SOIL SURVEY

The Duncan Area

Arizona-New Mexico

Series 1941, No. 1

Issued September 1950

UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Administration

Bureau of Plant Industry, Soils, and Agricultural Engineering

and

Soil Conservation Service

In cooperation with the

UNIVERSITY OF ARIZONA AGRICULTURAL EXPERIMENT STATION

How to Use THE SOIL SURVEY REPORT

FARMERS who have lived in one locality for a long time come to know about the soil differences on their own farms and on those of their immediate neighbors. What they do not know, unless a soil survey has been made, is how nearly their soils are like those at experiment stations or in other localities from which higher yields are reported. They do not know whether these higher yields are from soils like their own or from soils so different that they could not hope to get equally high yields, even if they adopted the practices followed in these other places. These similarities and differences among soils are known only after a map of the soils has been made. Knowing what kind of soil one has and comparing it with soils on which new developments have proved successful will remove some of the risk in trying new methods and varieties.

SOILS OF A PARTICULAR FARM

To find what soils are on any farm or other tract of land, locate the farm on the soil map, which is in the envelope inside the back cover. This is easily done by finding the township, section, and quarter section the farm is known to be in and locating its boundaries by such landmarks as roads, streams, villages, and other features.

Each kind of soil is marked with a symbol on the map; for example, all soils marked Gf are of the same kind. To find the name of the soil so marked, look at the legend printed near the margin of the map and find Gf. The color where Gf appears in the legend will be the same as where it appears on the map. The Gf means Gila fine sandy loam. A section of this report (see table of contents) tells what Gila fine sandy loam is like, for what it is mainly used, and some of the uses to which it is suited.

How productive is Gila fine sandy loam? Find this soil name in the left-hand column of table 5, page 36, and note the expected yields of the different crops opposite it. This table also gives expected yields for all other soils in the area, so that the different soils can be compared.

See the section on Soil Types and Phases to learn what are good uses and management practices for this soil. Look also at the section headed Productivity, Use, and Management of the Soils. Here soils are grouped according to their suitability for irrigation.

SOILS OF THE AREA AS A WHOLE

If a general idea of the soils of the area is wanted, read the introductory part of the section on Soils. This tells where the principal kinds are found, what they are like, and how they are related to one another. Then study the soil map and notice how the different kinds of soils tend to be arranged in different localities. These patterns are likely to be associated with well-recognized differences in type of farming and land use.

A newcomer who considers purchasing a farm in the area will want to know about the climate as well as the soils; the principal farm products and how they are marketed; availability of schools, churches, highways, railroads, telephone and electric services, and water supplies; and number of towns and other population characteristics. This information will be found in the sections on General Nature of the Area and on Agriculture.

Students and others interested in how the soils of the area were formed and how they are related to the great soil groups of the world should read the section on Morphology and Genesis of Soils.

This publication on the soil survey of the Duncan area, Ariz.-N. Mex., is a cooperative contribution from the—

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SOIL SURVEY OF THE DUNCAN AREA, ARIZONA-NEW MEXICO

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United States Department of Agriculture in cooperation with the University of Arizona Agricultural Experiment Station

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THE agricultural development of the Duncan area, where a long frost-free growing season and mild winter permit the cultivation of a variety of crops, was made possible by the establishment of extensive irrigation systems. Up to the time of its first permanent settlement in the early 1880's the area supported only a sparse semidesert vegetation of desert shrubs and scattered grasses. At present approximately 37 percent of the land is under cultivation and producing important crops of cotton, potatoes, and alfalfa as well as lesser quantities of small grains and sorghums. By improving the chemical composition and organic-matter content of the soil through silting, irrigation has improved the land from an agricultural standpoint. Problems presented by rapid erosion, by the need for providing better flood protection, and in determining the best possible use of much of the land, however, still await solution. To provide the basis for the best agricultural use of the area as well as a consideration of other outstanding problems a cooperative soil survey was begun in 1941 by the United States Department of Agriculture and the University of Arizona Agricultural Experiment Station. The essential features of this report are summarized as follows.

SUMMARY OF THE SURVEY

The Duncan area soils have developed under an arid or semiarid climate. They occur on broad basins or plains traversed by deeply cut washes and on alluvial fans and narrow flood plains. The differences in permeability, depth, water-holding capacity, drainage, salt content, and availability of irrigation are sufficient to cause wide variations among the several series, types, and phases in the kind of management practices required and the degree of productivity that may be expected.

The Gila and Pima soils are deep fertile permeable soils of the flood plains of the Gila River, well suited to the production, under irrigation, of cotton, alfalfa, corn, sorghums, small grains, potatoes, and vegetables. Imperial and Glenbar soils, which occur on fans and alluvial bottom lands along intermittent desert washes, on the other hand, are heavy and rather slowly permeable throughout and commonly contain harmful concentrations of soluble salts, or alkali, but where irrigated with river water gradually become suitable for a wide variety of crops.

Small silted areas of Stacy soils are fairly productive, but where they occur on the fans and along washes they are generally gravelly and porous. Cavot and Dos Cabezas soils of the terraces and alluvial fans along the outer margin of the valley trough have moderately compact limy subsoils. These soils usually occur above the irrigation canals and hence are not suitable for development. Lower lying areas of Dos Cabezas soils that can be irrigated are productive.

The Continental and Teague soils are on high terraces and mesas bordering the valley. The Continental have compact limy subsoils, and the Teague, a lime hardpan. These soils and the miscellaneous land types—Rough broken land and Riverwash—have no crop value but can be used as livestock range.

Silt deposited by irrigation water improves the poorer soils and helps maintain the productivity of the better soils.

Crop rotation, including the growing of alfalfa, helps maintain or improve soil tilth, permeability, and fertility.

Gullying and erosion are active in the area. Both the mesas, which have only limited value as pasture, and the fans with their potential value for cultivation are affected. The mesas suffer from erosion, and the fans that border the valley are subject to gullying. Along the Gila River and its tributary desert washes, serious problems are presented by bank cutting and detrimental deposition of sand and gravel. Floods occasionally damage land, crops, and improvements. At present check dams and dikes are effective in the control of runoff.

Temperature, moisture supply, and fertility and lay of the land are the chief factors determining the use suitability of any of these soils. The availability of water is largely the key to the actual or future value of the area as farm land. Because all the soils are not equally suited to irrigation, they have been classified in five general groups on the basis of the possibility or advisability of putting them under irrigation. Soils already being irrigated are also included in the groupings. Owing to their steepness or roughness, some soils are unsuited not only to irrigation but even to grazing, and a few have toxic concentrations of white alkali salts that prevent normal plant growth.

