounds per acre of total cover (upper) and a range with nearly 2,000 pounds per acre (lower).

Total vegetal cover, total herbage, amount of midgrass, shortgrass, and mulch were all significantly correlated with rate of water intake. Thickness of the first horizon and texture of the first and second horizons were correlated with rate of water intake (table 3).

A multiple stepwise regression analysis showed that the vegetative and soil factors measured were about equally important for this site, but the percentage of bare ground was the most important single factor. Total vegetation was second in importance.

Forty-six percent of the variation in rate of water intake was accounted for by the six selected variables. Three of the six variables were statistically significant for the range site shown in table 4.

The soils associated with the shallow complex range site varied in texture, depth, structure, and underlying material. Four soil profile descriptions, with their original range-soil-group designation, are given in the Appendix to show the diversity of the soil.

Clayey

The clayey range sites are found on the uplands in slight depressions, in shallow drainageways, and on nearly level high terraces.

The clayey range-soil-group was studied in Montana, Wyoming, South Dakota, and Kansas. Most of the tests were conducted in South Dakota and Montana. The tests were conducted in four different precipitation zones.

A similarity in species composition exists between the 10- to 14-inch and 15- to 19-inch precipitation zones. Differences in composition between precipitation zones for a range site may result from range condition class difference (fig. 6).

Buffalograss, western wheatgrass, and blue grama were the dominant grass species in the 10- to 14-inch precipitation zone; western wheatgrass in the 15- to 19-inch and 20- to 24-inch precipitation zones; and big bluestem, which accounted for 60 percent of the composition, in the 30- to 34-inch precipitation zone. The percentages annual and perennial forbs varied among precipitation zones and range conditions.

The amount of live vegetation increased with increased precipitation (table 2). The rate of water intake did not increase with the increased vegetal cover. This may be partially explained by variations in the physical characteristics of the soil.

Total vegetal cover, total herbage, amount of midgrass, shortgrass, and mulch were all significantly correlated with the rate of water intake (table 3).

The structures of the first and second natural horizon and the texture of the first horizon were correlated with the rate of water intake as well as the percentage of bare ground.

A multiple stepwise regression analysis showed that vegetative and soil factors were about equally important on a clayey range site. Forty-six percent of the variation in the rate of water intake

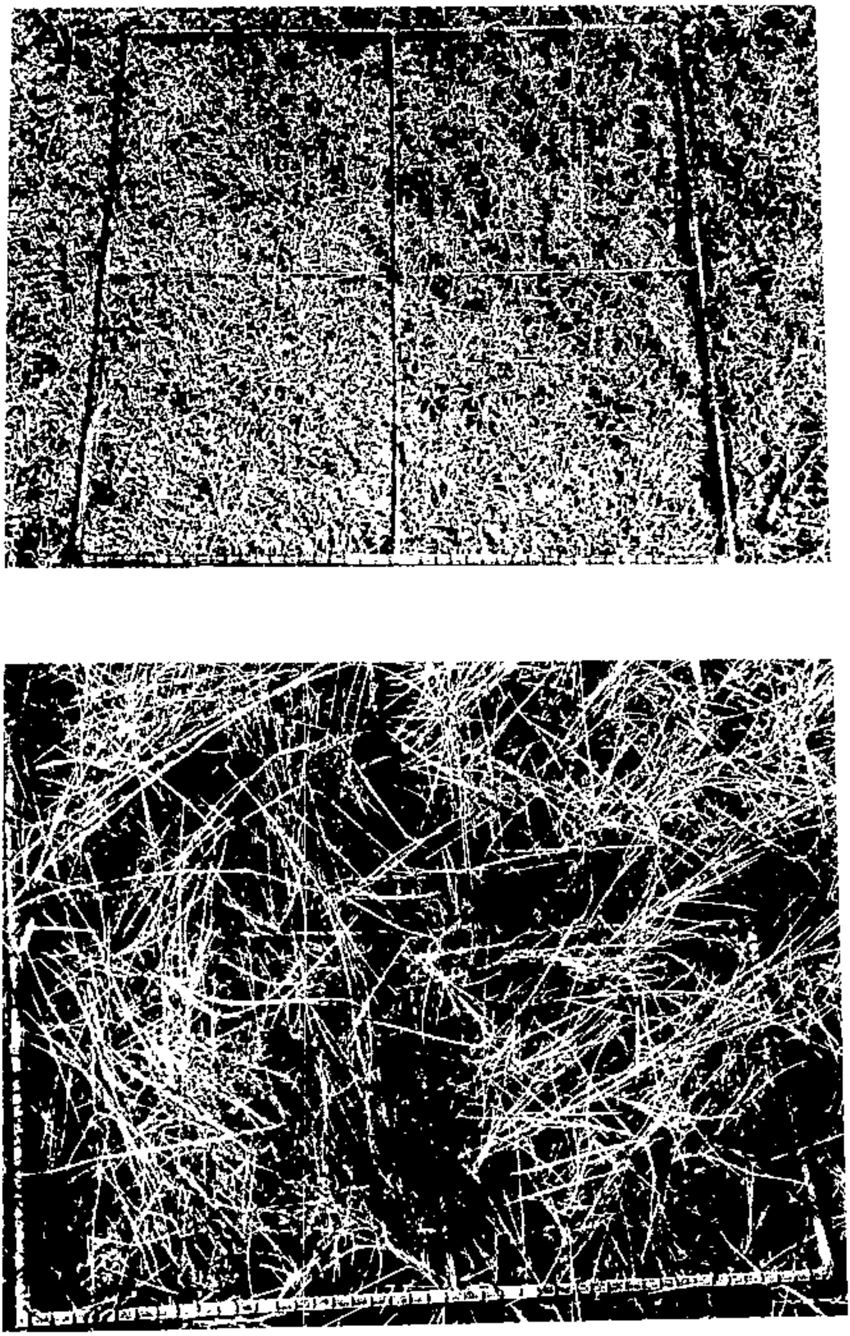

FIGURE 6.—A good cover of shortgrasses (upper) and a good cover of midgrasses (lower) on native rangeland. Total shortgrasses were 500 pounds per acre. Total midgrasses were 2,000 pounds per acre.

for this site was accounted for by six selected variables. Four of the six variables were statistically significant.

Silty

The silty range sites are found on nearly level to moderately steep alluvial-colluvial fans, footslopes, and uplands. Fenceline contrasts of the silty range-soil-group in four different precipitation zones are shown in figures 7, 8, 9, and 10.

The silty range-soil-group was studied in Montana, Wyoming, North Dakota, South Dakota, Nebraska, and Kansas. This range-soil-group was evaluated in seven precipitation zones, representing seven types of range sites.

Kinds and amounts of vegetation varied with precipitation zones. In the drier areas, western wheatgrass and blue grama were dominant, whereas in the wetter areas big and little bluestem were dominant. As expected, the least amount of vegetal cover was found on the test sites of the 5- to 9-inch precipitation zone (table 2). The amount and kind of vegetation also varied with the range condition. The percentage of bare ground decreased as the average annual precipitation increased. Thus, better protection of the soil surface was afforded in the higher precipitation zones.

Mulch material increased with increasing precipitation. Mulch material in the 25- to 29-inch and 30- to 34-inch precipitation zones was low because of the poorer range conditions sampled in these two precipitation zones.

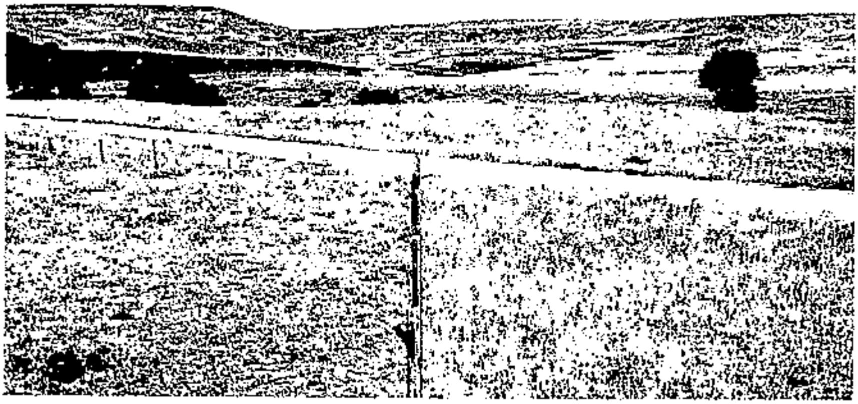

FIGURE 7.—Fenceline contrast near Columbus, Mont. Range in excellent (right) and fair (left) condition. Soil type: Amherst loam. Precipitation zone: 15 to 19 inches. Range site: Silty. Total vegetation: Fair range condition, 770 pounds per acre; excellent range condition, 1,450 pounds per acre. Water intake rate: Fair range condition, 1.30 inches per hour; excellent range condition, 2.45 inches per hour.

FIGURE 8.—Fenceline contrast near Phillipsburg, Mont. A pasture in fair condition (left), and a winter pasture in excellent condition (right). Soil type: Phillipsburg silt loam. Precipitation zone: 15 to 19 inches. Range site: Silty. Total vegetation: Fair range condition, 900 pounds per acre; excellent range condition, 3,400 pounds per acre. Water intake rate: Fair range condition, 1.17 inches per hour; excellent range condition, 2.08 inches per hour.

There was an unexpected similarity in amounts of herbage through several precipitation zones studied for the silty range site. The reason for this may have been that grazing left an almost uniform growth.

Amounts of total vegetal cover, mulch, total herbage, midgrasses, and shortgrasses were significantly correlated with the rate of water intake (table 3). Soil structure and soil texture of the first two natural horizons were the most important soil characteristics associated with rate of water intake for the silty range-soil-group. Percentage of bare ground was correlated negatively with water intake.

A multiple stepwise regression analysis showed that the vegetative factors were more important than the soil factors measured.

Sixty percent of the variation in rate of water intake was accounted for by the six variables chosen. Four of the six variables were statistically significant.

Sandy

The sandy range sites occur on nearly level stream bottoms, nearly level to sloping colluvial-alluvial fans, and gently sloping to moderately steep uplands.

Tests were conducted on sandy range sites in western South Dakota, Nebraska, and Wyoming. Three precipitation zones were represented.

FIGURE 9.—Fenceline contrast near Chico, Mont. A pasture in fair condition (left), and a protected area in excellent condition (right). Soil type: Loam. Precipitation zone: 5 to 9 inches. Range site: Silty. Total vegetation: Fair range condition, 400 pounds per acre; excellent range condition, 1,550 pounds per acre. Water intake rate: Fair range condition, 1.53 inches per hour; excellent range condition, 2.56 inches per hour.

