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MILTON WHITNEY, Chief of Bureau.

SOILS OF THE SAN LUIS VALLEY, COLORADO.

BY

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LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Soils,
Washington, D. C., November 18, 1911.

Sir: I have the honor to submit for publication as Circular No. 52 of this bureau a manuscript entitled "Soils of the San Luis Valley, Colo.," prepared by Macy H. Lapham, scientist in soil survey, in charge of inspection work in the western division. This article embodies the results of a reconnoissance survey of that portion of the San Luis Valley lying in Colorado, into which at present many settlers are going. Many of these settlers are unacquainted with the conditions of climate and soil in the valley, and it is believed the information afforded by this circular will be valuable to them in selecting lands suitable for the several lines of farming in which they may desire to embark. The peculiar methods of disposing of the lands of this section, which are briefly outlined in the accompanying article, make it especially necessary for the purchasers to be informed of local conditions in order that they may avoid failure and loss of their investments. The need for this information was brought to the attention of the bureau by prominent citizens of the valley, whose request for the detailing of a soil expert to report upon the soils bore the indorsement of Hon. Simon Guggenheim, United States Senator from Colorado.

Respectfully,

Milton Whitney,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

SOILS OF THE SAN LUIS VALLEY, COLORADO.

LOCATION AND BOUNDARIES.

The San Luis Valley lies principally in south-central Colorado. Although sometimes designated as San Luis Park, it is not to be confused in physiographic features and geologic history with the intermountain parks forming extensive land features in other parts of the State.

An extension of the valley continues for some distance southward into New Mexico. This portion is separated from the more northern part, which lies entirely within the State of Colorado and which is the subject of this report, by a series of flat-topped, lava-capped mesas or tablelands of moderate elevation as compared with regional mountain features, known as the San Luis Hills and extending in a northeasterly direction from a point near the Colorado-New Mexico boundary line. The valley extends in a north-and-south direction for a distance of about 80 miles and has a maximum width of 45 miles. It reaches an elevation of slightly more than 7,500 feet above sea level and is one of the most extensively cultivated irrigated districts of its altitude in the United States.

It is inclosed on the east by the bold and serrated Sangre de Cristo Mountains of abrupt slope, culminating in the peak of Sierra Blanca, reaching an altitude of more than 14,000 feet. Upon the west it is bounded by the Saguache and Conejos Ranges, of less abrupt character. These mountains gradually approach each other toward the north and unite at Poncho Pass, at the head of the valley. The valley is drained by the Rio Grande del Norte, which enters from the west at Del Norte and crosses the southwestern portion. A number of minor tributary streams debouching from the mountains find their way into the valley. Few of these are of perennial flow, but lose their waters by seepage through underlying sands and gravels. Of these, the more important having their source in the west side ranges, enumerated in order of occurrence from south to north, are the Conejos River, and Alamosa, Piedra Pintada, La Jarita, and Saguache Creeks. The last mentioned constitutes the most important stream of the northern part of the valley. Of the numerous streams entering the valley from the east only a few possess any degree of

importance or permanence of flow. They are of higher gradient than the west-side streams, usually head in glacial cirques, but cover only small drainage areas. The northern part of the valley trough is

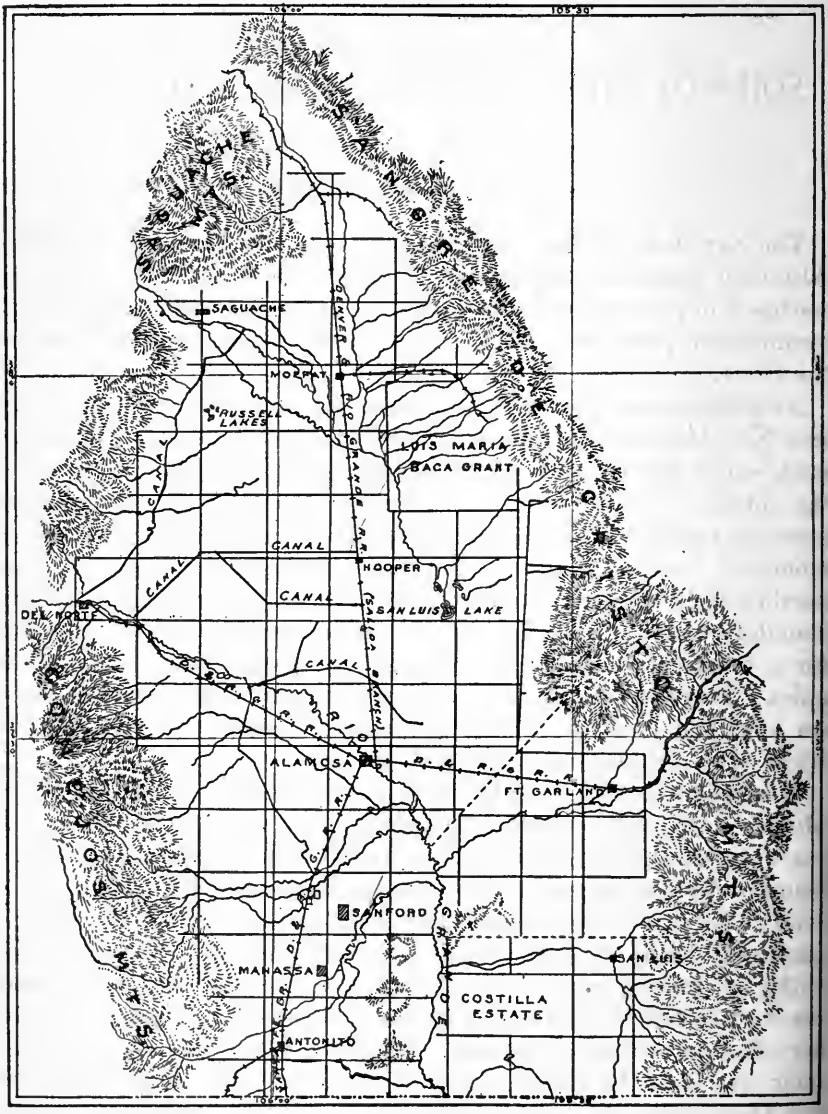

FIG. 1.—Sketch map of San Luis Valley, Colorado.

traversed for a distance of some 40 miles by San Luis Creek, rising in the vicinity of Poncho Pass. Like the less pretentious streams reaching the valley from either side, it is of inconsiderable flow.