The Duncan area is in the zone of the Red Desert and Reddish Brown soils, and its soils have developed largely from wind- or water-borne materials arising from a variety of rocky calcareous saline old lake-laid silts and clays, and gravelly alluvium. Moisture and vegetation have played only a relatively small part in the development of the soils.

The accompanying generalized map of the area shows the location and extent of each of the soil types and phases.

GENERAL NATURE OF THE AREA

LOCATION AND EXTENT

The Duncan area lies along the Gila River in Greenlee County, Ariz., and Hidalgo County, N. Mex. (fig. 1). It is about 20 miles long and approximately 1 to 3 miles wide. Of the 38 square miles (24,320 acres) comprising the area, about one-third is in New Mexico and two-thirds in Arizona. Duncan, Ariz., the largest town in the area, is 180 miles southeast of Phoenix and 115 miles northeast of Tucson, Ariz.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

Forming part of the Mexican Highland section of the Basin and Range province of the Gila River watershed, this area is characterized by the scattered groups of rugged mountains, volcanic peaks, and low lava hills, with intervening broad basins or plains that are traversed in places along the larger streams by narrow deeply incised valleys. The Gila River, bordered by its narrow alluvial flood plain, winds northwest in a trough flanked by terraces, some of which rise 100 feet or more above the valley floor. Intermittent tributary streams occupy the deep lateral valleys.

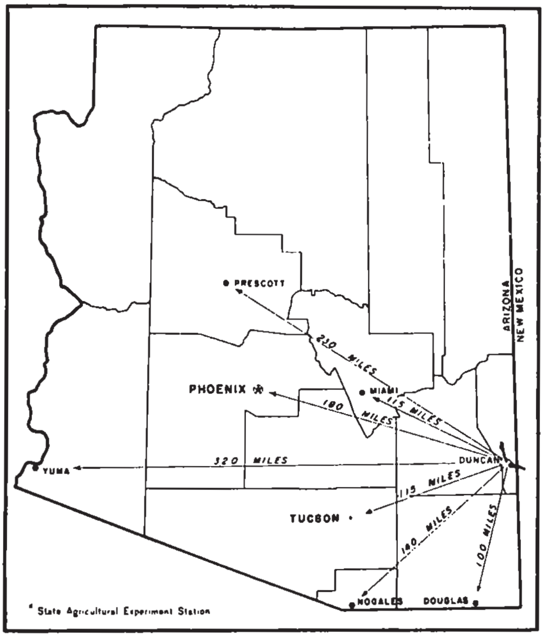
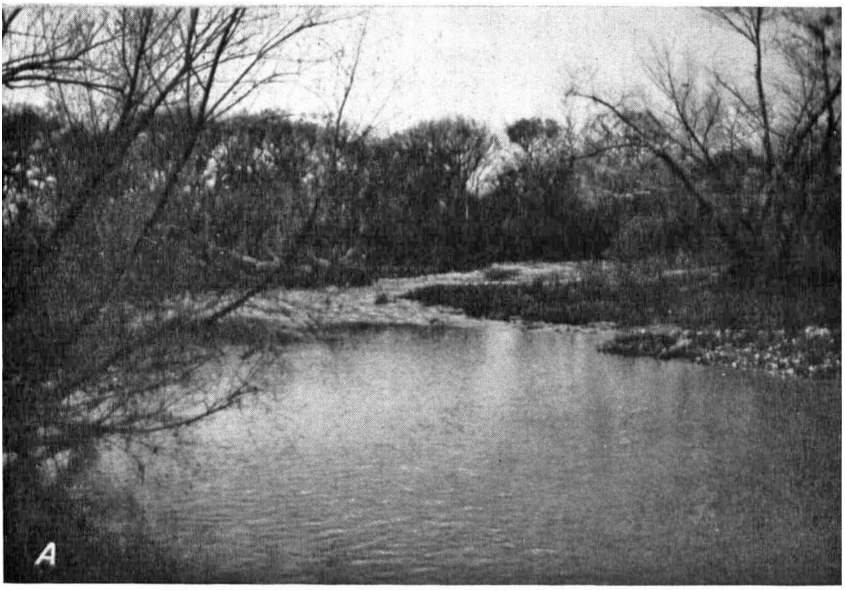


FIGURE 1.—Location of the Duncan area in Arizona-New Mexico.

The axis of the Gila River valley roughly parallels the Peloncillo Mountains on the western edge of Greenlee County. To the north and east are scattered volcanic ridges, peaks, and hills, and to the south, wide smooth plains.

The survey is confined largely to present and recent flood plains of the Gila River and adjoining smooth lands along its numerous intermittent tributaries. Elevations range from about 3,800 feet above sea level where the Gila River enters the area in New Mexico, to about 3,500 feet where it leaves north of York in Arizona. The elevation at Virden, N. Mex., is 3,750 feet and at Duncan, Ariz., 3,643 feet.

The Gila River has a more or less uniform gradient of about 10 or 15 feet to the mile. Its meandering course, which is often shifted, causes considerable bank cutting, and is partly responsible for its periodic overflow onto adjacent low-lying lands (pl. 1, *A*). Floods of 10,000 to 25,000 second-feet are relatively frequent and leave quantities of debris on lower areas. At times during the rainy season the flow may reach 40,000 second-feet or more and seriously damage the cultivated fields that it inundates. Disastrous floods in 1916 forced many settlers to move to higher land on the alluvial fans and bottoms of the tributary streams. Again in September 1941, water rose high in the valley and flooded the town of Duncan. The overflow not only



A, The Gila River as it enters Arizona from New Mexico.
B, Field of hegari on Pima silty clay loam.

caused extensive damage to crops, but in places laid down deposits of gravel and sand that presented serious problems to the farmers. A large part of this coarse alluvium has now been removed and the cultivated lands restored to normal, so that most of the low-lying lands are again under cultivation. Although frequently flooded, these lands have sufficiently good underdrainage to prevent all but inextensive parts from becoming waterlogged or affected by detrimental accumulations of alkali.[1] Narrow strips along the river subject to annual inundation are generally used only for pasture.

Since good quality water can be obtained at shallow depths, farmers throughout the area frequently drill wells to be used as a supplementary source of irrigation water when the river is low.

CLIMATE

In general the Duncan area may be described as arid or at least semiarid. The weather is clear and the sunlight intense for the greater part of the year. The winters are mild with little snowfall. Although the summers are hot the heat is not oppressive. Precipitation and humidity are low and the rate of evaporation high, especially in hot weather and in spring, when wind movement is high. The daily range in temperature is wide, the days being warm and the nights usually cool, but extremely high and low temperatures are uncommon.