The dominant grasses present were blue grama and needle-and-thread. Fringed sagewort was the dominant forb on two of the three sites. Annual and perennial forbs increased as the precipitation increased.

The range condition of the test areas decreased as the precipitation increased. The high fair condition in the 15- to 19-inch precipitation zone had a water intake rate similar to that found in a low good condition in the 10- to 14-inch precipitation zone. With nearly the same amount of vegetal cover for the sites in the 10- to 14- and 20- to 25-inch precipitation zones, there was 0.34-inch difference in the rate of water intake (table 2). Also, there was a full condition class difference between the two areas, which shows the importance of both cover and range condition. The lower condition range may have been overgrazed and the soil surface compacted by the grazing animals.

Total vegetal cover, total herbage, and amount of midgrass were significantly correlated with rate of water intake (table 3). The texture of the second natural horizon was the only soil variable measured that was significantly correlated with water intake rate.

A multiple stepwise regression analysis showed that vegetative factors were more important than the soil factors for high water intake rates on a sandy range site. The sum of the structure indices for the first three horizons was the most important soil variable measured.

The regression equation determined from the variables for this range site is presented in table 4. Twenty-four percent of the variation in rate of water intake for the sandy range site was accounted for by the six variables chosen. Four of the six variables were statistically significant.

Overflow

The overflow range site occurs along stream bottoms, alluvial-colluvial fans, and other water courses which regularly receive additional water as overflow from higher ground.

Eleven tests were conducted on the overflow range site; eight were located in Nebraska in the 25- to 29-inch precipitation zone, and three were located in Kansas in the 20- to 24-inch zone. Data from all tests were combined (table 2).

The site definition is broad and encompasses a range of soil textures and other soil characteristics. Good vegetal cover conditions were generally associated with the range-soil-group because of the additional water received. Midgrasses accounted for nearly

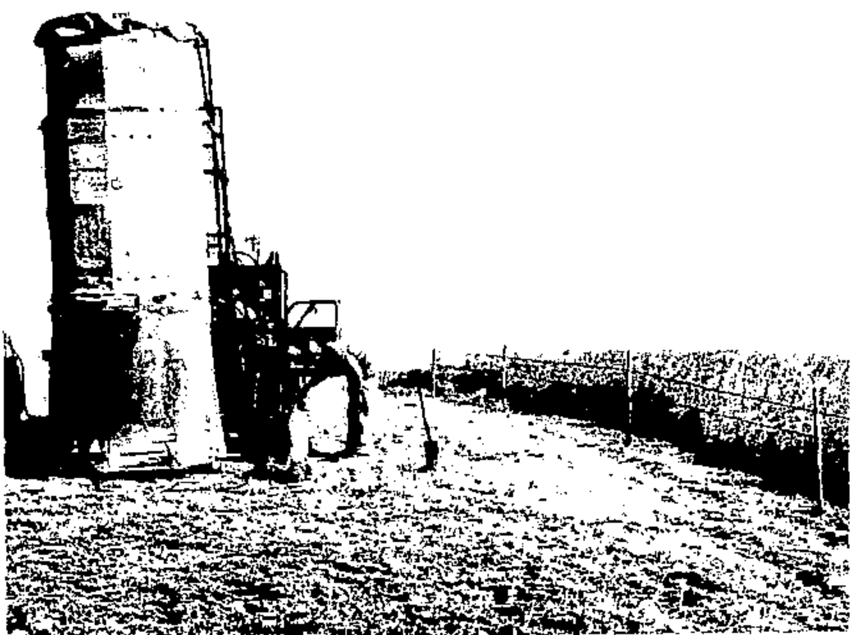

FIGURE 10.—Fenceline contrast near Hays Center, Nebr. A range in poor condition (left), and a range in excellent condition (right). Soil type: Keith silt loam. Precipitation zone: 20 to 24 inches. Range site: Silty. Total vegetation: Poor range condition, 750 pounds per acre; excellent range condition, 4,200 pounds per acre. Water intake rate: Fair range condition, 0.95 inch per hour; excellent range condition, 3.37 inches per hour.

all of the herbage. Dominant species were big bluestem and Kentucky bluegrass. Range condition for the overflow range-soil-group studied was rated high fair.

Because good cover conditions were present on the test area, high rates of water intake were obtained. Even higher rates of water intake could be expected from overflow range sites in good and excellent condition.

Total herbage and amount of midgrasses present were significantly correlated with the rate of water intake (table 3). Structure of the first horizon was highly correlated with the rate of water intake. None of the other soil factors measured was significantly correlated with the rate of water intake.

A multiple stepwise regression analysis showed that the sum of the structures indices and the sum of the boundaries indices of the first three horizons accounted for all the variation in the rate of water intake for this site. It is assumed that the vegetative factors were not significantly correlated because of sufficient cover on the test plots.

The six variables chosen accounted for 93 percent of the variation in the rate of water intake. The sum of structure was the only variable that was statistically significant.

Sands

The sands range sites occur on gently sloping to moderately steep sand hills and along some streams. Tests on such sites were conducted in Wyoming, Nebraska, and Kansas and were located in four precipitation zones.

The kinds and amounts of species on this range-soil-group were quite diverse because of precipitation zones and range condition classes. Dominant species in the various precipitation zones were as follows: 5- to 9-inch zone, shadscale and Gardners saltsage; 10- to 19-inch zone, prairie sandreed, annual forbs, *Carex* spp., and blue grama; and 20- to 25-inch zone, prairie sandreed, blue grama, and little bluestem.

The rate of water intake increased linearly with range condition (fig. 11). The amount of vegetal cover varied with range conditions within a precipitation zone (table 2). A sands range site in excellent range condition would not produce runoff in most rainstorms regarded as torrential.

The herbage from the 5- to 9-inch precipitation zone was practically all shrubs and is the reason for the high yield figure for that zone. The mulch figure was also high because small twigs were included in the mulch.

Average water intake rate for the sands range site was 3.13 inches per hour. Total herbage accounted for 56 percent of the total cover. Midgrasses accounted for 56 percent of the total herbage. Overall, the bare ground for the sands range site averaged 36 percent.

Amount of midgrass was the only vegetative factor measured that was significantly correlated with the rate of water intake (table 3). Structure and thickness of the second horizon were

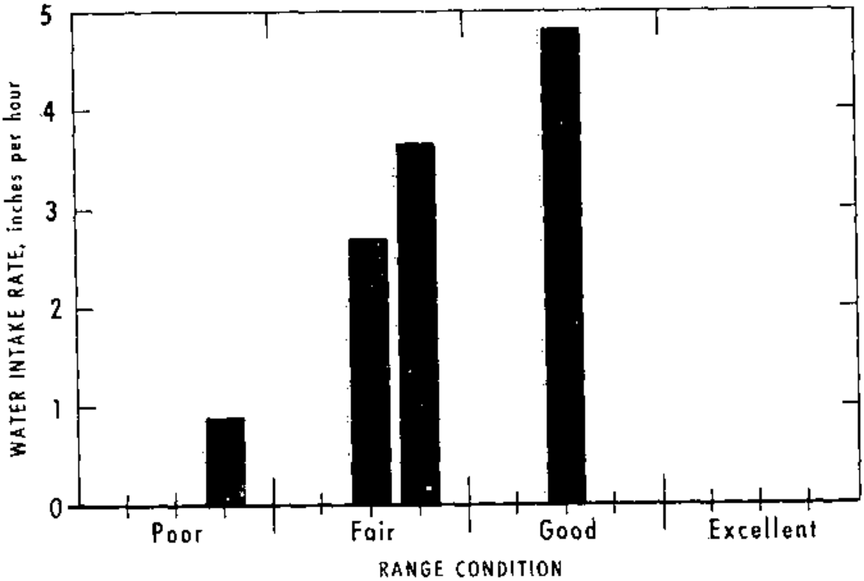

FIGURE 11.—Water intake for three condition classes on a sands range-soil-group.

significantly correlated with rate of water intake. The percentage of bare ground was significantly correlated with the rate of water intake. A multiple stepwise regression analysis showed that soil factors were more important than vegetative factors in determining high rate of water intake. The six variables chosen accounted for 86 percent of the variation in rate of water intake. The sum of the thickness and sum of the textures of the first three horizons were the two variables that were statistically significant.

All Range-Soil-Groups

A statistical analysis of all 670 tests was made for comparative purposes and to determine which of the factors measured were the most important in controlling water intake rates. Average water intake rates and vegetal covers are summarized for each range-soil-group, irrespective of precipitation and geographic area, and for a combination of all range-soil-groups in all areas sampled (table 5).

Average rate of water intake during the second 30-minute period of the 1-hour test was 1.35 inches per hour for the combined range sites. From table 5, it can be calculated that mulch material accounted for 46 percent of the total ground cover. Midgrasses, including tallgrasses, accounted for 70 percent of the total air-dry weight of herbage. Bare ground of the combined range-soil-groups averaged 37 percent. Amounts of total vegetal cover, total herbage, midgrass, mulch, bare ground, and range

TABLE 5.—*Rate of water intake, amount of vegetal cover, percentage of bare ground, and number of observations for various range-soil-groups*

Range sites	Rate of water intake, second 30-minutes	Vegetal cover (air dry)			Bare ground	Observations
		Midgrass	Herbage	Mulch		
	Inches per hour	*Lb./acre*	*Lb./acre*	*Lb./acre*	*Percent*	*Number*
All range-soil-groups	1.35	929	1,319	1,139	38	670
Alkali upland	.29	357	683	346	70	59
Dense clay	.50	1,003	1,108	445	59	59
Panspot	.90	768	1,317	528	46	29
Shallow complex	1.26	901	1,379	826	47	69
Clayey	1.45	736	1,154	993	32	138
Silty	1.46	1,136	1,487	1,665	26	218
Sandy	1.67	885	1,319	1,119	35	83
Overflow	2.31	2,905	2,942	2,406	14	11
Sand	3.13	997	1,785	1,412	36	23

condition were significantly correlated with the water intake rate for the combined range sites (table 3). Structure, texture, and thickness of the first and second horizons and boundary of the first horizon were significantly correlated with the water intake rate.

A multiple stepwise regression analysis using six variables showed that the amount of total vegetal cover was the most important factor measured. The sum of the structures indices for the first three horizons was the most important soil factor measured. This analysis showed that 56 percent of the variation in water intake rates was accounted for by the six variables chosen. A regression equation for the combined range-soil-groups showed that the six variables contributed significantly at the 5-percent level of probability (table 4).