The valley is traversed from north to south and from east to west by branches of the Denver & Rio Grande Railroad, affording connections with Salida and the main line of the Denver & Rio Grande Railroad upon the north; with Durango, Grand Junction, and intermediate points upon the west; and with Pueblo and Denver by way of La Veta Pass upon the east. The northern and western routes are by narrow-gauge lines, necessitating transfer of freight at Alamosa or other connecting points.

Alamosa, situated in the south-central part of the valley, has a population of 3,013 and is the principal town of the valley, being distant by rail from Pueblo 133 miles and from Denver 252 miles. Other locally important towns lying along the western margin of the valley are Saguache, Del Norte, and Monte Vista. Sanford, Conejos, Manassa, Antonito, and Richfield are small towns in the southern part of the valley, while Moffat, Hooper, and Mosca lie at intervals along the railroad traversing its central part.

CLIMATE.

The prevailing climatic conditions are healthful. When aided by irrigation, the climate is favorable to the development of grains, grasses, leguminous crops, root crops, and hardy vegetables.

The average annual rainfall for the valley is about 8¼ inches, though subject to wide variations from year to year. At certain points the annual precipitation has been known to amount to less than 3 inches and the maximum is often greatly in excess of the normal. Precipitation occurs mainly as brief local showers, chiefly during the spring and summer months and, while generally insufficient in itself, is important as supplementing irrigation.

The winter season is rather long and sometimes marked by low temperatures, occasionally reaching extremes of —30° F. The summer season is short and characterized by moderately warm to warm days, the temperature rarely exceeding 85° or 90°. An unusually large percentage of clear days prevails and a low relative humidity moderates the effect of low winter temperatures. The warm days of summer are rarely oppressive and are succeeded by cool evenings, induced by the rapid radiation favored by altitude and atmospheric conditions.

There is at times a brisk wind movement during the early spring months, usually from the southwest, and often continuing for several days at a time. This at times becomes excessive and gives rise to dust storms and upon the lighter sandy soils may cause some damage to young growing crops from drifting.

Destructive hailstorms frequently occur. A summary of available weather records maintained at various points in the valley is as follows:

Average monthly temperature at stations in San Luis Valley.[1]

[Degrees Fahrenheit.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Term of record.
Saguache	18.3	23.6	33.6	43.4	51.6	63.8	64.4	62.7	55.7	45.4	33.0	20.0	1886–1905
Garnett	13.5	21.7	31.2	41.6	49.2	57.8	61.3	60.6	53.6	41.4	30.0	13.4	1897–1905
Monte Vista	16.1	20.8	32.3	41.6	51.8	59.1	63.5	62.5	55.2	43.8	29.7	17.9	1886–1896
La Jara	22.1	22.3	34.8	45.0	52.3	60.8	64.2	63.7	58.5	47.6	35.2	25.0	1892–1897
Conejos	18.1	26.2	35.5	41.8	49.4	58.0	62.5	62.6	58.8	45.3	36.2	18.6	1904–1905
San Luis	19.5	24.2	33.3	42.3	50.5	58.6	63.1	62.4	55.8	45.3	34.0	22.5	1891–1905
Fort Garland	18.2	22.8	33.5	41.3	52.0	62.0	66.2	63.7	55.2	44.1	30.0	21.2	1852–1883
Average	18.0	22.9	33.2	42.1	51.3	60.8	64.3	62.8	55.5	44.6	31.6	20.0	

[1] From U. S. Geol. Survey Water-Supply Paper 240, Geology and Water Resources of the San Luis Valley, Colo. By C. E. Liebenthal.

Average monthly precipitation at stations in San Luis Valley.

[Inches.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Term of record.
Saguache	0.26	0.35	0.21	0.62	0.89	1.10	1.80	1.80	0.86	0.70	0.28	0.23	1886–1905
Garnett	.08	.24	.23	.25	.72	.59	1.23	1.35	.84	.40	.25	.25	1891–1905
Monte Vista	.24	.51	.32	.85	.81	.29	1.58	1.28	.87	.48	.22	.32	1886–1896
La Jara	.11	.91	.13	.15	1.00	.22	1.13	1.04	.64	.69	.30	.03	1892–1896
Conejos	.78	.67	.20	.00	.06	1.00	.94	1.46	3.53	.99	.00	.47	1904–1905
San Luis	.49	.64	.89	.95	1.23	.67	2.26	1.27	1.18	.92	.36	.79	1891–1905
Average for valley	.29	.48	.42	.62	.91	.65	1.66	1.19	.97	.66	.28	.40	

SOILS.

The valley is a basinlike depression, treeless, and topographically featureless. It is a desertlike plain of gentle, uniform slope, and except near the inclosing ranges apparently flat and broken only by miles of undeviating irrigation ditches. In the vicinity of the valley trough the slope becomes insufficient to afford free drainage, and a more or less permanently wet condition obtains over extensive areas of the northern and middle portions, which are traversed by no permanent stream and are in places characterized by shallow basins without drainage and occupied by alkali lakes.

The valley depression is partly filled with gravel, sand, and clay, derived principally from volcanic rocks of the adjacent mountains and deposited by the waters of a former lake or inland sea. This formation consists mainly of alternating strata of blue clay and water-bearing sand—the source of an extensive supply of artesian well water. The valley floor approaches the inclosing ranges by gently increasing slopes, usually merging into mountain foot slopes.

These foot slopes are mainly formed by a series of coalescing alluvial fans composed of the coarser detrital material distributed by torrential streams debouching from the mountain barriers. Since the larger streams of greater carrying capacity emerge from the west-side ranges, the fans are here much more extensive and have built their way farther out into the valley, pushing the valley trough toward its eastern margin. The waters of Saguache Creek appear to have carried comparatively little of the coarser detrital material, and the fan structure here is imperfectly developed. The soils of the fan deposits occur as a wide margin of sloping, naturally well-drained, porous, gravelly soils, bordering the flat area of deficient drainage occurring in the lower parts of the valley basin. Much of the material of the lower outlying portions of the fans has been assorted and deposited in the waters of the lake formerly occupying the valley basin and intermingled with the finer deposits of the valley floor, or the older detrital and lacustrine fan deposits have been covered by more recent gravels and other stream-distributed foot-slope material.