The highest temperature recorded at Clifton[2] is 113° F. and the lowest 13°. The mean annual temperature is 66.6°.

Although the ground becomes slightly frozen and farm work is retarded in winter, especially January, the rest of the year is favorable for farm work. The average date of the last killing frost in this locality is February 25 and the earliest, November 26—an average frost-free season of 274 days. The latest recorded frost is April 20 and the earliest, November 2. At Duncan the frost-free season is much shorter, probably less than 200 days. Government-kept weather records for the period 1901–6 showed the average last killing frost in spring to be May 13 and the first in fall, October 14, giving an average growing period of 153 days. During that period, however, killing frosts occurred as late as June 2 and as early as September 30. Winter-hardy small-grain crops grow during the winter, and late-fall and early-spring lettuce can be raised. The growing season is sufficiently long for short-staple cotton. Livestock graze throughout the year.

The mean annual precipitation is 12.33 inches at Clifton, but it is probably about 11 inches at Duncan. For the period 1889–1907 the mean rainfall at Duncan was 11.17 inches. Extreme ranges in seasonal rainfall are common. The lowest recorded annual rainfall at Clifton is 4.85 inches, and the highest, 22.53 inches. Torrential rains during July, August, and September account for about half of the precipitation. The rest is made up chiefly of gentle winter rains from December to March.

[1] The term "alkali" as used in this report refers to white alkali salts, consisting largely of sodium chloride and sodium sulfide.

[2] Complete weather records covering a long period are not available for any station within the area surveyed. Incomplete records were kept for a short period at Duncan. At Clifton, which is about 30 miles northwest of Duncan at a slightly lower elevation and situated in the mountains, records have been kept over a long period (37 years). Data from the Clifton station are indicative of the climatic conditions in the area, although Clifton has somewhat more rainfall and less frost than Duncan.

The normal monthly, seasonal, and annual temperature and precipitation at Clifton as reported by the United States Weather Bureau are given in table 1.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Clifton, Greenlee County, Ariz.*

[Elevation, 3,465 feet]

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year [1]	Total for the wettest year [2]
	°F.	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
December	46. 3	70	18	1. 17	0. 59	0. 40
January	46. 0	78	13	. 93	(3)	. 30
February	51. 9	83	22	1. 14	. 15	1. 38
Winter	48. 1	83	13	3. 24	. 74	2. 08
March	58. 3	91	26	. 78	1. 28	1. 50
April	65. 5	97	27	. 40	. 68	1. 51
May	74. 2	106	40	. 37	. 07	1. 05
Spring	66. 0	106	26	1. 55	2. 03	4. 06
June	83. 6	113	49	. 48	(3)	. 41
July	85. 7	112	61	2. 20	1. 27	5. 35
August	84. 3	108	57	2. 52	. 48	4. 08
Summer	84. 5	113	49	5. 20	1. 75	9. 84
September	79. 5	104	46	. 69	(3)	2. 53
October	68. 8	99	37	. 95	. 23	2. 03
November	55. 1	86	23	. 70	. 10	1. 99
Fall	67 8	104	23	2. 34	. 33	6. 55
Year	66. 6	113	13	12. 33	4. 85	22. 53

[1] In 1924. [2] In 1919. [3] Trace.

VEGETATION

The generally sparse native desert vegetation consists of shrubs, yucca, cacti, annual grasses and herbs, and a few trees. The thickest cover occurs along the river, where scattered cottonwood (*Populus fremontii*) and black willow (*Salix nigra*) grow in dense thickets of water motie (*Baccharis glutinosa*) and arrowweed (*Pluchea sericea*). In a few permanently wet or salty areas saltgrass (*Distichlis stricta*), seepweed (*Suaeda* spp.), chamiza (*Atriplex canescens*), water-tolerant grasses, and tules grow.

The alluvial fans and low stream terraces support a rather complex and varied association of plants, including mesquite (*Prosopis juliflora* and *P. glandulosa*), catclaw (*Acacia greggii*), creosotebush (*Larrea tridentata*), hairy squawberry (*Rhus trilobata*), lotebush

(*Condalia* spp.), crucifixion thorn, yucca (*Yucca elata*), Mormon-tea (*Ephedra* spp.), chamiza, broom baccharis (*Baccharis sarothroides*), low-growing cacti, broom snakeweed (*Gutierrezia sarothrae*), bush muhly (*Muhlenbergia porteri*), tobosa grass (*Hilaria mutica*), sacaton (*Sporobolus wrightii* and *S. airodes*), fluff grass (*Trioda pulchella*), six-weeks grama (*Bouteloua barbata*), needle grama (*B. aristidoides*), alfileria (*Erodium cicutarium*), and a number of flowering annuals.

On the more calcareous soils of the upland mesas, creosotebush grows to the almost total exclusion of other plants. Elsewhere burroweed (*Aplopappus tenuisectus*) grows extensively, with an associated scattering of mesquite, catclaw, creosotebush, Mormon-tea, yucca, crucifixion thorn, snakeweed, broom baccharis, cacti, bush muhly, tobosa, fluff grass, six-weeks grama, needle grama, silver beardgrass, known locally as feathergrass (*Andropogon saccharoides*), three-awn grass (*Aristida* spp.), side-oats grama (*Bouteloua curtipendula*), alfileria, and flowering annuals.

ORGANIZATION AND POPULATION

The part of the Gila River valley covered by this survey was explored by the Spaniards, but it remained practically unsettled until the early eighties, when the warlike Apache Indians were subjugated by military force. Ranches were established at places along the river where water could be diverted for irrigation, and by 1890 about 500 acres were under cultivation. Greenlee County, Ariz., was organized in 1911.

Most of the population in the area is centered at or near Duncan and Franklin, Ariz., and Virden, N. Mex. In 1940 Duncan, the largest town in the area, had a population of 887. Many of the first settlers were Mormons, and their descendants still make up a large part of the present population.

TRANSPORTATION AND MARKETS

The Clifton-Morenci branch of the Southern Pacific Railroad, United States Highway No. 70, and State Highway No. 75 provide the main transportation facilities in the Arizona section. The New Mexico part of the area is served only by graveled roads.

A large part of the produce of the area is consumed locally or sold in nearby mining towns. Cotton and cattle, however, are shipped to outside markets.

PUBLIC FACILITIES

Franklin and Virden have grade schools, and Duncan, both a grade school and a high school. Transportation to the schools from outlying districts is provided by school bus. Towns in the area also have churches and assembly halls. Electric power and telephone service are available in and near population centers. Duncan is piped for natural gas.