Soil Structure, Total Herbage, and Range Management

When water intake rates for comparable amounts of herbage were plotted in relation to differences in structure within soil groups, striking differences were revealed. In viewing these differences (figs. 12 through 16) note that the amount of cover on a plot, at the time of a test, varied with the degree of grazing removal and the cycle of annual growth. Therefore, amounts of cover recorded do not necessarily reflect normal annual production for the conditions of soil structure prevailing at the time of sampling. Thus, the anomalies in figures 12 and 15, showing decreasing intake with increasing plant cover on soils of poor structure, are explicable. Also note that these data show striking differences in intake related both to amounts of cover and to soil structure. Yet there is also a distinct pattern and level of vegetal cover and water intake for each major soil group or range site.

Even highly permeable sand range sites may have impaired ability to absorb rainfall where poor structure has been developed either by excessive trampling by livestock, by sealing of surface pores through splash erosion, or by deposition of wind- or water-carried sediments (fig. 12).

The sandy range-soil-group, for example, sandy loams, fine sandy loams, and loamy fine sands, has about one-half the water intake rate of the sand range sites but exhibits the same general relation of amounts of cover to water intake rates. Unfavorable soil conditions markedly reduce water intake rates (fig. 13). The general rate of increase of water intake with increased vegetal cover is 1 inch per 2,000 pounds per acre with good structure and 1 inch per 3,200 pounds per acre with poor structure.

A large number of tests on the silty range site enabled the separation of rates of water intake of three major soil structure classes. The amount of vegetal cover required to increase the rate of water intake 1 inch per hour for the silty range site is between 1,000 and 5,000 pounds per acre (fig. 14). At the 3,000-pound-per-acre level of vegetal cover the mean water intake rates are: for excellent structure, 2.40; for fair to good structure, 1.65; and for poor structure, 1.10 inches per hour.

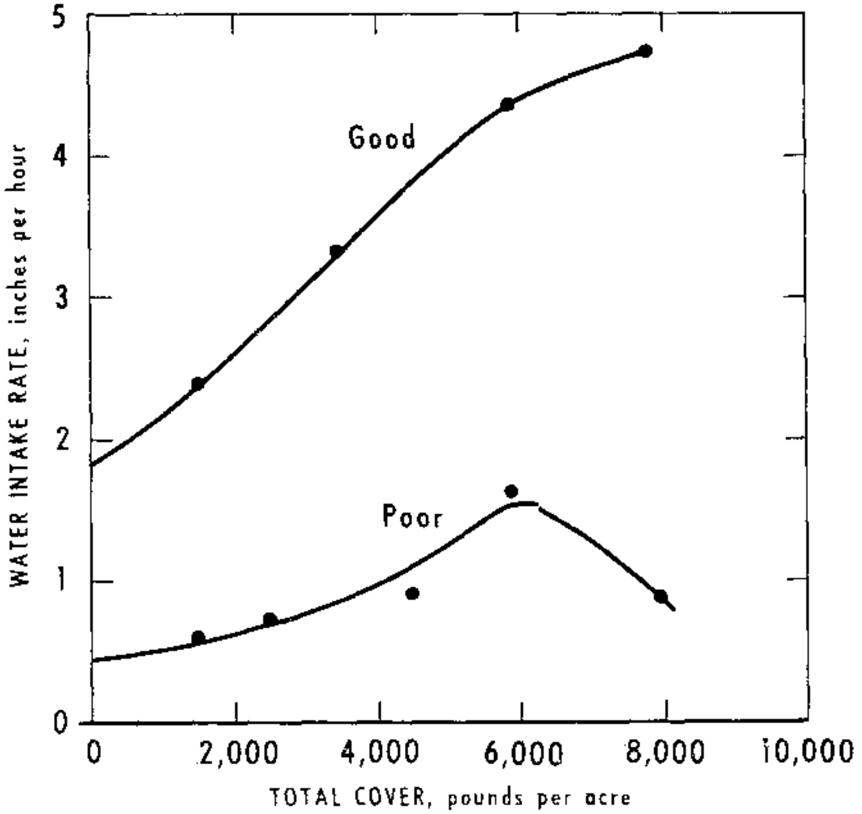

FIGURE 12.—Water intake rate compared to total vegetal cover and structure for the sands range-soil-group.

The clayey range site includes soil textures of sandy clay loams, silty clay loam, and clays. Water intake increases rapidly when the vegetal cover increases to between 500 and 3,000 pounds per acre (fig. 15). No increase in water intake and even a slight decrease is noted with more than 4,000 pounds per acre of total cover. Between 500 and 3,000 pounds, 1,700 pounds per acre of total cover was equivalent to an increase of 1 inch per hour of water intake on soils of good structure, but 3,750 pounds was required on soils of poor structure. Soils of good structure had 65 percent greater water intake rates than soils of poor structure at the 3,000-pound level of total cover.

Among those soils with naturally low water intake rates are soils with compact or blocky clay subsoils and clay or clayey soils affected by alkali. Figure 16 compares clay soils having good structure and no alkali, with clay soils of poor structure and alkali or saline-alkali soils. While both groups have low water intake rates as compared with sandy or silty range sites, those clay soils with good structure take water at rates three to four times the rates of alkali soils or dense clays with poor structure. An increase in the rate of water intake of 1 inch per hour would require 11,500 pounds of vegetation per acre for the upper curve and 7,500 pounds per acre for the lower curve. These range sites seldom produce over 4,000 pounds per acre under the best of conditions.

DISCUSSION

Long-continued close grazing results in radical changes in vegetal cover. The more productive tallgrasses and midgrasses are handicapped more than shortgrasses. The shortgrasses then increase. Weedy species, both annual and perennial, may invade and finally become dominant. Also, as a result of overuse, there is more bare ground throughout the year, and, therefore, an acceleration of runoff and erosion. Surface structure of most soils is altered from a desirable crumbly or granular to a platy or

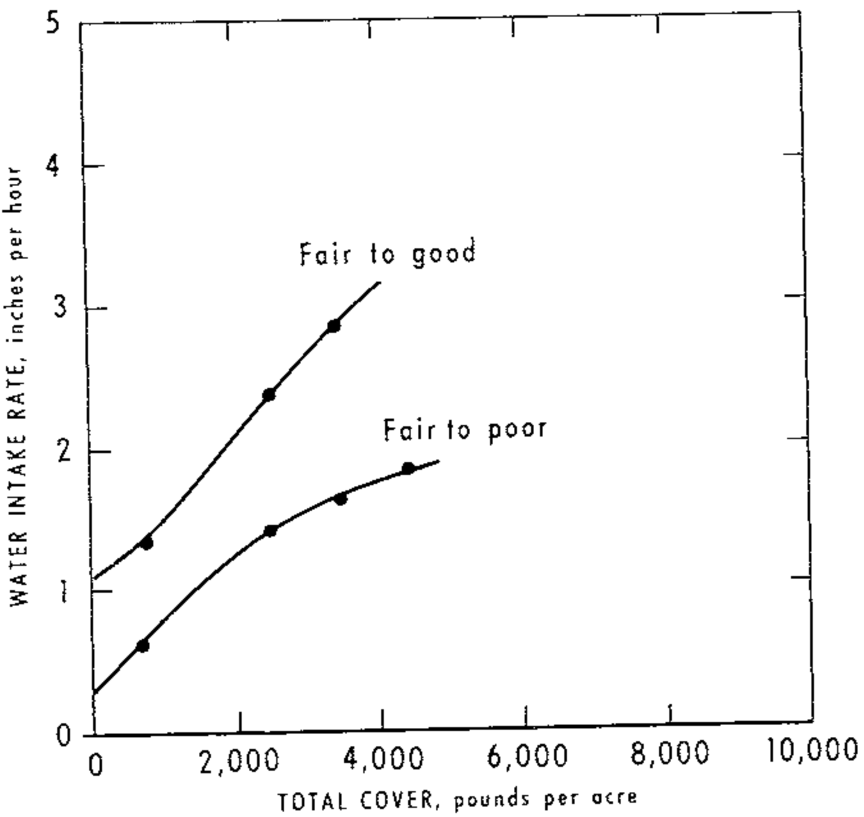

FIGURE 13.—Water intake rate compared to total vegetal cover and structure for the sandy range-soil-group.

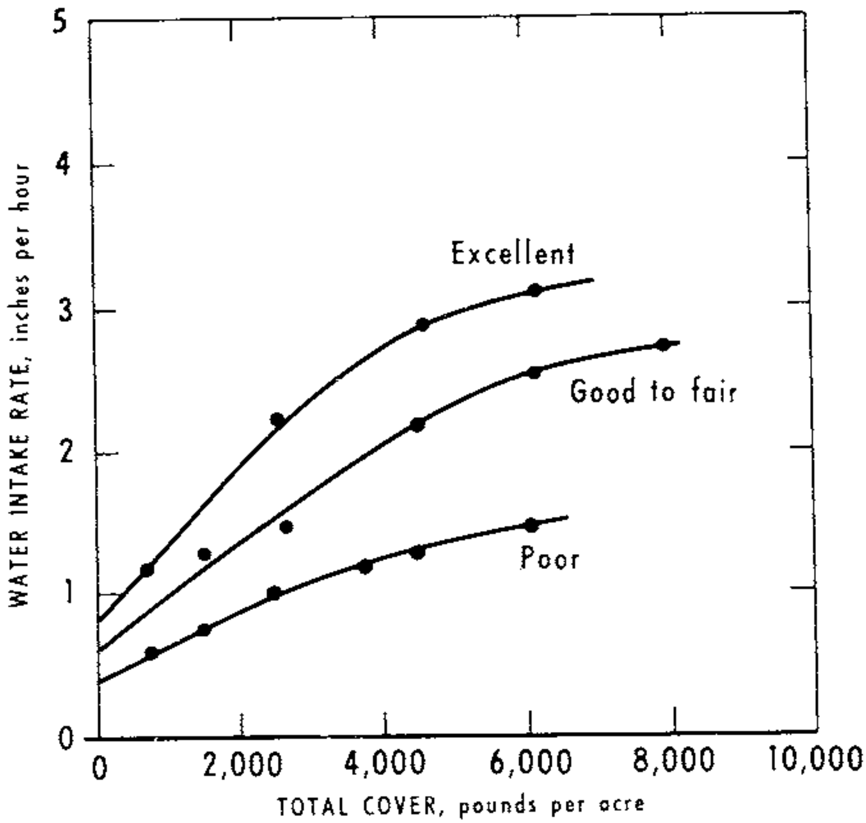

FIGURE 14.—Water intake rate compared to total vegetal cover and structure for the silty range-soil-group.

even dispersed condition. Subsurface structure may also be altered but seldom to depths of more than 5 inches.

Once the vegetative and soil characteristics of a range site have been altered by overuse, time and management are needed to change them. The time required to change a range from the poor condition class to the good or excellent condition class does not depend solely on the management of grazing. Vegetative changes and soil structural changes are much slower in semiarid regions than in subhumid regions. Within a climatic region the time required varies also with soil type. Thus, in the management of rangeland, potential conditions and time required for restoration depend on climatic as well as vegetative and soil characteristics. Degrees of deterioration in plant cover and soil structure for a type of range site can be evaluated by water intake determinations.