In the bottoms and flood plains of the larger or alluvium-carrying streams extensive areas of recent stream-deposited sediments occur, usually of darker color, heavier texture, and more compact structure than the soils of the foot slopes. The deposited areas are of gently sloping to level surface and are frequently subject to overflow, and sometimes support tree growth, consisting principally of cottonwood and willow. Soils of this character are of wide distribution, not only in stream bottoms, but over much of the lower valley plains, where as superficial deposits they obscure the earlier lacustrine sediments. Along the line of contact between the foot-slope deposits and the alluvial soils of the stream bottoms and valley floor the soils have been modified by intermingling of recent stream-deposited material. Extensive modification in mineral composition, texture, and structure has been brought about by decomposition or weathering of the mineral fragments subsequent to their deposition. In certain localities the effect of winds has caused modification of the original material by the formation of extensive areas of wind-drifted sands.

Soils of the Western and Southern Parts of the Valley.

Although a large number of soils occur throughout the valley, many of the types are of uniform and widespread occurrence. This is true particularly of the more thickly settled and highly developed farming districts of the western slopes covered by the great alluvial fan of the Rio Grande. This fan, having its apex at the entrance to the canyon of that stream near Del Norte, extends east with gently decreasing slope into the valley and includes the

greater part of the district lying between Mosca, Hooper, and Alamosa on the east and the mountains on the west. In this district, which was covered by a soil survey conducted by the Bureau of Soils in 1903,[1] the soils are of porous and gravelly character and underlain by gravelly subsoils. The prevailing types are of reddish-brown color, and are classed as the soils of the San Luis series, of which three members, viz, the San Luis sand, sandy loam, and loam, were recognized and mapped. They occur over extensive areas outside the limits of this earlier survey and represent the commonest soil features of the southern and western parts of the valley.

SAN LUIS SAND.

The San Luis sand occurs as a broad belt extending from the base of the mountains to the vicinity of Center and Monte Vista, or as narrow and irregular areas extending into the valley to the vicinity of the valley trough. It is of porous, incoherent, leachy character and consists mainly of fragments of the volcanic rocks of the adjacent mountains. It is somewhat subject to drifting by winds, forming occasionally slight ridges or dunes. It is underlain by a still coarser and more porous gravelly subsoil at a depth of from 2 to 4 feet. It never puddles or becomes sticky when wet and is readily permeated by water. These characteristics favor rapid drainage, but some of the lower and more gentle slopes have become swampy or waterlogged areas and more or less affected by alkali as the result of seepage of irrigation water from the more elevated slopes. Originally over much of the area covered by this soil type a compact and partially cemented layer occurred at the depth of penetration by rains. Under irrigation this has disappeared, except upon the higher ridges, owing to softening and dissolution of the cementing materials, rendering the soil still more leachy and porous and requiring copious irrigation to supply growing crops.

SAN LUIS SANDY LOAM.

The San Luis sandy loam ranks second in extent of area covered. It is a coarse, reddish-brown soil, carrying a large quantity of gravel and underlain by a coarse, porous, gravelly subsoil. The surface material extends to the depth of 18 to 36 inches and is of slightly heavier character than the San Luis sand. It is noticeably sticky when wet, and is marked by narrow strips occupied by heavier phases of the soil. The surface is subject to minor irregularities, but is readily leveled and prepared for irrigation, not, however, without some danger of exposing the coarse, gravelly subsoil. It is readily penetrated by drainage or irrigation waters and the more elevated

[1] Soil Survey of the San Luis Valley, Colorado. Field Operations, Bureau of Soils, 1903.

areas are naturally well drained. The lower lying districts have been injured from seepage and accumulation of alkali. These unfortunate conditions are of more widespread occurrence upon this type than upon the adjacent San Luis sand.

SAN LUIS LOAM.

The third member of the San Luis series of soils, the San Luis loam, covers but limited areas of the fan slopes. This type ranges in texture from a fine sandy loam to a light loam and represents a finer grade of material, transported by mountain torrents or derived in part from wash from slightly more elevated adjacent soils. It is similar in appearance to the San Luis sandy loam, but is of heavier character and becomes sticky and plastic when wet. It carries but little coarse sand, but contains some fine gravel. It occupies lower levels and depressions between adjacent low slopes of coalescing detrital fans and in places is affected by accumulation of seepage water. The soil material is inclined to puddle, and the surface frequently becomes baked and hard. It is usually underlain at a depth of from 2 to 3 feet by sand or sandy loam, grading into the usual gravelly subsoil of the San Luis series. The surface is such as to favor irrigation, but the type is generally poorly drained and contains injurious quantities of alkali salts. It produces good yields of native grasses where flooded, and when drained becomes a valuable soil for the production of grains, alfalfa, and other staple crops of the valley.

RIO GRANDE AND OTHER ALLUVIAL SOILS.

The recent soils of the river flood plains embraced within the limits of the survey of 1903 in the Rio Grande fan district are classed as the Rio Grande series, which, like the San Luis series, has a wide distribution in the valley outside the limits of the survey. They are dark brown to black in color, carry considerable quantities of organic matter, frequently support some timber growth, and are usually underlain by sandy and gravelly subsoils.

Of the members of this series recognized and mapped in the earlier survey the Rio Grande sandy loam is the more extensive, occupying a belt from one to several miles wide along the Rio Grande River. It is a friable soil of fine sandy loam texture and easily maintained in good tilth. The surface soil is less gravelly than the soils of the San Luis series, owing to superficial covering of fine alluvium, but it is underlain, generally at about 2 feet, by a sandy and gravelly subsoil of loose, porous structure similar to the San Luis series, which in this type is frequently exposed at the surface over small areas. The type is of gently sloping surface, favoring irrigation, but cut in places by remnants of former stream courses or bands of gravel

where such channels have been filled. Much of the type is subject to overflow or is purposely flooded to promote the growth of wild hay. Surface flooding, coupled with the porous subsoil, favoring rapid percolation, has tended to keep the soil relatively free from alkali salts, although these occur in certain areas. With protection from overflow and efficient irrigation, cultivation, and drainage, it is admirably adapted to the production of alfalfa, sugar beets, and potatoes, and constitutes the most promising trucking soil in the district.