AGRICULTURE

EARLY AGRICULTURE

Indian burial grounds and other evidence indicate that the Gila River valley was occupied even in prehistoric times. When the first white settlers came, however, its only inhabitants were roaming hostile

Apaches. Permanent settlement began when the Indians were, at least in part, subjugated by military force. In the early eighties settlers began organizing irrigation districts and diverting water from the Gila River for irrigation. The Cosper-Windham Canal, now greatly extended and known as the Sunset Canal, was begun in 1883. Construction was begun on the Valley Canal in 1886, on the Collminero in 1895, and the Moddle in 1896. Irrigated land included 2,500 acres in 1900, and by 1916 the cultivated acreage was as large as at present, if not larger. Damaging floods in 1916 forced many settlers from the lower bottom land and considerably reduced the crop acreage for a time.

Because of the extent of the open range livestock raising was an important feature of pioneer agriculture. Crops consisted of hay and grain necessary for supplementary feed for animals and of vegetables and grains for human consumption.

In 1884 a narrow-gage railroad was built into Duncan. Construction work, together with increased nearby mining operations, created considerable demand for agricultural products, especially alfalfa hay for work stock and corn for Mexican laborers. As mining activities at Clifton and Morenci increased, market demands continued to increase. By 1900 standardization and extension of the railroad were necessary.

CROPS

Federal census data for Graham County, of which Greenlee County was a part until 1911, though not strictly applicable to the area surveyed, indicate early agricultural trends. Although in 1890 the principal crops were hay, corn, barley, and wheat, by 1900 wheat had taken first place, followed by alfalfa, barley, and corn. By 1910 alfalfa had become the leading crop, followed in order of importance by barley, wheat, and corn. The production of tree fruits and small fruits attained its peak in 1910. At present there are no large orchards, but a few trees are grown in home gardens. Vegetables seem to have followed the same general trend as fruits, although head lettuce and other truck crops recently have occupied a considerable acreage. Livestock production has likewise increased during recent years.

Since nearly all the agricultural land in Greenlee County is in the Duncan area, census data on agriculture in this county, as shown in table 2, may be considered approximate to that for the Arizona part of the area. Likewise, most of the crops listed for Hidalgo County, N. Mex., in table 2 are reasonably indicative of the type of agriculture carried on in the New Mexico part of the survey.

In 1920 alfalfa and corn were the leading crops in both counties. Corn and sorghums are grown to a considerable extent in Hidalgo County outside of the area covered by this survey. By 1930 cotton had been introduced and was the leading crop in both counties. Potatoes had become an important crop in Hidalgo County by 1930 and they continue to occupy a large acreage. In 1940 the acreage in alfalfa far exceeded that of cotton in both counties and corn still ranked high in both. Wheat and oats were the leading small grains.

In 1920 livestock and livestock products ranked first in value, followed by hay and cereals. By 1930 these products still retained the lead, but field crops, such as cotton and potatoes, had a greater value than hay and cereals. Cattle that range outside the area make up a large part of the number of livestock reported.

TABLE 2.—*Acreages of the principal crops in Greenlee County, Ariz., and Hidalgo County, N. Mex., in stated years*

Crop	Greenlee County, Ariz			Hidalgo County, N. Mex.		
	1920	1930	1940	1920	1930	1940
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Cotton	(1)	1, 685	786	(1)	643	274
Alfalfa	1, 663	1, 006	1, 192	455	532	730
Corn for grain	1, 501	814	404	1, 139	579	275
Oats	578	13	238	181	8	81
Wheat	347	268	232	317	108	155
Barley	237	142	170	26	51	161
Sorghums:						
For grain	39	42	68	(1)	42	116
For silage	(1)	92	276	(1)	(1)	(1)
Potatoes	26	81	55	39	421	295

[1] None reported.

At present cotton is the important cash crop in the Arizona part of the survey and potatoes in the New Mexico part. Since a diversified system of agriculture is being followed, alfalfa ranks next to cotton and potatoes because of its importance as both a hay crop and soil builder. The small grains—wheat, oats, and barley—which are cool-weather crops used extensively in the rotation, are next in importance, each ranking about the same. Grown for pasture, hay, and grain, depending on the season and individual preference, the small grains can be planted the same year as grain sorghums, corn, or other crops that thrive in the heat of summer. Although not so important as the small grains, the hot weather crops—grain sorghums and corn—occupy a considerable acreage. Vegetables and truck crops, especially head lettuce and potatoes, add considerably to the cash income throughout the area. A wide variety of vegetables and berries, including boysenberries, blackberries, and raspberries are grown in home gardens. Apples, peaches, plums, and apricots are used for garden and yard planting. Grapes are grown successfully.

Cotton is largely of the Acala variety, although Stoneville is also grown successfully. The lower lying Pima and Gila soils occurring along the Gila River are the most productive soils for cotton, and where a choice is possible farmers prefer them for this crop. Deposits of silt from irrigation waters improve the tilth, water-holding capacity, and fertility of the originally less productive soils and increase their productiveness. Yields of as high as 3 bales an acre are reported on the better soils in favorable seasons when irrigation water is plentiful. The average acre yield, however, ranges from about 1 to 1½ bales. In 1940 the average yield in Greenlee County was approximately 1⅐ bales. This crop can ordinarily be disposed of readily for cash or, if stored, used as security for loans.

Potatoes are raised in various parts of the area. One early crop of large commercial potatoes and one later crop of smaller size, sold as new potatoes or as seed, commonly are grown in the same year. Irish

Cobbler, Bliss Triumph, Chippewa, and White Rose are the principal varieties. The light- and medium-textured well-drained soils are preferred, but the Chippewa variety does well on heavy soils, such as the Pima, provided drainage is good. Yields range from 250 to 325 bushels an acre of marketable potatoes for the two crops.

Alfalfa, which is next in importance after cotton and potatoes, for the most part is fed to livestock on the farms where raised, but in years when prices are satisfactory it is shipped to outside markets. This crop is used in rotation with all crops and is grown on all soils, being planted not only for hay but for its ability to provide organic and nitrogenous residues essential in the maintenance or improvement of soil fertility. Farmers in the area consider alfalfa one of their best hay crops for both yield and quality and find that it usually can be produced satisfactorily without the use of fertilizer and amendments, although yields and quality may be increased by their application. Alfalfa is essential as a supplementary feed for fattening livestock or as a reserve when farm pastures and the range have a low carrying capacity, as in times of drought. The Chilean variety is grown almost exclusively. Five cuttings are obtained annually. The average annual yield is 3½ to 4½ tons an acre.

In this area important plantings are made of small grains for grain, pasture, and hay for livestock. Wheat is used chiefly for grain, oats for winter pasture, and barley for both purposes. A variety of wheat known locally as Australian Club seems best adapted and does not shatter like the Baart, although this too is grown to some extent. Under good management 30 to 35 bushels an acre are obtained. Oats, mostly Texas Red, yield 50 to 70 bushels an acre when harvested as grain. Barley, largely of the Vaughn variety, yields 45 to 65 bushels an acre when grown for grain.