Range-soil-groups with equal amounts of vegetal cover do not necessarily have similar water intake rates. Differences are usually traceable to good or poor soil structure related to recent history of grazing use. Physical changes of the soil are brought about more slowly than vegetative changes, but they are related to one another.

Textural differences of topsoil are mapped because they are more stable than structural differences; however, the structure (aggregation of soil particles) exerts profound influence on the functional properties of the soil.

Movement of water into the soil may be less on a "cemented" sandy loam than on a granular clay, irrespective of range condition class. Generally, however, rangelands with comparable soil texture in good or excellent range condition have a crumbly or granular surface structure conducive to a high rate of water intake; while ranges in poor or fair condition have a platy or dispersed soil surface with correspondingly slower water intake.

Granular structure in the surface soil of ranges often is associated with accumulating old growth on the soil surface and improving range condition, as well as with a high range condition

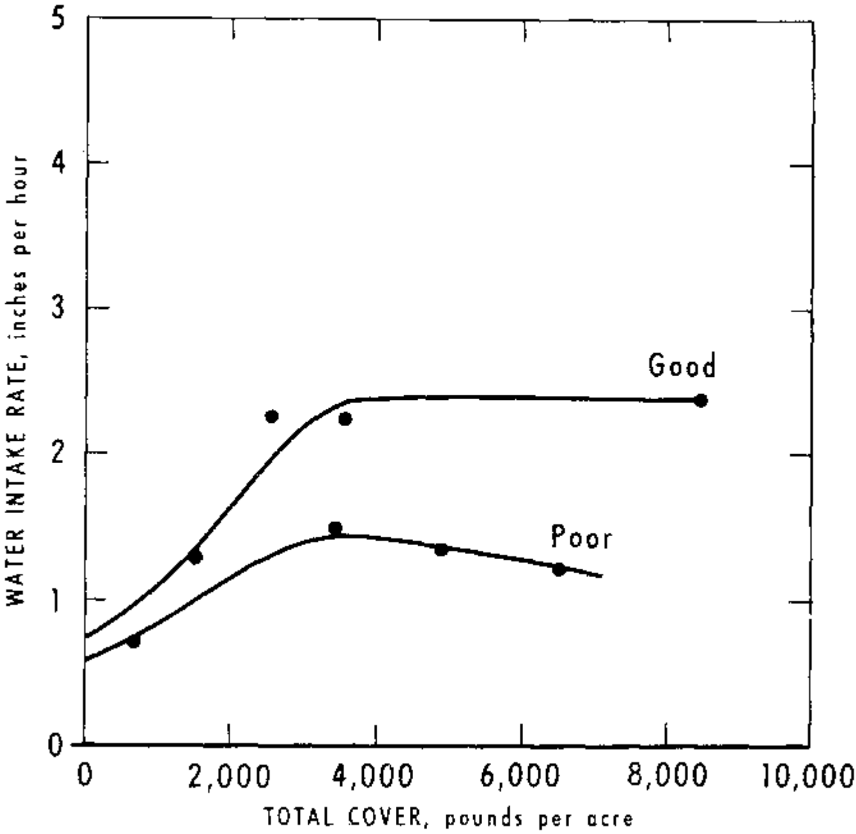

FIGURE 15.—Water intake rate compared to total vegetal cover and structure for the clayey range-soil-group.

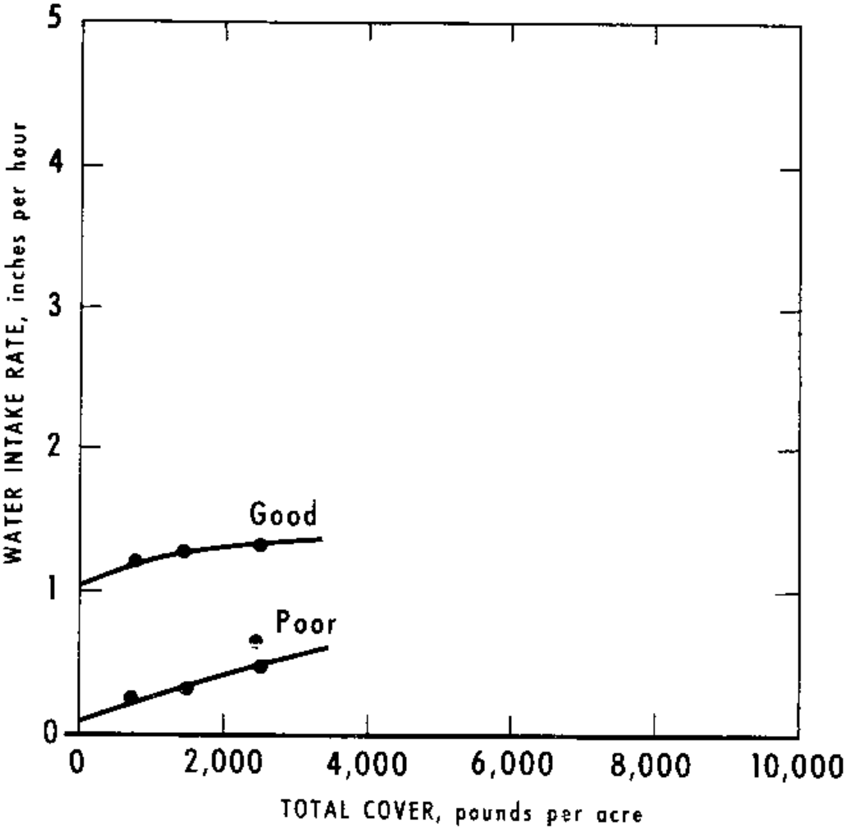

FIGURE 16.—Water intake rate compared to total vegetal cover and soil structure for the saline-alkali upland and the dense clay range-soil-groups.

class. Climate, chemical properties, faunal and floral activities, and the nature and origin of parent material determine to a large extent structural patterns of virgin soil.

The subsurface texture and structure influence the downward movement of water after the surface layer is saturated. Prismatic and subangular blocky structure with vertical cleavage in the subsoil is conducive to water movement. Coarse blocky or angular blocky structure with greater horizontal than vertical cleavages retards downward movement of water.

The beating action of raindrops on bare soil tends to disperse granules and puddle, compact, and seal the surface to water intake. Adequate plant cover prevents fine soil particles from being splashed into suspension in surface water and later deposited to clog the pore spaces.

Seven structural features were recognized and evaluated for the first three natural horizons. The sums of the structural features were related to the rate of water intake on five range soil groups. Evaluation of the data showed that with equal vegetal cover the rate of water intake was always greater on soils with good structure than on soils with poor structure.

Plant cover contributes to the protection of the soil surface and is the source of soil organic matter. Plant roots bind the soil particles, organic matter cements them, and, thus, a stable structure is formed.

The amount of vegetal cover required to increase the rate of water intake varies with range site characteristics.

Soils of poor structure required 50 to 100 percent more vegetal cover to affect a given increase in water intake than did soils of good structure, except for saline-alkali and dense clay soils. The latter had relatively low and erratic water intake rates and seldom had over 3,000 pounds of vegetal cover per acre.

SUMMARY

Water intake studies were conducted with a mobile raindrop applicator on rangeland sites in six States in the Northern and Central Plains. Tests were designed to measure the effect of vegetational differences on the water intake of comparable soil mapping units at range fenceline contrasts. In addition, concentrations of tests were made on certain small experimental rangeland watersheds containing permanent hydrologic installations.

Results of 670 tests on nine range-soil-groups located throughout a wide range in precipitation zones and latitudes were evaluated. Statistical analyses of the data included simple and multiple stepwise regressions. Equations were developed for estimating water intake rates for each range-soil-group. The following results were obtained from the study.

1. Average rate of water intake during the second 30-minute period of the 1-hour test for all range sites was 1.35 inches per hour. Total vegetal cover averaged 2,458 pounds per acre. Neither average is weighted for relative areas of range sites.

2. Water intake rates at their extremes were lowest on the range sites characterized by fine-textured dispersed soils, and highest on the range sites characterized by coarse-textured soils. These rates were for saline-alkali clays of Wyoming desert ranges (0.2 in. per hr.) and deep sands of Nebraska Sandhill ranges (4.8 in. per hr.).

3. The amounts and kinds of vegetal cover varied within a local range-soil-group because of differences in range condition and current degree of use. Different climatic conditions and associated soil conditions were associated with differences in plant cover of a range-soil-group over broad areas.

4. Among all variables measured, the amount of both new and old vegetation showed greatest general correlation with water intake rate. Simple correlations between water intake rates during the second 30-minute period of the 1-hour test showed also that soil structure of the first horizon was highly correlated with water intake. Texture of the second horizon was next in order of

importance, followed by the nature of the boundary of the first horizon.

5. Within the same geographic area and precipitation zone, herbage production of a range soil is related to soil characteristics that can be modified by grazing management, especially soil structure.

6. Average water intake rates of saline-alkali upland range sites studies were 0.36, 0.26, and 0.20 inch per hour for the Montana, South Dakota, and Wyoming sites, respectively. Total vegetal cover, including woody stems, for the three sites ranged from 820 to 1,360 pounds per acre. Of the factors studied, water intake rates appeared to be influenced more by vegetative than by soil factors.

7. In western South Dakota, the water intake rate of a dense clay range site averaged 0.50 inch per hour. Total vegetal cover averaged 1,653 pounds per acre. Departures from average water intake rate showed best correlation with differences in vegetal cover as compared with differences in soil properties.

8. The water intake rates on the interareas of a panspot range site in western South Dakota averaged 0.90 inch per hour. Total vegetal cover averaged 1,845 pounds per acre. As on dense clay, the vegetative factors influenced the water intake rate more than did the soil factors.

9. Intake was evaluated for a complex of shallow range-soil-groups which included all the shallow sites studied in Montana, Wyoming, South Dakota, Nebraska, and Kansas. Water intake rates ranged from 1.18 to 1.53 inches per hour with an average of 1.26 inches per hour. Four precipitation zones were involved. Total vegetal cover for the four precipitation zones averaged 2,205 pounds per acre. The vegetative and soil factors studied appeared to have equal influence on the water intake rate.

10. The water intake characteristics of the clayey range-soil-group were studied in Montana, Wyoming, South Dakota, and Kansas and in four precipitation zones. Average water intake rate ranged from 1.13 to 1.53 inches per hour. Total vegetal cover for the four areas averaged 2,147 pounds per acre. The vegetative and soil factors equally influenced water intake rates.