Other less extensive members of the Rio Grande series occur as narrow to moderately wide belts parallel to the course of the Rio Grande or less important streams. They range from fine sandy loams and loams to heavy silt and clay loams, often carrying some gravel. Usually within a few feet of the surface they are underlain by sandy and gravelly subsoils. Like the Rio Grande sandy loam, they are often subject to overflow. The heavier members become sticky when wet, puddle readily, and are maintained in good tilth with difficulty, except when in a favorable condition as regards moisture. When artificially drained, effectively irrigated, and thoroughly cultivated they are better adapted to the production of grains and grasses than the lighter soil types. Alfalfa, sugar beets, and hardy vegetables can be successfully grown upon these soils. Owing to the compact structure of the soil and consequent slow rate of moisture movement by percolation or capillarity, these heavier types are not well adapted to the method of subirrigation usually practiced in the valley.

Soils of the Northern Part of the Valley.

In the more northern portions of the valley the soils are prevailingly heavier in character, the alluvial fan-forming streams being of less volume or lower gradient, causing less extensive distribution of the coarser material. The quantity of lime in the soils is also less. The sandy and gravelly subsoils often disappear or occur at greater depth, except upon the more pronounced slopes in the immediate vicinity of the mountains.

Upon the more elevated portions of the fans and foot slopes the surface soils are usually of chocolate-brown to light-brown color and generally gravelly sandy loams. They are underlain by porous subsoils of coarse texture and are related to the San Luis series. The percentage of gravel, particularly in the subsoil, is excessive. The soils support a sparser growth of native desert vegetation than do the lower lying soils of the valley. They usually occur above the sources of water available for irrigation and are utilized only for grazing. Near the valley margins the soils merge into a number of interme-

diate types having some characteristics of the San Luis series and some of the Rio Grande series.

These intermediate types are light-brown or chocolate-brown to dark grayish brown in color and generally a heavy loam to clay loam in texture, with but little gravel. At Swede Corners, near the mountain foot slope, 6 miles south of Saguache, the prevailing soil is a light-brown, friable sandy loam, retentive of moisture, and underlain by a grayish-brown or chocolate-brown compact clay loam. It is well suited to irrigation and the production of vegetables and staple farm crops. In the district north of the various branches of Saguache Creek and below the "mesas," as the alluvial fans and foot slopes are locally termed, the mixing of material washed from the hills with the heavier lake and stream sediment of the valley floor has given rise to chocolate-brown, dark-brown, or gray soils, generally of heavy clay loam texture, becoming lighter in color and texture below the first foot, but usually extending with but little change to depths greater than 3 feet. The surface is here slightly sloping or flat and drainage is deficient. The soils generally support a heavy growth of the usual desert shrubs, but barren areas sometimes showing surface incrustation of alkali salts occur in the more poorly drained localities.

Samples collected in sec. 2, T. 44 N., R. 9 E., in the margin of a wet, barren depression, contained slightly more than 1 per cent of alkali salts in the soil and subsoil, an amount in excess of that which can be withstood by ordinary farm crops. Additional samples collected in sec. 30, T. 44 N., R. 10 E., on soil of similar character, were found to carry 3.61 per cent of total salts in the first 18 inches and 2.45 per cent in the subsoil to 3 feet. The soils of this district are tenacious heavy clay loams. When dry they frequently assume a peculiar granular condition, giving them a porous, mealy structure. They are at present not extensively utilized except for grazing, and without irrigation and drainage are not generally suitable for the production of crops. With irrigation and artificial drainage, which favor the removal of excess alkali salts, they would be available for alfalfa, grasses, grains, and some of the hardier vegetables adapted to heavy soils.

While drained by no permanent stream, the northern part of the valley is traversed by a large number of creeks carrying considerable quantities of water after heavy rainfall on the mountain slopes. Of these Saguache Creek is the largest and of most constant flow. Upon reaching the valley many of these streams divide into a network of channels covering extensive areas which, during floor periods, are subject to overflow. The most of the tributary waters pass into the subsoils, and with those of the Rio Grande and other streams lying to the south become the source of supply for the artesian basin cover-

ing the valley. At times these waters become charged with sediment. Owing to the agencies favoring wide distribution and deposition afforded by the network of streams of slight gradient, this material has been deposited superficially over extensive areas, giving rise to several types of soil related to the Rio Grande series.

Much of the territory in the vicinity of Moffat and Saguache consists of soils of this character. Deficient slope and the absence of any efficient natural drainage outlet, with the nearly constant water supply afforded by Saguache Creek, has here developed extensive areas suited for the production of native hay. Poor drainage has also caused the accumulation of alkali over wide areas and the saturation of the subsoils of the lower districts. Owing to these conditions, the soils are often adapted only for native grasses for hay or grazing. The soils are usually dark in color, well supplied with organic matter, friable under cultivation, and retentive of moisture, and when adequately irrigated and drained they will be adapted to the production of the grains, grasses, potatoes, and truck crops. Samples taken in sec. 3, T. 43 N., R. 9 E., in an area used for wild hay west of Moffat, show a dark-gray, friable sandy loam soil, extending to a depth of 24 inches, underlain by a heavier sticky loam. Both soil and subsoil carry a small quantity of alkali salts, which have only locally become sufficiently concentrated to cause injury to crops, the excess of salts having here been removed by periodical flooding.

West of this section, in the Warner neighborhood, drainage conditions show improvement, the soil being a dark heavy loam, generally free from alkali and excellently adapted to the production of root crops, hardy vegetables, and general farm crops. In the vicinity of Saguache the prevailing soils occurring along Saguache Creek consist of dark-colored to black loams and heavy loams, carrying a large quantity of organic matter, friable, productive, and frequently underlain by sands and gravels at less than 3 feet. They are sometimes subject to overflow or poor drainage and to local accumulation of alkali salts.

In the districts covered by recent alluvial stream deposits in the extreme northwestern part of the valley occur limited areas of dark loam of a more silty character than is typical of the larger soil areas of the valley. This soil is friable, easily tilled, and of excellent moisture-retaining properties. It is usually well drained and free from alkali, well situated for irrigation, and ranks as one of the most promising soils of the entire valley. One area of particularly desirable character and location occurs in the vicinity of Mirage.

Near the northern extremity of the valley trough, where it is crossed by San Luis Creek, the soils are dark-gray to black in color, usually heavy loam or clay loam in texture, and carry a large quantity of organic matter. When in a favorable condition as regards moisture

they are fairly friable, though when wet they are decidedly sticky. Owing to deficient regional drainage, extensive areas are in native grasses or exist as alkali flats supporting only a growth of salt grass.