Of the grain sorghums, hegari is grown most extensively, although Manko and red maize occupy a considerable acreage. Hegari is the most popular because of high grain yields and the large quantity of palatable forage obtained. Sweet sorghums are largely of the Atlas sorgo and hybrid varieties. They make better feed when supplemented with legumes and grain. All the sorghums are fed on the farm. Farms with hammer mills prepare an excellent feed from grain and fodder harvested together. Hegari yields about 4 tons an acre of dry feed, and an average of 2,500 to 3,500 pounds when harvested as grain alone. Other grain sorghums yield about the same. Sweet sorghums yield 8 to 10 tons of forage an acre. In some cases the sorghums are put in pit silos for ensilage.

In most sections there is a large acreage in corn. Corn is produced chiefly for grain, but some is used for fodder and silage. The most popular is Duncan Dent, a native white variety. Mexican June and a native yellow dent corn also are grown. Duncan Dent may yield as high as 100 bushels of grain an acre if all conditions are favorable, but the average is probably 50 to 60 bushels. The ears of Mexican June are said to become so large that they do not ripen on Pima and Gila soils.

Of the vegetable and truck crops other than potatoes, spring and fall crops of head lettuce provide a considerable cash income. Lettuce is grown most successfully on the Pima and Gila soils. The slope of the land and the soils are chosen with considerable care for this crop.

A wide variety of vegetables are grown in the home gardens. Among these are carrots, red beets, radishes, summer squash, onions, sweet corn, beans, chili peppers, spinach, cauliflower, melons, tomatoes, and peas.

Owing to the extensive range lands available for grazing and the practice of using a large number of farm crops, as alfalfa and small grains, throughout all or part of the year as pasture, permanent irrigated pastures are not common. Pasture generally is adjusted to the cropping system. Small grains, seeded in the fall, often are used as pasture throughout winter and early spring and then grown for grain. Alfalfa likewise may be pastured before and after the summer hay season.

AGRICULTURAL PRACTICES

Tractors are used extensively for the heavier tillage operations and are usually rented by farmers who have only small holdings. Most farmers prefer horses for cultivating and for other lighter tillage practices. Since plowing can be done a large part of the year, land can be prepared over a considerable period to meet the seasonal requirements of individual crops.

Because the silt deposited by irrigation water is fertile, there is less need for crop rotation in this area than in many irrigated sections. Although commercial fertilizer is seldom used, single crops, as cotton, can be grown for a number of years with comparatively little decrease in yield. Because of the high clay content of the sediments, the soils may become dense and tight, but this condition can be alleviated by the commonly employed practice of growing alfalfa 3 or 4 years in the rotation. Alfalfa roots incorporate coarse organic residues with the heavy soil material. In addition farm manure, crop residue, and green manure, usually oats, are plowed under, especially where potatoes and head lettuce are being grown. This keeps the soil in the friable well-aerated condition so necessary in potato culture.

Cotton usually is planted between April 10 and 20. Because the winters are mild and sunny the crop can be picked late in fall and early in winter. Cotton ordinarily is grown 2 years in succession, followed first by alfalfa, which occupies the land for 3 years, and then by grains, as hegari or corn, for 1 or 2 years. Small grains are usually followed by hegari the same year. The clean cultivation necessary for cotton tends to control weeds and insect pests, which is essential to the rotation system.

Two crops of potatoes are grown on the same land during a season. One is planted about the first of April and harvested from July 10 to August 1, and the other immediately thereafter to be harvested from November 15 to December 1.

Two crops of head lettuce also are grown on the same land in one season. The spring crop is planted in January and harvested from May 20 to June 1. The fall crop is planted about August 15 and harvested from October 15 to November 15. Land is selected with great care, and rotation and cultural practices similar to those for potatoes are used.

Alfalfa can be sown either in fall or in spring. Farmers usually grow it with a nurse crop of small grain. Small grains often are sown in mature stands of alfalfa to provide increased pasture in winter when alfalfa makes little or no growth. An increase in the early hay cuttings also is obtained by this practice. Hay fields generally are plowed after 3 years, since weeds and diseases seriously reduce the yield and impair the quality of the hay after this period of growth.

Wheat is grown largely for grain and is sown either in fall or in spring. Fall sowings are made from November 20 to December 1, spring plantings, late in January. Winter wheat is harvested in June; spring wheat, in July. Oats, which provide the principal winter pasture, are sown in September, or about the middle of June if they are to be harvested following the winter pasture period.

Although barley is pastured to some extent, it is grown chiefly for grain, because it is pulled up when grazed. Fall sowings are made from October 1 to 20, the grain being harvested about June 15. Spring sowings, made late in January, are harvested a little later.

Sorghums, which are used in the rotation the same year following the small grains or other crops, are planted from June 1 to July 15. Hegari is usually planted earlier than the others. These crops are harvested from September 15 to October 15.

Corn is planted from May 20 to June 10. If the small grains are plowed under following winter pasturing, a corn crop can follow and mature, but the season is too short for both crops to be harvested for grain.

LIVESTOCK AND LIVESTOCK PRODUCTS

Livestock and livestock products provide a considerable cash income in the area, although the number of livestock farms has fluctuated with price changes. Range cattle make up a large part of the livestock, but beef cattle fed within the area also are an important source of income. In 1920 there were 64,600 head of beef cattle valued at $2,447,206 in Greenlee County, Ariz., and 27,305 head valued at $1,407,478 in Hidalgo County, N. Mex. Most of the dairy cattle, swine, and chickens reported for the two counties are raised within the Duncan area. In 1920 Greenlee County had 600 dairy cattle valued at $42,402; 1,299 hogs, valued at $21,124; and 8,862 chickens and 306 other poultry valued at $9,897. Hidalgo County had 546 dairy cattle, valued at $34,006; 1,503 hogs, valued at $22,687; and 6,449 chickens and 229 other poultry, valued at $6,935.

By 1930 the number of all cattle in Greenlee County had decreased to 38,500, with a value of $1,913,893, and hogs to 617, valued at $7,289. Chickens increased to 10,608, valued at $8,699. Similar decreases of all cattle to 25,897, valued at $1,135,307, and of hogs to 671, valued at $7,836, occurred in Hidalgo County. As in Greenlee County, however, chickens increased in number and in value, in 1930 numbering 11,369, and valued at $8,527.