11. Water intake rates for the silty range-soil-group were investigated in Montana, Wyoming, North Dakota, South Dakota, Nebraska, Kansas and in seven different precipitation zones. These included the 5- to 9-inch through the 35- to 39-inch precipitation zones. Average water intake ranged from 1.03 to 1.77 inches per hour or an average of 1.46 inches per hour for the seven precipitation zones. Total vegetal cover ranged from 1,297 to 4,629 pounds per acre. Water intake rates were influenced more by vegetative than by soil factors.

12. The water intake rates of the sandy range-soil-group were investigated in Nebraska, western South Dakota, and Wyoming and involved three precipitation zones. Average water intake rate for the three areas was 1.67 inches per hour. Total vegetal cover averaged 2,438 pounds per acre. Water intake rate was influenced more by vegetative than by soil factors.

13. In Kansas and Nebraska, water intake characteristics of the overflow sites were studied. Average water intake rate was 2.31 inches per hour. Total vegetal cover averaged 5,348 pounds per acre. Soil factors influenced water intake rates more than did the vegetative factors.

14. Sands range sites were studied in Nebraska, Kansas, and Wyoming and occurred in four different precipitation zones. These sites are characterized by topsoils of true sands, as distinguished from merely sandy topsoils. Some were deep sands but others had topsoils of finer textures. Water intake rate ranged from 0.69 to 4.83 inches per hour, or an average of 3.13 inches per hour. Total vegetal cover averaged 3,197 pounds per acre. Soil factors influenced water intake rate more than did the vegetative factors.

15. Analysis of the data from all tests showed that water intake rate in the second 30 minutes of simulated rainfall was most clearly correlated with either total vegetal cover or total weight of herbage. Soil structure was the most important soil influence measured.

16. Water intake rate, range condition class, and herbage production tended to vary together for a specific type of range site. Rates of intake and amounts of herbage also varied among the range sites described.

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APPENDIX

Common and Botanical Names of Plants Mentioned in This Report

GRASSES AND SEDGES

1. Alkali sacaton .... *Sporobolus airoides* (Torr.) Torr.
2. Bearded wheatgrass ..... *Agropyron subsecundum* (Link) Hitchc.
3. Big bluegrass .... *Poa ampla* Merr.
4. Big bluestem .... *Andropogon gerardi* Vitm.
5. Bluebunch wheatgrass ... *Agropyron spicatum* (Pursh) Scribn. & Smith
6. Blue grama .... *Bouteloua gracilis* (HBK.) Lag. ex Steud.
7. Buffalograss .... *Buchloe dactyloides* (Nutt.) Engelm.
8. Canby bluegrass .... *Poa canbyi* (Scribn.) Piper
9. Canada bluegrass .... *Poa compressa* L.
10. Canada wildrye .... *Elymus canadensis* L.
11. Cheatgrass brome .... *Bromus tectorum* L.
12. False buffalograss ...... *Munroa squarrosa* (Nutt.) Torr.
13. Green needlegrass .... *Stipa viridula* Trin.
14. Griffiths wheatgrass ...... *Agropyron griffithsii* Scribn. & Smith ex Piper
15. Hard sheep fescue .... *Festuca ovina* var. *duriuscula* (L) Koch introduced
16. Idaho fescue .... *Festuca idahoensis* Elmer
17. Indiangrass .... *Sorghastrum nutans* (L.) Nash
18. Indian ricegrass .... *Oryzopsis hymenoides* (Roem. & Schult.) Ricker
19. Inland saltgrass .... *Distichlis stricta* (Torr.) Rydb.
20. Japanese brome .... *Bromus japonicus* Thunb.
21. Junegrass .... *Koeleria cristata* (L.) Pers.
22. Kentucky bluegrass ...... *Poa pratensis* L.
23. Little barley .... *Hordeum pusillum* Nutt.
24. Little bluestem .... *Andropogon scoparius* Michx.
25. Muttongrass .... *Poa fendleriana* (Steud.) Vasey
26. Needle-and-thread .... *Stipa comata* Trin. & Rupr.
27. Plains reedgrass .... *Calamagrostis montanensis* Scribn. ex Vasey
28. Poverty oatgrass .... *Danthonia spicata* (L.) Beauv. ex Roem. & Schult.
29. Prairie sandreed .... *Calamovilfa longifolia* (Hook.) Scribn.
30. Rough fescue .... *Festuca scabrella* Torr.
31. Ringgrass .... *Muhlenbergia torreyi* (Kunth) Hitchc.
32. Sandberg bluegrass ...... *Poa secunda* Presl.
33. Sand dropseed .... *Sporobolus cryptandrus* (Torr.) A. Gray
34. Sand paspalum .... *Paspalum stramineum* Nash
35. Scribner panicum .... *Panicum scribnerianum* Nash
36. Side-oats grama .... *Bouteloua curtipendula* (Michx.) Torr.
37. Silver bluestem .... *Bothriochloa saccharoides* (Sw.) Rydb.
38. Sixweeks-fescue .... *Festuca octoflora* Walt.
39. Stony hills muhly .... *Muhlenbergia cuspidata* (Torr.) Rydb.
40. Switchgrass .... *Panicum virgatum* L.
41. Tall dropseed .... *Sporobolus asper* (Michx.) Kunth
42. Three-awn .... *Aristida fendleriana* Steud.
43. Tumblegrass .... *Schedonnardus paniculatus* (Nutt.) Trel.
44. Western wheatgrass ...... *Agropyron smithii* Rydb.
45. *Carex* spp. .... *Carex* spp.

FORBS

1. Aster .... *Aster* spp.
2. Chickweed .... *Cerastium arvense* L.
3. Curlycupgumweed .... *Grindelia squarrosa* (Pursh) Dunal
4. Dandelion .... *Taraxacum officinale* Web. ex Wigg.
5. Fringed sage .... *Artemisia frigida* Willd.
6. Hairy goldaster .... *Chrysopsis villosa* (Pursh) Nutt. ex DC.

7. Halogeton ---------------*Halogeton glomeratus* C. A. Mey.
8. Lambsquarter -----------*Chenopodium album* L.
9. Tansymustard ----------*Sisymbrium altissimum* L.
10. Phlox ------------------*Phlox* spp.
11. Plains plantain ---------*Plantago purshii* Roem. & Schult.
12. Pussytoes --------------*Antennaria aprica* Greene
13. Sagewort ---------------*Artemisia* spp.
14. Sandwort ---------------*Arenaria* spp.
15. Scarlet globemallow -----*Sphaeralcea coccinea* (Pursh) Rydb.
16. Stickseed ---------------*Lappula* spp.
17. Western yarrow ---------*Achillea millefolium* L.
18. Western ragweed --------*Ambrosia psilostachya* DC.

SHRUBS

1. Gardners saltsage --------*Atriplex gardneri* (Moq.) Standl.
2. Greasewood -------------*Sarcobatus vermiculatus* (Hook.) Torr.
3. Rose --------------------*Rosa* spp.
4. Shadscale ---------------*Atriplex nuttallii* S. Wats.
5. Silver sage --------------*Artemisia cana* Pursh
6. Shrubby cinquefoil -------*Potentilla fruticosa* L.

OTHER

1. Selaginella -------------*Selaginella densa* Rydb.

Plant Species Composition as Determined From Test Plots for the Various Range-Soil-Groups

Saline-Alkali Upland

5- TO 9-INCH PRECIPITATION ZONE IN WYOMING AND 10- TO 14-INCH PRECIPITATION ZONE IN MONTANA AND SOUTH DAKOTA

Species	Wyoming	Montana	South Dakota
	Percent	*Percent*	*Percent*
Western wheatgrass	------	40.6	22.7
Blue grama	------	14.5	26.3
Buffalograss	------	23.2	------
Sandberg bluegrass	------	10.6	.8
Inland saltgrass	------	------	5.2
Sand dropseed	------	------	2.3
Carex spp	------	------	3.4
Annual grasses	------	1.2	4.7
Halogeton	3.0	------	------
Other annual and perennial forbs	1.0	9.9	32.0
Shrubs	------	------	2.6
Gardners saltsage	96.0	------	------

Dense Clay

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Western wheatgrass	60.5
Blue grama	11.7
Griffiths wheatgrass	7.3
Inland saltgrass	1.9
Needle-and-thread	.4
Carex spp	1.1
Annual grass	1.1
Annual and perennial forbs	16.0

Panspot

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	55.8
Western wheatgrass	22.7
Needle-and-thread	5.6
Inland saltgrass	3.4
Sand dropseed	3.0
Sandberg bluegrass	1.6
Carex spp	4.3
Annual grass	1.0
Annual and perennial forbs	2.6

Shallow Complex

5- TO 9-INCH PRECIPITATION ZONE

Species	*Percent*
Indian ricegrass	44.3
Alkali sacaton	27.3
Three-awn	12.5
Annual and perennial forbs	15.9

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	26.2
Western wheatgrass	17.9
Needle-and-thread	7.5
Griffiths wheatgrass	4.8
Hard sheep fescue	2.9
Bluebunch wheatgrass	2.0
Sand dropseed	.9
Side-oats grama	.4
Sandberg bluegrass	.1
Switchgrass	.1
Carex spp	7.6
Annual and perennial forbs	19.6

15- TO 19-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	51.3
Western wheatgrass	14.2
Needle-and-thread	12.3
Cheatgrass brome	10.6
Carex spp	11.6

25- TO 29-INCH PRECIPITATION ZONE

Species	*Percent*
Big bluestem	33.2
Little bluestem	24.2
Kentucky bluegrass	11.2
Tall dropseed	10.4
Switchgrass	7.3
Blue grama	3.9
Scribner panicum	1.7
Little barley	.4
Carex spp	.4
Perennial forbs	7.3

Clayey

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Buffalograss	51.4
Western wheatgrass	18.2
Blue grama	10.6
Needle-and-thread	2.5
Side-oats grama	1.8
Bluebunch wheatgrass	1.8
Sandberg bluegrass	1.5
Green needlegrass	.8

Species	*Percent*
Sand dropseed	.3
Junegrass	.1
Three-awn	.1
Annual grass	.7
Carex spp	6.4
Annual and perennial forbs	3.8

15- TO 19-INCH PRECIPITATION ZONE

Species	*Percent*
Western wheatgrass	16.5
Idaho fescue	13.7
Big bluestem	8.4
Blue grama	6.6
Bluebunch wheatgrass	5.7
Sandberg bluegrass	3.2
Green needlegrass	3.2
Plains reedgrass	2.5
Kentucky bluegrass	2.2
Muttongrass	2.0
Rough fescue	2.0
Needle-and-thread	1.8
Poverty oatgrass	.8
Junegrass	.5
Carex spp	9.3
Annual and perennial forbs	20.4
Shrubs	1.2