Samples collected in sec. 6, T. 44 N., R. 10 E., showed 3.61 per cent of total alkali salts in the surface foot and 1.91 per cent in that portion of the soil profile included between depths of 12 and 30 inches. In sec. 8, T. 43 N., R. 10 E., about 1 mile southeast of Moffat, the surface foot was found to contain 0.48 per cent of alkali; the subsoil to the depth of 24 inches carried 0.38 per cent, an amount which is tolerated by the more alkali-resistant crops, but sufficient in concentration to cause injury to young vegetables and nearly all staple farm crops of the valley.

The district lying south of Moffat and east of Mosca and Hooper, including the valley trough and eastern slope, is covered mainly by wind-blown sands, broken by barren playas or flats, which during wet weather are occupied by shallow alkali lakes and ponds. The region is sparsely settled and is inadequately supplied with water for irrigation. Artesian wells may be developed, but owing to unfavorable soil and drainage conditions this region gives but little promise. Where utilized the soils are devoted mainly to grazing.

The conditions observed in a brief reconnoissance of the northern part of the valley in September, 1910, are in some respects disappointing, yet with adequate irrigation and drainage facilities, the soils should prove superior in point of productiveness to the porous sandy and gravelly soils of the central and eastern parts of the valley.

AGRICULTURE.

Mexicans entering from New Mexico first settled the valley, locating along the Rio Grande bottoms, where a permanent water supply was available. Stock raising was the principal industry, and irrigation consisted mainly of desultory wild flooding to promote the growth of native grasses. Later there followed a considerable influx of American settlers, French Canadians, Scandinavians, and others of foreign birth or extraction.

The first important irrigation canals were constructed in the sixties to supply lands adjacent to the Rio Grande. Some time later other and more extensive systems taking water from the Rio Grande for the valley floor and slopes were projected, and within a few years a number of canals had been completed. These systems covered most of the district on both sides of the Rio Grande, and west of the towns of Mosca and Hooper, which became important grain shipping points in the late eighties. From here irrigation extended westward to the coarser gravelly soils of the San Luis series, covering the more elevated slopes of the Rio Grande alluvial fan.

With the advent of extensive irrigation wheat became the dominant crop, the yield being high and prices attractive. The farming methods adopted were, however, unsuited to maintaining the soils in a permanently productive condition. The farms were large, the fields poorly prepared for seeding, and irrigation consisted in allowing the water to seep from open ditches into the subsoils until a condition of saturation was reached and the level of the water table raised sufficiently to render the surface moist. This permitted the loss of much water by percolation and led to the water-logging of extensive areas of soils upon the lower slopes. Here excessive quantities of alkali salts accumulated. The fields became infested with weeds, and continuous cropping of grain exhausted the supply of organic matter of the soil, reducing its power to hold moisture, and decreasing its productiveness. Several years of unusual shortage in water supply ensued, farms were mortgaged and passed into the hands of creditors, and large areas of land lying above the more reliable sources of water supply or occurring upon the lower water-logged slopes, some of which lay within the older and more highly developed districts, were practically abandoned.

Owing to these circumstances, agricultural production has declined in some extensive sections and the rural population is less at present than a number of years ago. In other districts the introduction of different crops, such as field peas and sugar beets, the adoption of improved cultural methods, and the development of artesian water have resulted in the revival of agriculture on a more permanent and successful basis than could ever have been brought about under the old régime. The most prominent of these successful districts are in the vicinity of Monte Vista, Center, and Saguache. Still more recently, attention has been directed to the settlement and development of the northern part of the valley around Moffat. The valley was for many years an important grazing region, and Moffat and other small towns scattered along the railroad have ranked among the leading cattle shipping centers of the State. At the present day the cutting of wild hay and cattle raising constitute the principal industries of the valley, only a relatively small proportion of which is actually under cultivation. Even in the more thickly settled districts of prosperous farms, tracts of unbroken, wild meadow, desert, or abandoned land are seen. Settlement and the development of agriculture have been viewed with indifference or open opposition by the cattlemen. This condition still exists, though to a less pronounced extent, and the holdings of the cattlemen are being gradually acquired and placed upon the market in tracts of suitable size for farming.

Little desirable land now remains subject to entry under the homestead or desert-land acts, but many tracts occur upon which final

proof has not yet been made. Many of these will doubtless be relinquished before permanent settlement is effected. Desirable farm lands may be secured at reasonable prices in almost all parts of the valley. These may be either improved tracts or wild or abandoned lands capable of improvement or reclamation. In the newer and less developed sections desirable farm lands, with either gravity or artesian water supply, may be secured at from $30 to $60 an acre, depending upon location and improvements. In the older and more highly developed districts the price ranges from $75 to $150 an acre. Extensive areas of unproductive lands capable of improvement and reclamation only at great expense under present conditions, will, however, be put in the way of the careless or uninitiated prospective buyer.

Recent methods in promoting the sale of lands and colonization embrace certain unique features not always conducive to permanent and efficient development of agriculture. The usual plan consists first in acquiring a large body of undeveloped or partially improved land, usually previously devoted to grazing, which is subdivided into a number of small tracts, varying from 5 to 10 acres to a quarter section or more in extent, the smaller tracts predominating. After an extensive advertising campaign contracts are sold upon a specified date at public auction, designated as a "land drawing," held upon the ground, each contract entitling the buyer to a tract of land designated by number, the buyer to obtain possession upon a predetermined date following sale of contract. Usually but a small deposit is required to be paid down, the balance being due in monthly installments. As a rule, the purchaser has little or no opportunity of learning the location, character, or extent of the tract for which he is bidding. With each tract is given as a bonus a town lot, some one or more of which may have been augmented in value by more or less attractive improvements. The average price paid for contracts has usually been low for the more desirable lands, but inclusion of the undesirable tracts and the system of disposing of the lands by these methods have been subjected to severe criticism.

The most recent operations of this character have been conducted in the vicinity of the town of Moffat during the summer of 1910 by one company controlling some 24,000 acres of land lying mainly west and northeast of Moffat.