For the most part continued declines in the number of livestock were indicated for the year 1940. Greenlee County reported 13,155 cattle, valued at $463,079; 509 hogs, valued at $4,084; and 7,858 chickens, valued at $5,186. During the same year, Hidalgo County had 22,321 cattle, valued at $814,844; 926 hogs, valued at $5,852; and 8,863 chickens, valued at $6,204.

Beef cattle, which are of the Hereford breed, graze largely on ranges outside the area. These ranges are well stocked with purebred bulls, and the quality of the cattle is steadily improving. Calves 8 to 10 months old, weighing 350 to 400 pounds, and "short yearlings," weighing 600 or 650 pounds, are preferred in the markets. Most of the calves and yearlings are shipped to the lower valleys in Arizona and to California and a few to the Middle West.

Farmers frequently cross-breed cattle for all-around farm purposes, but better grades are found on dairy farms, where there are purebred bulls. The dairy breeds are largely Holstein-Friesian and Jersey, but there are some Guernseys. Cream and milk are the principal dairy products sold outside the area.

Many of the farms keep hogs for home consumption; a few raise them on a commercial scale. Duroc-Jersey and Hampshire breeds are preferred. Small flocks of sheep and of milk goats are kept on a few farms. The sheep are Rambouillet. Poultry raising is confined largely to chickens. White Leghorns, Rhode Island Reds, and New Hampshires are the principal breeds. Poultry products are shipped chiefly to nearby mining towns. Work horses are predominantly of Percheron breeding, purebred sires being kept on a number of farms.

SOIL SURVEY METHODS AND DEFINITIONS

In making a soil survey the soils are examined, classified, and mapped in the field and their characteristics recorded, particularly in regard to the growth of various crops, grasses, and trees.

The soils and the underlying formations are examined systematically in many locations. Test pits are dug, borings made, and highway or railroad cuts and other exposures studied. Each reveals a series of distinct soil layers, or horizons, termed collectively the soil profile. Each horizon, as well as the underlying parent material, is studied in detail, and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The chemical reaction of the soil and its content of lime and salts are determined by simple tests.[3] Other features taken into consideration are drainage, both internal and external, relief, or lay of the land, and the interrelations of soil and vegetation.

The soils are classified according to their characteristics, both internal and external, with special emphasis upon the features that influence the adaptation of the land to the production of crop plants, grasses, and trees. On the basis of these characteristics the soils are grouped in the following classification units: (1) Series, (2) type, (3) phase, and (4) miscellaneous land types.

The series is a group of soils having the same genetic horizons, similar in their important characteristics and arrangement in the profile and having similar parent material. Thus, the series comprises soils having essentially the same color, structure, natural drainage, and other important internal characteristics and the same range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The series are given geographic names taken from localities near which they were first identified. Gila, Glenbar, Imperial, and Stacy are the names of important soil series in the Duncan area.

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[3] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality; higher values, alkalinity; and lower values, acidity. Indicator solutions are used to determine the chemical reaction. The presence of lime is detected by the use of a dilute solution of hydrochloric acid.

Within a soil series are one or more types, defined according to the texture of the upper part of the soil. Thus, the class name of this texture—sand, loamy sand, sandy loam, silt loam, clay loam, silty clay loam, or clay—is added to the series designation to give a complete name to the soil type. Gila fine sandy loam, Gila loam, and Gila clay loam are soil types within the Gila series. Except for the texture of the surface soil, these types have approximately the same internal and external characteristics. The soil type or, where the soil type is subdivided, the soil phase is the principal unit of mapping, and because of its specific character it is usually the unit to which agronomic data are definitely related.

A soil phase is a variation within the type, differing from other phases of the type in some feature, generally external, that may be of special practical significance but not differing in the major characteristics of the soil profile. For example, within the normal range of relief of a soil type some areas may have slopes that allow the use of machinery and the growth of cultivated crops and others may not. Differences in relief and degree of accelerated erosion may be shown as phases. Even though no important differences may be apparent in the soil profile or in the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such instances the more sloping parts of the soil type may be segregated on the map as a sloping or a rolling phase. Gila fine sandy loam, channeled phase, is a variation within the type. Where soil types of this area are subdivided into phases, the term "normal phase" is used for that phase or part of the type not otherwise designated by a specific phase name.

Miscellaneous land types are areas that have no true soil, as Rough broken land and Riverwash.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types in relation to roads, houses, streams, lakes, section and township lines, and other cultural and natural features of the landscape.

SOILS

In their virgin state the soils of the Duncan area are similar to those of adjacent valleys and much of the arid Southwest. Moisture is the principal factor limiting plant growth. Under natural conditions it is such that only desert or semidesert plants can survive, except along the Gila River, where there is sufficient moisture for trees.

The dominant soils of the area owe many of their important characteristics to their desert environment. They are comparatively low in organic matter and nitrogen and high in lime carbonate and salts of sodium, potassium, and other alkali and alkaline earth elements. In a few places these salts are concentrated to the degree of being toxic to plant growth. Although phosphorus apparently is present in sufficient quantity for normal plant growth in most of the soils, it may be largely unavailable in the more calcareous or highly alkaline or puddled soils. The same probably is true of iron and other elements used in small quantities by plants. Most of the soils are light in color and many of them have a reddish tinge. This coloring ordinarily is more pronounced in the upper subsoil, where there are unhydrated iron oxides.

The most extensive soils of the area are not the most important from the agricultural standpoint. Actually the Gila and Pima soils—which are deep permeable soils of the alluvial flood plains along the Gila River—are the most important soils for agriculture in the area. Relatively dark and rich in organic matter and nitrogen, they are more fertile than soils covering larger acreages. The soil material of the Pima series is very similar to irrigation-laid silt. Soils that have been irrigated for many years usually have a comparatively thick dark-colored fertile surface layer. The longer the land is irrigated the thicker the silt deposit becomes. Thus the different soils gradually lose their identity and become more alike.

The soils of the area represent a wide range in stage of development, as indicated not only by differences in position but by variations in the concentration of lime and clay in the subsoil. The soils which have no definite subsoil concentration of lime and clay occur on the valley floor and lower alluvial fans; the soils which have high concentration of lime in the subsoil and in some instances a clayey subsoil layer and lime hardpan occupy higher terraces and fans and upland mesas or benches.

Being nearly level to gently sloping, most of the irrigated soils are favorable for the distribution of water and have good surface and internal drainage. The configuration of the surface has been somewhat modified as a result of artificial leveling and silting, but over most of the area the conditions that made for good drainage in the natural state still exist. In the New Mexico part, the more sloping and gravelly fan areas are relatively free from toxic salt concentration. Westward in Arizona, the tributary fans and bottoms are less gravelly and, though largely silted and reclaimed, have occasional scattered areas of alkali soils. The heavy refractory soils from alluvial deposits derived from old lake clays, as those in the vicinity of Franklin, retain considerable quantities of soluble salts in the subsoil.