Clayey

20- TO 24-INCH PRECIPITATION ZONE

Species	*Percent*
Western wheatgrass	40.1
Buffalograss	30.4
Blue grama	28.7
Carex spp	.3
Annual and perennial forbs	.5

30- TO 34-INCH PRECIPITATION ZONE

Species	*Percent*
Big bluestem	60.0
Little bluestem	3.2
Sand dropseed	1.3
Annual grass	10.3
Carex spp	2.6
Annual and perennial forbs	22.6

Silty

5- TO 9-INCH PRECIPITATION ZONE

Species	*Percent*
Western wheatgrass	19.8
Bluebunch wheatgrass	18.9
Sandberg bluegrass	15.7
Junegrass	7.8
False buffalograss	3.7
Rough fescue	2.3
Needle-and-thread	1.4
Carex spp	.5
Selaginella	18.4
Annual and perennial forbs	11.5

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	34.6
Western wheatgrass	27.3
Needle-and-thread	17.7
Sandberg bluegrass	2.0
Junegrass	1.4
Green needlegrass	.8
Big bluestem	.6

Species	*Percent*
Canby bluegrass	.2
Japanese brome	.2
Carex spp	3.9
Selaginella	6.8
Annual and perennial forbs	4.3
Shrubs	.2

Silty

15- TO 19-INCH PRECIPITATION ZONE

Species	*Percent*
Rough fescue	17.2
Blue grama	16.4
Idaho fescue	9.1
Bluebunch wheatgrass	6.2
Western wheatgrass	5.4
Bearded wheatgrass	4.1
Needle-and-thread	2.1
Kentucky bluegrass	2.0
Junegrass	1.4
Poverty oatgrass	1.0
Sandberg bluegrass	.8
Big bluegrass	.8
Stony hills muhly	.4
Prairie sandreed	.4
Carex spp	9.0
Annual and perennial forbs	20.5
Shrubs	3.2

20- TO 24-INCH PRECIPITATION ZONE

Species	*Percent*
Buffalograss	32.7
Big bluestem	25.6
Blue grama	13.0
Little bluestem	8.5
Side-oats grama	4.7
Indiangrass	4.0
Western wheatgrass	3.0
Prairie sandreed	2.3
Silver bluestem	1.1
Needle-and-thread	.7
Idaho fescue	.2
Alkali sacaton	.1
Carex spp	1.4
Annual and perennial forbs	2.7

Silty

25- TO 29-INCH PRECIPITATION ZONE

Species	*Percent*
Kentucky bluegrass	27.7
Buffalograss	20.7
Blue grama	13.7
Side-oats grama	7.3
Big bluestem	7.3
Sand dropseed	4.5
Little barley	2.0
Western wheatgrass	1.4
Scribners panicum	.6
Carex spp	5.6
Annual and perennial forbs	9.2

30- TO 34-INCH PRECIPITATION ZONE

Species	*Percent*
Big bluestem	32.5
Little bluestem	9.9
Tall dropseed	7.4
Kentucky bluegrass	6.7
Buffalograss	5.4
Switchgrass	1.2

Species	*Percent*
Sand papsalum	1.0
Scribner panicum	.7
Western wheatgrass	.4
Windmillgrass	.3
Junegrass	.1
Alkali sacaton	.1
Annual grasses	18.1
Carex spp	.7
Annual and perennial forbs	15.5

Sandy

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	34.1
Needle-and-thread	13.9
Western wheatgrass	8.2
Prairie sandreed	5.4
Little bluestem	2.6
Big bluestem	1.4
Junegrass	1.1
Green needlegrass	.7
Windmillgrass	.4
Sandberg bluegrass	.1
Carex spp	22.9
Selaginella	6.1
Annual and perennial forbs	2.9
Silver sage	.2

15- TO 19-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	36.6
Needle-and-thread	25.2
Sandberg bluegrass	4.0
Western wheatgrass	3.0
Prairie sandreed	2.3
Green needlegrass	.3
Junegrass	.3
Carex spp	18.9
Annual and perennial forbs	9.4

20- TO 29-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	40.0
Western wheatgrass	11.2
Needle-and-thread	8.8
Buffalograss	5.0
Sand dropseed	4.5
Big bluestem	4.3
Prairie sandreed	3.3
Scribner panicum	1.2
Switchgrass	1.0
Little barley	2.1
Carex spp	5.7
Annual and perennial forbs	12.9

Overflow

20- TO 29-INCH PRECIPITATION ZONE

Species	*Percent*
Big bluestem	36.3
Kentucky bluegrass	23.3
Switchgrass	12.7
Sand dropseed	11.3
Sandberg bluegrass	7.8
Indiangrass	1.6
Little bluestem	.6
Little barley	.6
Windmillgrass	.4

Species	*Percent*
Western wheatgrass	.4
Tall dropseed	.2
Carex spp	1.0
Annual and perennial forbs	3.8

Sands

5- TO 9-INCH PRECIPITATION ZONE

Species	*Percent*
Shadscale	69.6
Gardners saltsage	25.2
Three-awn	3.7
Scarlet globemallow	1.5

10- TO 14-INCH PRECIPITATION ZONE

Species	*Percent*
Blue grama	57.9
Needle-and-thread	34.9
Sand dropseed	6.0
Carex spp	1.2

15- TO 19-INCH PRECIPITATION ZONE

Species	*Percent*
Prairie sandreed	34.0
Blue grama	17.6
Needle-and-thread	6.6
Carex spp	18.7
Annual forbs	19.8
Perennial shrubs	3.3

20- TO 25-INCH PRECIPITATION ZONE

Species	*Percent*
Prairie sandreed	31.3
Blue grama	30.8
Little bluestem	25.1
Side-oats grama	2.4
Sand dropseed	1.9
Western wheatgrass	.5
Inland saltgrass	.5
Carex spp	4.7
Annual and perennial forbs	2.8

SOIL PROFILE DESCRIPTIONS

Range-Soil-Group: Saline upland.
Precipitation Zone: 5 to 9.
Soil Type: Chipeta clay
Location: Glen Foe Ranch, Greybull, Big Horn Country, Wyo.

Horizon	*Depth, in inches*	*Profile description*
A1	0–2	Light gray (2.5Y 7/2) when dry, grayish brown (5/2) when moist; silty clay; weak, fine granular structure; loose when dry, firm when moist, sticky and plastic when wet; slightly calcareous; pH 8.5 (thymol blue); unstable when wet; many medium and small discontinuous pores; surface dispersed and with scattering of small angular fragments of shale; abrupt smooth boundary.
AcsCcs	2–5	Grayish brown (2.5Y 5/2) when dry, dark grayish brown (4/2) when moist; silty clay; weak, fine, subangular blocky structure that crushes to very fine granules slightly hard when dry; very firm when moist, sticky and plastic when wet; slightly calcareous; unstable when moist; few roots; soluble salts segregated and in form of nests, streaks, and splotches; salts contain considerable crystalline gypsum such as selenite; reaction fragments pH 9.3 (thymol blue); reaction of crystalline salt nests pH 7.6 (phenol

Horizon	*Depth, in inches*	*Profile description*
		red); soluble salt content estimated to be greater than 3 mmhos but less than 5 mmhos; clear wavy boundary.
CcsRcs	5–17	Light olive brown (2.5Y 5/3) when dry, olive brown (2.5Y 4/3) when moist; silty clay; cloddy peds that crumble to shaly plates under moderate pressure; slightly hard when dry, very firm when moist, sticky and plastic when wet; slightly calcareous; very unstable when moist; composite pH 8.5 (thymol blue); soluble salts segregated in form of nests, streaks, and splotches; population of selenite crystals high; reaction of shale fragments pH 9.4 (thymol blue); reaction of efflorescent salts pH 7.7 (phenol red); soluble salt content estimated to be greater than 4 mmhos; diffuse wavy boundary.
Rcs	17	Dark-gray Cody shale. A structureless type that contains efflorescent gypsum, probably selenite.

Range-Soil-Group: Saline upland.
Precipitation Zone: 10 to 14.
Soil Type: Arvada silty clay loam.
Location: Range Experiment Station, Summer pasture, Miles City, Custer County, Mont.

Horizon	*Depth, in inches*	*Profile description*
A21	0–1¼	Light gray (2.5Y 7/2) when dry, very fine sandy loam, grayish brown (2.5Y 5/2) when moist; vesicular crust; extremely hard, friable, slightly sticky, and slightly plastic; common very fine pores, few medium pores; noncalcareous; pH 7.4 (phenol red); abrupt boundary. Thickness range ¾ to 1¼.
A22	1¼–1¾	Light gray (2.5Y 7/2) when dry upper sides of plates, light brownish gray (6.5/2) when moist lower sides of plates, light clay loam, dark grayish brown (2.5Y 4/2) when moist; weak, very fine platy structure; slightly hard, friable, sticky, plastic; noncalcareous; pH 7.6 (phenol red); abrupt boundary.
B21t	1¾–6	Grayish brown (2.5Y 5/2) when dry, silty clay; dark grayish brown (2.5Y 4/2) when moist; moderate, medium columnar breaking to moderate, fine angular blocky structure with bleached fine sand and silt along prism faces; extremely hard, firm, very sticky and very plastic; common fine and medium pores; noncalcareous; pH 7.8 (phenol red); clear boundary.
B3ca	6–17	Grayish brown (2.5Y 5.4/2) when dry; light silty clay; dark grayish brown (2.5Y 4/2) when moist; moderate, medium angular blocky structure; very hard, friable, very sticky and plastic; common fine and medium pores; strongly calcareous; pH 9.2 (thymol blue); gradual boundary.
C1cs	17–30	Light brownish gray (2.5Y 6/2) when dry; light silty clay loam; dark grayish brown (2.5Y 4/2) when moist; weak, medium subangular blocky structure; very hard, friable, very sticky, and plastic; common fine and few medium and coarse pores; strongly calcareous; pH 8.8 (thymol blue); diffuse boundary.

Horizon	*Depth, in inches*	*Profile description*
C2cs	30–42	Grayish brown (2.5Y 4/2) when dry; light silty clay; dark grayish brown, (2.5Y 4/2) moist; massive; extremely hard, firm, very sticky, and plastic; strongly calcareous; pH 8.4 (thymol blue); many fine prominent lime nodules and threads, and few gypsum nests; gradual boundary.
C3cs	42–60	Grayish brown (2.5Y 5/2) when dry; silty clay; dark grayish brown (2.5Y 4/2) moist; massive; extremely hard, firm, very sticky, and very plastic; very weakly calcareous; pH 8.8 (thymol blue); few fine prominent gypsum nests.

Range-Soil-Group: Dense clay.
Precipitation Zone: 10 to 14.
Soil Type: Samsil clay.
Location: Twelve miles east of Newell, Butte County, S. Dak.