The tracts disposed of ranged in size from 5 to 160 acres, some of which were partially improved with either irrigation ditches, fences, corrals, buildings, or one or more artesian wells. Only a few of the tracts were supplied with actual facilities for irrigation from gravity sources, and the predominating 5-acre tracts were laid out in the form of long, narrow rectangular blocks, without regard to surface contour and of awkward shape, to permit irrigation of the tract from a

single well. Some effort has been made in apportioning the land to have the smaller tracts embrace the more productive lands. The average price is reported to be $200, or at the rate of $40 an acre for the 5-acre tracts.

While occasionally desirable, partially improved lands may be purchased in this vicinity at a lower figure, the amounts paid for the above tracts are probably not excessive, and many of the tracts are doubtless worth more than the purchase price. On the other hand, but little of the land is capable of successful and permanent production of crops without improvements in the way of irrigation or drainage, both often being necessary. Few purchasers of the smaller tracts have sufficient money to make these improvements. Moreover, the short growing season, the limited local market for vegetables and truck crops, and the remoteness from the centers of population within the State limit possibilities in the production of intensively cultivated crops of high value upon the 5-acre tracts, without which such tracts are, except in unusual cases, insufficient to support a family.

The water for irrigation within the valley is drawn principally from the Rio Grande, and with the present gravity systems the supply is inadequate. During flood seasons an excess of water leaves the valley by this river or is lost by seepage, but many of the ditches and canals are without water during the drier months. There is no way to increase the supply of gravity water except by constructing storage reservoirs, many excellent natural sites for which exist. Such steps have for some time been projected and some actual construction work has been performed. The creation of the Rio Grande project under the United States Reclamation Service for the irrigation of lands in New Mexico and Texas by stored waters of the Rio Grande demands conservation of the available water for this purpose. All available reservoir sites adjacent to the San Luis Valley have accordingly been withdrawn from entry and no further permits for right of way over Government lands in connection with any storage reservoirs or distributing canals will now be granted. Upon completion of this project these restrictions will doubtless be removed as far as surplus water is concerned.

Water is usually supplied by some system of subirrigation. This method of application is economical of labor, but with the porous, gravelly soils of the upper valley slopes it is wasteful of water and results in accumulation of seepage waters and alkali salts in lower lands. Irrigation of the soils of the San Luis series by flooding would require frequent applications and should be accompanied by repeated shallow cultivation. This would result in increasing the cost of irrigation and would require some preliminary leveling, with construction of more numerous laterals. It should, however, result

in economy in water, as only enough need be applied to moisten that part of the soil within the root zone of crops, and it would, if generally practiced, be followed by improvement in the condition of the lower lands now rendered worthless by seepage waters and alkali. In the areas of gravelly porous soils heavy losses of water take place through seepage from the canals and ditches. This condition can be overcome by the use of temporary canvas lining, the installation of permanent cement-lined ditches, or wooden or metal pipes. Such expensive methods will be found profitable only where the lands served may be used in the cultivation of intensively farmed crops of high market value.

An extensive underground supply of water has been partially developed. Pumping of seepage water from wells sunk in dry stream beds has been successfully tested and is capable of considerable extension, but the most widely utilized source consists of the artesian water. Artesian wells may be secured in almost all portions of the valley except the upper margins, where the pressure becomes insufficient to produce a flow in quantities suitable for irrigation without pumping. More than 3,000 wells have already been driven, the most of which occur in the southwestern and western parts of the valley. But few occur east of the valley trough, and these are confined to occasional stock ranches.

The wells range in depth from 100 to 800 feet and in temperature from 40° to 75°.[1] The wells of relatively high temperatures are confined principally to the Swede Corners district and should prove of distinct advantage in the irrigation of early vegetables. The water-bearing strata consist of bluish or dark gray sand, alternating with impervious clay. The usual well has a 3-inch casing, while larger wells are of 4, 5, and 6 inch bore. The water is of good quality, except in the lower part of the valley basin, where it is more or less stained with organic matter and frequently charged with gas and alkali salts. Here frequently the water is unfit for domestic use, although usually satisfactory for stock and irrigation. In most cases the wells are cased only to the depth of the first clay stratum occurring below the superficial gravelly soil material, at a depth usually from 10 to 75 feet, the cost, including high freight charges, restricting the use of pipe to that absolutely necessary. It is reported to be unsafe to attempt to cap the partially cased wells so that the flow may be controlled, as this tends to cause caving in of the lower part of the bore. Consequently, the wells are usually allowed to flow continuously, resulting in waste of water, a permanent high water table, and saturation of adjacent areas. Increase in the number of wells, the only available source of supply for irrigation in

[1] See Water Supply Paper No. 240, U. S. Geological Survey, Geology and Water Resources of the San Luis Valley, Colo.

much of the valley, will doubtless result in some loss of pressure and diminished flow. It is to be regretted that conditions are not such as to permit general storage of the water in artificial reservoirs and the regulation of flow. A more abundant supply would thus be assured, while prevention of further waste would improve many areas now swamped with seepage or rendered worthless by the accumulation of alkali.

The alkali salts consist mainly of sulphate of sodium, or Glauber's salts, and of chloride of sodium, or common salt. With these frequently occur smaller quantities of sulphate of magnesium, or epsom salts, bicarbonate of sodium, or common cooking soda, and chloride and sulphate of potassium. The carbonate of sodium—the so-called "black alkali"—is of only occasional occurrence. Calcium sulphate, or gypsum, is found more frequently. This is a relatively insoluble salt of beneficial rather than injurious effect, owing to its chemical action in converting the black alkali into less harmful salts.

These salts are derived by decomposition of the minerals forming the soils—a process begun before the mineral fragments were transported and deposited in the valley and still continuing. The salts are nearly all readily soluble and are carried from place to place in the drainage waters. When, owing to a high water table or to outcropping of underlying impervious strata, the water approaches the surface sufficiently to maintain a moist column of soil between the water table and the surface, an upward capillary movement of the solution takes place, the moisture evaporating from the surface being continuously renewed from below. As the moisture evaporates the salts which it contains crystallize and deposit in the soil at or near the surface, forming, when the quantity is great enough, a crust or a powdery efflorescence. As evaporation in the San Luis Valley is particularly rapid and the supply of impregnated water practically constant, the tendency under present conditions is toward an increasing accumulation of the deleterious salts. With the lowering of the water table the rate of evaporation is decreased or the movement discontinued. The occurrence of rains or the application of irrigation waters may reverse the process and cause leaching from the surface by percolating waters of a large proportion of the salts, which return to the subsoils or subsoil waters, and under favorable drainage conditions may be discharged into the country drainage and permanently removed.