The early settlers concentrated largely on the flat low-lying lands along the Gila River, where they could easily divert water for irrigation. The soils along the river were fertile, and because of their smooth relief could be easily cultivated. With irrigation and consequent deep silting they have become the most productive in the valley.

Destructive floods in 1916 temporarily drove many settlers from the lower lands to less productive areas on the adjacent fans and alluvial flats of the tributary streams. Some of the higher locations that had favorable texture and smooth gently sloping relief have since become deeply silted and are nearly as productive as the lower lying areas. Some of the salty intractable soils were silted and reclaimed. The coarse gravelly soils are also greatly improved, especially where the relief is favorable for silting. Federal aid has made possible the construction of check dams and levees to protect the higher lands from floods of lateral desert washes carrying coarse sediments.

Silting as used in this report relates to the deposition of comparatively fine-textured (largely silt and clay) material from turbid irrigation water. The silting of soils in this area is highly beneficial. Silting is detrimental in some areas but is favorable in this valley and in somewhat similar ones of the West and Southwest. In these valleys irrigated areas are located adjacent to streams, the upper drainage basins of which originate in densely grass-covered areas or in areas of comparatively high precipitation where oakbrush or oak trees and piñon occur. In this and in other drainage basins, yellow pine is the dominant vegetation above the oak. The grasslands, the areas of oak, and those of yellow pine, respectively, are in somewhat higher and cooler locations, where the soils are of more granular structure and are comparatively fertile and high in content of organic matter. The silt has its origin in these areas of comparatively dark soils, and as it is deposited on the surface of cultivated soils, a layer of very fertile soil material is added.

It is estimated that probably 90 percent of the land under the irrigation canals is cultivated. With flood-protection works already constructed and with the availability of Federal aid for the establishment of ground-water pumping projects to supplement the gravity flow, much of the remaining acreage within the outer limits of the canals can soon be placed under cultivation. The low area immediately adjacent to the Gila River probably will always be more or less endangered by seasonal floods, and even higher land occasionally may suffer crop damage as a result of unusually high water.

The Gila, Pima, and the other soils that have been artificially silted are adapted to a wide range of crops, the exact nature of which is determined by individual preferences and economic conditions. The relatively uniform texture and fertility established by silting are especially important in cotton growing as they tend to promote the development of the long uniform fiber much in demand by buyers. The deeply silted soils produce the best cotton, although some farmers state that silted land tends to promote tall woody growth. Some varieties of corn are said to grow so rank that the ears do not ripen. Excellent grain crops are produced. Soils that are lighter textured and less altered by silting are used for all crops but are most satisfactory for alfalfa, potatoes, hegari, and corn.

More than half the area lies above the irrigation canals and provides only limited grazing. The larger part of this unirrigated land consists of steep escarpments and eroded broken areas along the bordering high terraces of gravel-capped lacustrine sediments.

The general characteristics of the soil series of the Duncan area are given in table 3.

SOIL TYPES [4] AND PHASES

In the following pages the soil types, phases, and land types are described in detail and their agricultural relations discussed. Their location and distribution are shown on the accompanying map, and their acreage and proportionate extent are given in table 4.

Cavot gravelly sandy loam, eroded undulating phase.—This inextensive phase occupies small flat tops of low-lying gravelly terrace remnants bordering the valley floor. In places it is almost completely surrounded by steep fronts, mapped as Rough broken land of coarse or fine-textured materials. Slopes are 2 to 5 percent. Most of the phase is subject to moderate sheet erosion. In places it is gullied. A profile of the soil is as follows:

1. Light- or pale-brown noncalcareous friable gravelly sandy loam topped by thin vesicular platy layers, extending to about 6 inches.

[4] When a soil type is subdivided into phases that part of the type that bears no phase name is referred to as the normal phase of the type.

2. Moderate-brown colloidal-stained noncalcareous gravelly gritty clay loam to about 16 inches; gravel coated with plastic clay.
3. Light- to moderate-brown gravelly sandy loam or loamy sand looser than the layer above, about 30 inches thick; white lime seams and lime and clay coating on the pebbles, which are held together in fragile masses.
4. Loose porous lime-coated coarsely stratified sand, gravel, and cobbles, extending to considerable depth; occasional softly cemented lime layers or lenses.

Cavot gravelly sandy loam, eroded sloping phase.—In general this soil is similar to the eroded undulating phase. Its slope is stronger (5 to 10 percent), and consequently runoff is more rapid. In places, the soil is more shallow over bedrock and may be calcareous.

Cavot gravelly sandy loam, gullied rolling phase.—Although similar to the eroded sloping phase, this soil is characterized by a rolling rather than sloping surface. It has numerous gullies and occurs on terrace fronts in association with the eroded undulating phase, and adjacent to Rough broken land, coarse and fine-textured materials. Slopes range from 5 to 10 percent. Runoff is rapid.

Continental gravelly sandy loam, eroded level phase.—This phase occupies rather flat gravelly terrace tops or mesas of intermediate elevation. Slopes range from nearly level to 2 percent. Since the soil is above the irrigation level its use is limited to grazing. The native vegetation is largely of broom snakewood and burroweed, although scattered brushy growths of desert trees and shrubs are common. The grass cover is scanty. The soil profile is as follows:

1. Light-brown to moderate-brown noncalcareous gritty gravelly loam 6 inches thick with a thin vesicular crust and desert pavement.
2. Moderate-brown or weak reddish-brown noncalcareous plastic gritty clay loam with large quantities of gravel to a depth of about 14 inches.
3. Strong-brown or weak reddish-brown noncalcareous highly colloidal prismatic gritty clay loam with imbedded angular mineral fragments and rounded gravel, continuing to about 28 inches.
4. Similar material, with lime seams, continuing to about 60 inches.
5. Very pale-brown or pale-orange compact layer of marly or softly cemented gravelly loam, at times continuing into the substratum or more frequently intermittently alternating with a strong-brown clayey layer with imbedded gravel and sand, the degree of lime concentration extremely variable within short distances.

The gravelly capping material is primarily rhyolite, but it also includes considerable quantities of other igneous rock. The surface is moderately sheet eroded.

Continental gravelly sandy loam, eroded undulating phase.—This soil strongly resembles the eroded level phase except in slope and lies near the steep terrace fronts, where the soils have little definite profile development and are mapped as Rough broken land, coarse materials. Its relatively short slopes (2 to 5 percent) produce an undulating relief. In certain places the soil has relatively deep-channeled gullies. The surface layer may be grayish and contain considerable quantities of lime, or be absent, leaving the subsoil exposed.