Horizon	*Depth, in inches*	*Profile description*
A11	0–1	Gray (5Y 5/1) when dry; clay; olive gray (5Y 4/2) when moist; weak, medium platy structure breaking to moderate medium granules; hard when dry, firm when moist; noncalcareous; abrupt wavy boundary.
A12	1–3	Same color as above; clay; weak medium and fine blocky structure; hard when dry; very firm when moist; noncalcareous; clear wavy boundary.
A13	3–8	Olive gray (5Y 4.5/2) when dry; clay; dark olive gray (5Y 3/2) when moist; weak, very coarse prismatic structure with moderate, coarse angular block and wedge-shaped aggregates; extremely hard when dry, very firm when moist; noncalcareous; cleary wavy boundary.
C1cs	8–12	Same color as above; clay; weak to moderate angular blocky and wedge-shaped aggregates; very hard when dry, very firm when moist; noncalcareous; gypsum segregations common; clear wavy boundary.
C2cs	12–19	Dark gray (5Y 4/1) when dry; clay; dark olive gray (5Y 3/2) when moist with streaks of light olive brown (2.5Y 5/6) when moist; massive with distinct oblique cleavage planes (slickensides); hard when dry, firm when moist; shale chips common; noncalcareous; soft gypsum segregations common; gradual boundary.
R	19+	Gray (5Y 5/1) when dry; shale; dark olive gray (5Y 3/2) when moist; some shale faces stained olive (5Y 5/4, 4/4); moist; platy, bedded; noncalcareous; nests of visible gypsum in upper part.

Range-Soil-Group: Panspot (interarea).
Precipitation Zone: 10 to 14.
Soil Type: Regent clay loam.
Location: Butte County, S. Dak.

Horizon	*Depth, in inches*	*Profile description*
A11	0–2	Grayish brown (10YR 4.5/2) when dry; loam; very dark grayish brown (10YR 3/2) when moist; moderate, fine granular structure; soft when dry, friable when moist.
A12	2–5	Same color as above; clay loam; weak, medium prisms and subangular blocks; slightly hard when dry, friable when moist.

Horizon	*Depth, in inches*	*Profile description*
B21t	5–8	Dark grayish brown (10YR 4/2) when dry; clay loam; very dark grayish brown (10YR 3/2) when moist; moderate, medium prismatic structure with moderate medium and fine blocky secondary structure; thin patchy clay films; hard when dry, firm when moist.
B22t	8–16	Grayish brown (10YR 5/2) when dry; clay; brown (10YR 5/3) when moist; moderate, medium prisms with strong fine angular blocky secondary structure; moderately thick continuous clay fiims; very hard when dry, firm when moist.
B31ca	16–21	Light brownish gray (10YR 6/2) when dry; silty clay; grayish brown (10YR 5/2) when moist; weak, medium prisms with moderate medium and fine angular blocky secondary structure; moderately thicky patchy clay films; hard when dry, firm when moist; moderately calcareous with a few, fine lime segregations.
B32ca	21–28	Same color as above; silty clay loam; weak, medium blocky structure; thin, patchy clay films; hard when dry, firm when moist; moderately calcareous.

Range-Soil-Group: Panspot.
Precipitation Zone: 10 to 14.
Soil Type: Rhoades loam.
Location: Thirty-five miles north of Newell, Harding County, S. Dak.

Horizon	*Depth, in inches*	*Profile description*
A2	0–2	Grayish brown (2.5Y 5/2) when dry; very fine sandy loam; very dark grayish brown (2.5Y 3/2) when moist; thin platy structure; soft when dry, very friable when moist; abrupt boundary.
B21t	2–8	Olive gray (5Y 5/2) when dry; clay; dark olive gray (5Y 3/2) when moist; strong, coarse columnar structure with moderate to strong, fine angular blocky secondary structure; tops of columns bleached gray (5Y 5/1) when dry; thick, continuous clay films; extremely hard when dry, very firm when moist; clear boundary.
B22t	8–18	Same color as above; heavy clay loam; weak, coarse angular blocks with moderate, medium and fine angular blocky secondary structure; thick, continuous clay films; very hard when dry, firm when moist; clear boundary.
C1	18–28	Gray (5Y 5/1) when dry; shaly, silty clay loam; dark gray (5Y 4/1) when moist; massive; hard when dry, firm when moist; clear boundary.
R1cs	28–36	Gray (5Y 5/1) when dry; weathered silty shale; dark gray (5Y 4/1) when moist; massive; fine segregations of gypsum and other salts common; gradual boundary.
R2	36+	Light gray (5Y 7/2) when dry; silty to very fine sandy shale; olive gray (5Y 5/2) when moist; massive; gypsum and salts on some shale faces.

Range-Soil-Group: Shallow complex (shallow limy).
Precipitation Zone: 15 to 19.
Soil Type: Epping silt loam.
Location: Two miles southeast of Stegal, Scotts Bluff County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A1p	0–1	Light brownish gray (10YR 6/2) when dry; dark grayish brown (10YR 4/2) when moist; silt loam; weak, medium platy structure; soft when dry; friable when moist; noncalcareous; abrupt smooth lower boundary.
A12	5–12	Grayish brown (10YR 5/2) when dry; very dark grayish brown (10YR 3/2) when moist; silt loam; weak, coarse prismatic breaking to weak, medium subangular blocky structure; slightly hard when dry, friable when moist; noncalcareous; clear smooth boundary.
C1	12–15	Light brownish gray (10YR 6/2) when dry; dark grayish brown (10YR 4/2) when moist; silt loam; structure and consistence as in above horizon; strong effervescence abrupt wavy lower boundary.
C2cR1	15–18	Light gray (10YR 7/2) when dry; grayish brown (10YR 5/2) when moist; weathered and fractured Brule siltstone; violent effervescence; clear smooth boundary.
R2	18+	White (10YR 8/2) when dry; very pale brown (10YR 6.53) when moist; Brule siltstone; violent effervescence; fractures to coarse blocky structure.

Range-Soil-Group: Shallow complex (shallow limy).
Soil Type: Potter silt loam.[1]

Precipitation Zone: 20 to 24.
Location: Seventeen miles northeast of Ashland, Clark County, Kans.

Horizon	*Depth, in inches*	*Profile description*
A1	0–9	Gray (10YR 5/1) when dry; silt loam; very dark gray (10YR 3/1) when moist; moderate, fine granular structure; friable when moist, slightly hard when dry; strongly calcareous; clear smooth lower boundary.
R	9+	White, hard, caliche.

Range-Soil-Group: Shallow complex (shallow to gravel).
Soil Type: Beaverton loam.

Precipitation Zone: 10 to 14.
Location: Sixteen miles southwest of Glendive, Dawson County, Mont.

Horizon	*Depth, in inches*	*Profile description*
A1	0–1½	Grayish brown (10YR 5/2) when dry, very dark grayish brown (3/2) when moist; gritty loam; moderate, fine crumb structure; soft, friable, and slightly sticky; clear boundary.
B2t	1½–4½	Dark grayish brown (10YR 4/2) when dry, very dark grayish brown (3/2.5) when moist; gritty silty clay loam; weak, medium prismatic breaking to moderate, medium and fine crumb structure; slightly hard, firm, slightly sticky and slightly plastic; patches of clay skins on all faces.

[1] Tentative name.

Horizon	*Depth, in inches*	*Profile description*
C1ca	4½–9½	Light gray (10YR 7/2) when dry, light brownish gray when moist; gritty silty loam; moderate, coarse blocky structure; slightly hard, very friable, and slightly sticky; very strongly calcareous.
IIC2ca	9½–18	This horizon consists of coarse sands and gravel with lime on the underside of the gravel. The lower portion of the profile is very loose and porous.

Range-Soil-Group: Shallow complex (shallow clay). Soil Type: Lismas clay.
Precipitation Zone: 10 to 14. Location: Twelve miles east of Newell, Butte County, S. Dak.

Horizon	*Depth, in inches*	*Profile description*
A1	0–4	Olive gray (5Y 4.5/2) when dry; clay; olive (5Y 4/3) when moist; weak, medium and coarse subangular blocky structure breaking to moderate, coarse granules; hard when dry, firm when moist; noncalcareous; clear wavy boundary.
C1	4–10	Olive gray (5Y 5/2) when dry; clay; olive (5Y 4.5/3) when moist; massive; very hard when dry, very firm when moist; a few fine shale chips; noncalcareous; clear wavy boundary.
C2cs	10–16	Olive gray (5Y 5/2) when dry; shaly clay; olive gray (5Y 4/2) and olive (5Y 4/3) when moist; massive; hard when dry, very firm when moist; nests of gypsum; noncalcareous; clear wavy boundary.
R1	16–28	Gray (5Y 6/1) and light olive gray (5Y 6/2) when dry; shale; dark gray (5Y 4/1) and olive gray (5Y 4/2) when moist; a few shale faces stained olive (5Y 5/4); platy; noncalcareous; gradual boundary.
R2	28+	Light olive gray (5Y 6/2) when dry; shale; olive gray (5Y 4/2) when moist; shale faces stained pale olive (5Y 6/3) to olive yellow (5Y 6/6); olive (5Y 5/4 and 5Y 5/6) when moist; platy; noncalcareous.

Range-Soil-Group: Clayey. Soil Type: Nunn clay loam, footslope phase.
Precipitation Zone: 10 to 14. Location: One mile northeast of Jordan, Garfield County, Mont.

Horizon	*Depth, in inches*	*Profile description*
A11	0–2½	Dark grayish brown (2.5YR 4/2) when moist; light clay loam with weak, medium plates breaking to moderate, fine granules; friable, slightly sticky and nonplastic; noncalcareous; clear boundary to A_{12}.
A12	2½–4	Dark grayish brown (2.5YR 4/2) when moist; heavy loam; moderate, medium and fine platy breaking to moderate, fine crumbs; very friable, nonsticky, and nonplastic; noncalcareous; abrupt boundary to B_{2t}.
B2t	4–10	Dark grayish brown (2.5YR 4/3) when moist, dark grayish brown (2.5Y 4/2) when moist crushed; silty clay loam; moderate, medium prismatic breaking to moderate, medium blocky structure; very hard, firm, sticky, and plastic; weak effervescense; thin, continuous clay films on all ped surfaces; clear boundary to B_{3ca}.