The seepage and alkali problems are thus intimately related and yield readily to the same treatment. The first step is the removal of the seepage waters and the lowering of the water table. The position at which the water table becomes a source of danger depends upon textural and structural characteristics of the soil and subsoil. In the open porous soils of the San Luis series the upward movement

of capillary moisture takes place rapidly, but can only be maintained through a relatively short soil column. In such soils the water table may remain within a few feet of the surface without danger of alkali accumulation. In the case of the alluvial soils of finer texture and compact structure the capillary movement takes place more slowly, but is capable of being maintained through a much greater vertical distance. In this case it becomes necessary to lower the water table to a greater depth, which should generally be from 6 to 10 feet, depending upon rapidity of drainage, cultural methods employed, and the character of crops for which the land is used.

In the southern and west-central parts of the valley of good slope and covered by the San Luis series occasional open ditches, accompanied with cultural and irrigation practices designed to prevent waste of water, would probably prove sufficient to control the drainage conditions. In the more northern districts covered by the heavier soils of compact structure, installation of underground drains will be necessary in places, although the prevailing conditions could be greatly improved by open ditches. Stream courses could be utilized to some extent as drainage outlets, but some enlargement and straightening of these channels would prove advisable. Efficient and comprehensive drainage of the northern portion of the valley would call for organization on the part of the landowners and supervision by competent engineers. The available fall measured along the trough of the valley is relatively slight, amounting to about 65 feet between Moffat and the Rio Grande. To obtain this, considerable excavating in the southern part of the valley would be necessary. To justify the expense incurred in operations of this magnitude, the profit accruing from increased productiveness of the soil must be more than sufficient to bear the original cost with interest charges thereon. With the rapid advance in values of western irrigated lands and the agricultural opportunities offered in this valley, a comprehensive project for draining the entire district should be feasible. Transmission of electric power from adjacent mountain water-power sites at a cost low enough for pumping from shallow subsurface waters also offers some future possibilities in connection with irrigation and drainage.

Besides drainage surface flooding will be necessary for the reclamation of lands badly affected with alkali. In this process a system of checks must be formed in order that water may be held on the land constantly during the leaching process. The efficiency of this method of alkali removal has been demonstrated by the Bureau of Soils in a number of cases involving much greater difficulties than would be encountered in the San Luis Valley.[1]

[1] See Bulletins 42, 43, and 44 and Circulars 11 and 12, Bureau of Soils, U. S. Department of Agriculture.

In areas of soil of the San Luis series removal of the salts by flooding would take place rapidly, and with facilities permitting regulation of the water table by properly controlled drainage outlets, only occasional flooding after one or two thorough leachings would probably be necessary. In the case of the heavier alluvial soils of compact structure and low-lying position irrigation by flooding should be permanently substituted for subirrigation, and drainage outlets should be maintained in an open condition, except in such cases as it might be desired to continue the production of wild hay.

As soon as the greater portion of the salts have been removed, but before the land becomes suitable for the production of the more sensitive crops, it may be utilized for the production of some of the more alkali-resistant crops, such as sugar beets, barley, and certain varieties of sorghum, including kafir. In handling the land a soil mulch should be maintained whenever it is in fallow or in intertilled crops, or some close-growing crop thoroughly shading the ground should be grown, for it is essential to prevent evaporation in every practicable way.

The leading farm products of the San Luis Valley are wheat, oats, barley, native hay, Canada field peas, potatoes, and, in certain sections, sugar beets. The production of alfalfa is of minor but increasing importance. Timothy is successfully grown in some districts. The hardier vegetables, capable of being brought to maturity during the short growing season, such as cabbage, cauliflower, onions, parsley, celery, lettuce, and the root crops, including carrots, beets, parsnips, and turnips, yield well and are of high quality. They are grown for home consumption and local markets. Regional conditions are not generally favorable to the commercial production of fruits, although crab apples and some of the hardier varieties of apples and other tree fruits can be grown for home use. The growing of brambleberries, currants, strawberries, and gooseberries has been attempted. These fruits are of good quality and yield well, but require protection by mulching or burial of the canes during the winter season. Tomatoes and other more delicate vegetables must be grown under glass. Protection from winds by planting windbreaks about the buildings and garden tracts is to be recommended. Upon the lower-lying soils of deficient drainage and high water table the native willow and cottonwood are well adapted to this purpose. Limited quantities of small fruits, even if grown at the cost of considerable labor, should command fancy prices and might find an important place in the products of the small, intensively cultivated tracts.

The sandy and gravelly soils of the San Luis series are not well adapted to grain crops, except when grown in rotation with field peas or some other crops which may be utilized for green manuring purposes to restore organic matter and improve the structure and

moisture-retaining capacity of the porous soils. Canada field peas are usually sown with oats for feeding lambs or hogs. The crop is harvested by turning the lambs into the field, followed by the hogs, or it may be cut and thrashed. Feeding or finishing of lambs and hogs, an industry of much local importance, has resulted from the introduction of this crop. The practice is to be commended as tending to maintain the soils in a productive condition. The field pea is best suited to loam soils of medium heavy texture. It may be grown upon a variety of soils of lighter character, but in this case often produces a poor growth of vine. The heavy soils of high moisture capacity and organic content tend to produce an abundance of vegetation at the expense of seed.

Wild hay is harvested in large quantities, both for feeding within the confines of the valley and for shipment to mining camps or other outside markets. It is of excellent quality, being usually preferred to alfalfa, and commands a high price. Drainage of the wild hay lands would diminish the production of wild hay, but would render the land now devoted to this purpose available for some other crops.

While alfalfa is not in as great local demand as the native hay, heavier yields of greater value could be obtained. The lighter soils of the San Luis series are not so well adapted to the crop as the soils of the Rio Grande series, or other brown or dark-colored alluvial loams of the northern part of the valley. The greater part of this district is at present unsuited to alfalfa production, since the plant roots deeply and requires well-drained soils. Though a good stand may occasionally be secured, the plant dies as soon as the roots reach the zone of saturation. Alfalfa culture should find a favorable field for extension in the districts covered by the light-brown to dark-colored loams of medium to heavy texture covering the valley margins, such as occur about Swede Corners, Saguache, and Mirage, in the northern part of the valley.

Potatoes are quite widely grown. The most favorable conditions for this crop are found in the soils of the Rio Grande series in the southwestern and in the related alluvial loams of the northern part of the valley. Under favorable conditions of irrigation and drainage the yields are unusually high and the tubers of excellent quality. Sugar beets are not extensively grown, except in the vicinity of the sugar factory at Monte Vista, but extensive soil areas in the vicinity of Veteran Schoolhouse, Swede Corners, Saguache, Warner School, and Mirage are well adapted to the production of this crop. With improvement in drainage conditions the crop could be extended to much of the lower and northern-central parts of the valley. Field and sweet corn, milo, kafir, and similar crops rarely mature, but are suited to the heavier soils of the valley and produce a heavy growth of vegetable matter suitable for forage or silo purposes in connection

with dairying or stock raising. In this connection sugar beets, rutabagas, and other root crops will be found important crops. They can be grown profitably for such purposes upon the heavier and imperfectly drained types.

Mexican labor is employed to a considerable extent, but upon the average farm the most of the labor is performed by members of the farmer's family.

A limited local market for vegetables, fruit, and truck crops is offered by towns within the valley, but with extensive development of intensive farming of small irrigated tracts this demand would soon be supplied.

The benefits accruing from the application of barnyard and stable manures and the use of green manure crops is worthy of much wider recognition, particularly on the porous soils of coarse texture occupying upper valley slopes and alluvial fans.

The home seeker in the San Luis Valley will find a healthful and invigorating climate. By judicious selection he will be able to secure desirable land at less than the average price for irrigable lands. He will find the range of crops suited to the soils and climatic conditions sufficiently wide to admit his engaging in general farming, stock raising, and stock feeding, dairying, or in the production of intensively cultivated crops, such as sugar beets and hardy vegetables.

He should, however, be provided with sufficient capital to comfortably house himself and family and to provide shelter for stock, to purchase necessary farm equipment and live stock, and provide for fencing, drainage, and irrigation improvements. Before purchasing he should investigate sources and adequacy of water supply for irrigation purposes, and should extensive drainage or reclamation operations be necessary to bring the land to a productive state, he must look into the feasibility of such improvements and be provided with sufficient means to tide over the unproductive period during which such improvements are being made.

He will be able to provide, for home consumption, practically all necessary vegetables and dairy and poultry products, which may also be made to yield some additional revenue in supplying local markets. He will do well, however, to devote his land to staple and tried crops, leaving the promising but unproved crops alone until they have passed through the experimental stage.

SUMMARY.

The San Luis Valley lies partly in south-central Colorado and partly in New Mexico, at an altitude of approximately 7,500 feet. The part in Colorado covered by this report runs north and south for about 80 miles and has a maximum width of 45 miles. It is drained by the Rio Grande del Norte.

Alamosa is the principal town. Transportation is afforded by several lines of the Denver & Rio Grande Railroad.

The climate is healthful and favorable to the production of grains, grasses, legumes, and certain vegetables. The annual rainfall is about 8¼ inches. Cold winters, short summers with cool nights, many sunshiny days, and a low relative humidity are salient climatic features.

The valley is flat and treeless. The soils of the foot slopes and alluvial fans are of porous, sandy, and gravelly character, underlain by leachy, gravelly subsoils. The alluvial soils of the valley floor and tributary stream bottoms are of darker color, heavier texture, and more compact structure. Those of the valley floor sometimes occupy poorly drained flats subject to overflow.

The prevailing soils of the marginal slopes are included in the San Luis series. They are gravelly sand, sandy loam, or loam, and derived mainly from volcanic rocks. The surface is well adapted to irrigation. The soils are usually easily cultivated, but are leachy and not retentive of moisture. Lower lying slopes and depressions suffer from seepage water and alkali.

The alluvial soils of the stream bottoms are usually sandy loams, loams, or clay loams, underlain by gravelly subsoils. They are more retentive of moisture than the soils of the Rio Grande series, but not so well drained. Accumulation of seepage water and alkali in places causes considerable injury, but otherwise they are well adapted to grains, alfalfa, grasses, field peas, and vegetables, including the root crops.

The northern and central parts of the valley contain small areas of the gravelly foot-slope soils. The alluvial soils and intermediate types cover more extensive areas, while the central and eastern parts of the valley contain large areas of wind-drifted sands, broken by low flats without drainage and occupied in places by alkali lakes.

Very little desirable public land remains subject to entry, but partially improved lands suitable for farming may be purchased at moderate prices.

The available supply of water for irrigation by gravity systems is inadequate, but the area served might be increased by less wasteful methods of distribution and use. Storage reservoirs may in the future relieve conditions, but are not favored by present circumstances.

The prevailing method of applying water is by subirrigation. This system is wasteful, is not adapted to the soils of the San Luis series or other porous, gravelly types, and has resulted in widespread damage to lands upon lower slopes through the water-logging of the subsoils and the accumulation of alkali.

There are more than 3,000 flowing wells within the valley furnishing water of good quality for irrigation, except in the central and lower part of the valley basin, where the water is dark colored and often carries considerable quantities of gas and alkali.

With proper drainage, accompanied by surface flooding, most of the alkali areas of the valley may be reclaimed.

The chief farm products are wheat, barley, oats, Canada field peas, potatoes, and wild hay. Sugar beets, alfalfa, and hardy vegetables constitute important products in restricted districts. Field peas are utilized for feeding lambs and hogs, which, with cattle, constitute an important source of income.

The lighter gravelly soils of the foot slopes are not adapted to permanent grain production, but may be utilized for this purpose with careful irrigation and in rotation with field peas or other suitable crops. The alluvial soils of the stream and valley bottoms are, under favorable conditions of drainage and irrigation, well adapted to alfalfa, potatoes, root crops, grasses, and vegetables. Alfalfa culture is capable of much wider extension under present conditions upon the loams in the vicinity of the valley margins.

Careful selection is necessary on the part of the home seeker purchasing lands in the valley. He should possess sufficient capital to construct necessary buildings, purchase equipment, install irrigation and drainage, and to tide him over unproductive periods.

Small local markets and distance from larger ones restrict the cultivation of vegetables and truck crops. For the present the settler should confine his efforts to the production of the staple crops, grain, hay, forage, or root crops, with some live stock to consume whatever surplus may be grown.

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