Horizon	Depth, in inches	Profile description
B3ca	10–14	Dark grayish brown (2.5YR 3.5/2) when moist; clay loam; weak, medium prismatic breaking to weak, medium blocky structure; thin, patchy clay skins on ped surfaces; very hard, firm, very sticky, and slightly plastic; violent effervescense; lime splotches throughout; gradual boundary to C_1.
C1	14–23	Dark grayish brown (2.5YR 4/2) when moist; clay loam; very weak, coarse prismatic structure; hard, friable, sticky, and slightly plastic; strong effervescense; streaks and some splotches of lime; gradual boundary to C_2.
C2	23–42	Dark grayish brown (2.5YR 4/2) when moist; clay loam; massive and slightly stratified; slightly hard, friable, slightly sticky, and slightly plastic; strong effervescense; contains a few fragments of partially weathered soft shales in lower portion of this horizon.

Range-Soil-Group: Silty.
Precipitation Zone: 10 to 14.

Soil Type: Conner loam.
Location: Eight miles northeast of Sundance, Crook County, Wyo.

Horizon	Depth, in inches	Profile description
A11	0–2	Reddish brown (5YR 1/4) when dry, dark reddish brown (3/3) when moist; weak thin platy loam which breaks to very fine granules; soft, very friable, and nonsticky; noncalcareous; pH 7.8 (phenol red); moderate organic matter; many worms; many pores; clear smooth boundary.
A12	2–9	Dark reddish brown (5YR 3/4) when dry, dark reddish brown (3/3) when moist; moderate coarse, prismatic structure breaks to fine prisms; loam; hard, very friable, and slightly sticky; noncalcareous; pH 7.8 (phenol red) moderate organic matter; many worms; many pores; clear smooth boundary.
C1ca	12–22	Light reddish brown (5YR 6/4) when dry, reddish brown (4/4) when moist; weak, coarse prismatic loam; slightly hard, very friable, and nonsticky; strongly calcareous; pH 8.0 (phenol red), many roots and pores; occasional wormholes; secondary lime carbonate in reticulate forms, white (5YR 8/1) when dry; clear wavy boundary.
C2ca	22–34	Reddish brown (5YR 5/4) when dry, reddish brown (4/4) when moist; moderate, coarse prismatic to fine angular blocky; structure loam; hard, firm and nonsticky; very strongly calcareous; secondary lime carbonate in reticulate and soft concretionary forms pH 8.0 (phenol red); many roots; occasional worm holes and pores; clear smooth boundary.
C3	35–50	Yellowish red to reddish yellow (5YR 5/6) when dry, reddish yellow and yellowish red (6/6–4/6) when moist; massive; loam; slightly hard, friable, and nonsticky; strongly calcareous; pH 8.0 (phenol red) clear smooth boundary.
C4	50–84	Reddish yellow (5YR 6/6) when dry, yellowish red (5/6) when moist; massive; loam; slightly hard, friable, and nonsticky; strongly calcareous; pH 8.0 (phenol red).

Range-Soil-Group: Silty.

Precipitation Zone: 15 to 19.

Soil Type: Mitchell very fine sandy loam, thin topsoil phase.

Location: One mile west of Scottsbluff National Monument, Scottsbluff, Scotts Bluff County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A1	0–3	Light brownish gray (10YR 6/2) when dry, dark grayish brown (10YR 4/5/2) when moist; very fine sandy loam; weak fine crumb; soft when dry, friable when moist; strong effervescence; clear smooth boundary.
C1	3–13	Light gray (10YR 7/2) when dry; grayish brown (10YR 5/2) when moist; very fine sandy loam; weak, coarse prismatic breaking to a weak, fragmental structure; abrupt smooth boundary.
A1b	13–15	Grayish brown (10YR 5/2) when dry; very dark grayish brown (10YR 3/2) when moist; very fine sandy loam; moderate coarse prismatic breaking to moderate, medium fragments; soft when dry, friable when moist; slight effervescence; clear smooth boundary.
C1b	15–22	Light brownish gray (10YR 6/2) when dry; dark grayish brown (10YR 4/2) when moist; very fine sandy loam; weak, coarse prismatic breaking to weak, fragments; soft when dry; friable when moist; violent effervescence; insect burrows evident; clear smooth boundary.
C2b	22–60	Color, texture, and consistence as in above horizon; massive; violent effervescence; partially weathered Brule chips are numerous in this horizon.

Range-Soil-Group: Silty.
Precipitation Zone: 20 to 24.

Soil Type: Ulysses silt loam.
Location: Ten miles east of Hayes Center, Hayes County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A1	0–8	Dark grayish brown (10YR 4.5/2) when dry, very dark grayish brown (10YR 3.5/2.5) when moist; silt loam; weak, coarse subangular blocky structure; soft when dry, very friable when moist; noncalcareous; abrupt smooth boundary.
B21t	8–13	Grayish brown (10YR 5.2/5) when dry, very dark grayish brown (10YR 3.5/2.5) when moist; silt loam; weak coarse prismatic structure; soft when dry, very friable when moist; noncalcareous; clear smooth boundary.
B22t	13–19	Light brownish gray (10YR 6/2) when dry, dark grayish brown (10YR 4/2) when moist; silt loam; weak, coarse prismatic structure; soft when dry; very friable when moist; strong effervescence; clear smooth boundary.
C1ca	19–32	Light gray (10YR 7/2) when dry, grayish brown (10YR 5/2) when moist; silt loam; weak, coarse prismatic; structure; soft when dry; very friable when moist; violent effervescence; clear smooth boundary.
C2	32–48	Light gray (10YR 7/2) when dry, light brownish gray (10YR 6/2) when moist; silt loam; massive; soft when dry; very friable when moist; strong effervescence.

Range-Soil-Group: Silty.
Precipitation Zone: 25 to 29.

Soil Type: Judson silt loam.
Location: Eleven miles east of Nelson, Nuckolls County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A1p	0–6	Grayish brown (10YR 5/2) when dry, very dark brown (10YR 2/1.5) when moist; silt loam; moderate, distinct, fine granular structure; soft when dry, friable when moist.
A12	6–14	Dark grayish brown (10YR 4/2) when dry, black (10YR 2/1) when moist; silt loam; moderate, distinct, fine granular structure; soft when dry, friable when moist. This horizon and the one above derive as alluvial deposits from loessial topsoil from the slope above.
A1b	14–31	Dark grayish brown (10YR 4/2) when dry, very dark brown (10YR 2/2) when moist; silt loam; moderate, fine granular structure; soft when dry, friable when moist.
B2b	31–46	Pale brown (10YR 6/3) when dry; very dark grayish brown (10YR 3/2) when moist; silty clay loam; moderate, coarse and medium granules; slightly hard when dry, firm when moist.
C1b	46+	Light yellowish brown (10YR 6/4) when dry; brown (10YR 5/3) when moist; silty clay loam; moderate, coarse blocky structure breaking to moderate, very fine blocks; slightly hard when dry, firm when moist.

Range-Soil-Group: Sandy.
Precipitation Zone: 15 to 19.

Soil Type: Maysdorf sandy loam.
Location: Twenty-nine miles west of Gillette, Campbell County, Wyo.

Horizon	*Depth, in inches*	*Profile description*
A1	0–6	Very dark grayish brown (10YR 3/2) when moist, gray (10YR 5/1) when dry; coarse sandy loam; very fine granular structure; soft, very friable, and nonsticky; noncalcareous; pH 7.2 (phenol red); abrupt smooth boundary.
B21t	6–13	Reddish brown (5YR 4/3) when moist; coarse sandy loam; very weak, coarse prismatic structure which breaks to weak coarse subangular blocks; slightly hard, very friable, and nonsticky; noncalcareous; pH 7.2 (phenol red); clear smooth boundary.
B22t	13–21	Reddish brown (5YR 4/4) when moist; sandy clay loam with thick continuous clay films; moderate, medium prismatic structure which breaks to moderate, coarse angular blocks; hard, firm, and sticky; noncalcareous; pH 7.4 (phenol red); clear smooth boundary.
B3	21–40	Dark brown (7.5YR 4/2) when moist; coarse sandy loam; very weak, very coarse, subangular blocky structure; slightly hard, very friable, and slightly sticky; noncalcareous; pH 7.4 (phenol red); clear smooth boundary.
C1	40–48	Light yellowish brown (10YR 6/4) when moist; coarse sandy loam; single grained; slightly hard; noncalcareous; pH 7.4 (phenol red).

Range-Soil-Group: Sandy.
Precipitation Zone: 20 to 24.

Soil Type: Holt fine sandy loam.
Location: Game refuge, Valentine, Cherry County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A11	0–2	Dark grayish brown (10YR 3/2) when moist; fine sandy loam; surface accumulation; noncalcareous.
A12	2–5	Very dark brown (10YR 2/2) when moist; fine sandy loam; high in organic matter; very friable; noncalcareous.
B2	5–30	Grayish brown (10YR 5/2) when dry; sandy loam; noncalcareous; texture slightly more clay at 12 to 15 inches.
C1	30–42	Light gray (10YR 7/1) when dry; weathered limy sandstone with some unweathered fragments; calcareous; fine sand loam matrix.
R	42+	Partially weathered, soft, limy sandstone and caliche.

Range-Soil-Group: Overflow.
Precipitation Zone: 25 to 29.
Soil Type: Silt loam (Judson).
Location: Nuckolls County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A1P	0–6	Grayish brown (10YR 5/2) when dry to very dark brown (10YR 2/1.5) when moist. Silt loam with moderately distinct, fine granular structure; soft when dry, friable when moist.
A12	6–14	Dark grayish brown (10YR 4/2) when dry to black (10YR 2/1) when moist. Silt loam with moderately distinct, fine granular structure; soft when dry, friable when moist. This horizon and the one above are alluvial deposits of loessial topsoil from the slope above.
A1b	14–31	Dark grayish brown (10YR 4/2) when dry to very dark brown (10YR 2/2) when moist. Silt loam with moderate, fine granular structure; soft when dry, friable when moist. This is the "A" horizon of a buried Hastings silt loam soil.
B2b	31–46	Pale brown (10YR 6/3) when dry to dark gray brown (10YR 3/2) when moist. Silty clay loam with moderately distinct, coarse and medium granules; slightly hard when dry, firm when moist.
C1b	46+	Light yellowish brown (10YR 6/4) when dry to brown (10YR 5/3) when moist. Silty clay loam with moderately distinct coarse blocky structure breaking to moderate, very fine blocky; slightly hard when dry, firm when moist.

Range-Soil-Group: Sands.
Precipitation Zone: 20 to 24.
Soil Type: Valentine sand.
Location: Game refuge, Valentine, Cherry County, Nebr.

Horizon	*Depth, in inches*	*Profile description*
A1	0–5	Light brownish gray (10YR 6/2) when dry; fine sand; surface inch slightly darker due to high organic content. This surface layer varied in depth from 3 to 7 inches around the area under study.
Ac	5–18	Grayish brown sand (10YR 5/2) when dry; fine sand with some coarse sand.
C1	18+	Light gray (10YR 7/2) when dry; fine sand mixed with some coarse sand; noncalcareous.

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