Dos Cabezas clay loam (silted).—This soil occurs on a gently sloping (nearly level to 2 percent) alluvial fan northwest of Franklin, adjacent to the unsilted Dos Cabezas sandy loam, eroded phase, from which it has developed. Although the silt is less than a foot

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TABLE 3.—*General characteristics of the soil series of the Duncan area, Arizona-New Mexico*

DEEP SOILS OF FLOOD PLAINS AND FANS

Series	Parent material	Surface soil	Subsoil
Gila	Mixed river alluvium	Medium to light textured, friable, pale to weak brown, calcareous.	Readily permeable, medium to light textured, pale brown, calcareous.
Pima	do	Moderately heavy textured, granular and friable, brownish gray to dusky brown, calcareous.	Medium to heavy textured, moderately to readily permeable, brownish gray to pale brown, calcareous.
Glenbar	Local wash from lacustrine clays and silts.	Medium to heavy textured, modrately friable, pale or very pale brown, calcareous.	Moderately heavy, moderately compact and rather slowly permeable, pale to light brown, thin layers of gravel in places, calcareous.
Imperial	do	Heavy textured, plastic when wet, slowly permeable, light brownish gray, calcareous.	Heavy textured, compact, slowly permeable, light brownish gray, calcareous.
Stacy	Local wash from gravelly mesas; rhyolitic, andesitic, and basaltic gravel.	Medium to light textured, friable, pale brown, often gravelly, calcareous.	Medium to light textured, gravelly, porous, pale brown to light brownish gray, calcareous.

SOILS OF HIGHER ALLUVIAL FANS AND LOWER TERRACES

Series	Parent material	Surface soil	Subsoil
Dos Cabezas	Mixed alluvium from lacustrine deposits and volcanic gravel.	Medium to light textured, friable, pale to very pale brown, calcareous.	Medium to light textured, friable to moderately compact, very pale brown, contains lime nodules, highly calcareous.
Cavot	Mixed gravelly alluvium, dominantly rhyolitic.	Coarse, gravelly friable, pale brown, noncalcareous.	Upper subsoil coarse textured but plastic when wet, weak to dark brown, noncalcareous; lower subsoil and substrata coarse, porous, brownish gray, highly calcareous.

SOILS OF HIGH TERRACES WITH COMPACT LIMY SUBSOILS			
Continental	Old gravelly alluvium; gravel mixed but dominantly rhyolitic.	Coarse, gravelly, friable, pale to dark brown, noncalcareous.	Upper subsoil heavy but gritty or gravelly, reddish brown, noncalcareous; lower subsoil compact, gravelly, very pale brown or light brownish gray, highly calcareous.
SOILS OF HIGH TERRACES WITH LIME HARDPAN SUBSTRATUM			
Teague	Old gravelly alluvium; gravel mixed but largely rhyolite and other volcanic material.	Coarse, gravelly, friable, pale to dark brown, noncalcareous.	Compact, heavy but gravelly, reddish-brown subsoil over conglomeratelike light-gray lime hardpan, noncalcareous.
MISCELLANEOUS NONARABLE LAND TYPES			
Rough broken land	Undifferentiated	Varied	Varied.
Riverwash	do	Coarse, loose, porous	Coarse, loose, porous.

TABLE 4.—*Acreage and proportionate extent of the soils of the Duncan area, Arizona–New Mexico*

Soil [1]	Acres	Percent
Cavot gravelly sandy loam:		
Eroded sloping phase	29	0. 1
Eroded undulating phase	278	1 1
Gullied rolling phase	41	. 2
Continental gravelly sandy loam:		
Eroded level phase	114	. 5
Eroded undulating phase	334	1. 4
Dos Cabezas clay loam (silted)	31	. 1
Dos Cabezas gravelly sandy loam:		
Eroded gently sloping phase	46	2
Eroded level phase	17	. 1
Eroded undulating phase	75	. 3
Dos Cabezas sandy loam, eroded phase	165	. 7
Gila clay loam (silted)	900	3. 7
Gila fine sandy loam	1, 561	6 4
Channeled low-bottom phase	1, 458	6. 0
Channeled phase	38	. 2
Low-bottom phase	63	. 2
Gila loam:		
Channeled low-bottom phase	69	. 3
Low-bottom phase	47	. 2
Glenbar loam:		
Gullied gently sloping gravelly subsoil phase	120	. 5
Gullied level gravelly subsoil phase	501	2. 0
Level gravelly subsoil phase	359	1. 5
Glenbar sandy clay loam	139	. 6
Gullied phase	80	. 3
Glenbar silt loam:		
Eroded gravelly subsoil phase	89	. 4
Gravelly subsoil phase	137	. 6
Gullied gravelly subsoil phase	237	1. 0
Glenbar silty clay loam:		
Eroded level phase	472	1. 9
Glenbar silty clay loam—Continued		
Gently sloping phase	48	0. 2
Gently sloping phase (silted)	86	3
Gravelly subsoil phase (silted)	434	1. 8
Gullied gently sloping phase	88	4
Gullied level phase	459	1 9
Level phase	291	1. 2
Level phase (silted)	1, 091	4. 5
Imperial silty clay:		
Eroded gently sloping phase	93	. 4
Eroded level phase	101	. 4
Gullied level phase	392	1. 6
Level phase	33	. 1
Imperial silty clay loam (silted)	1, 675	6. 9
Pima silty clay loam	1, 123	4. 6
Riverwash	629	2. 6
Rough broken land:		
Coarse materials	2, 511	10 3
Fine-textured materials	3, 283	13. 5
Stacy clay loam:		
Gently sloping phase (silted)	424	1. 7
Level phase (silted)	678	2. 8
Stacy gravelly clay loam:		
Gently sloping phase (silted)	78	. 3
Level phase (silted)	108	. 4
Stacy gravelly sandy loam:		
Gently sloping phase	115	. 5
Gullied gently sloping phase	1, 314	5. 4
Gullied level phase	1, 090	4. 5
Level phase	200	. 8
Stacy sandy loam	90	4
Eroded phase	314	1 3
Teague gravelly sandy loam:		
Eroded level phase	23	. 1
Eroded undulating phase	149	. 6
Total	24, 320	100. 0

[1] Where data are given for phases only, the normal type is not mapped in the area.

thick, it is fairly uniform. Moisture-holding capacity, runoff, and underdrainage are good. The principal crops of the area yield well on this type, their output comparing favorably with that obtained on Glenbar silty clay loam, gravelly subsoil phase (silted).

Dos Cabezas gravelly sandy loam, eroded gently sloping phase.—This soil occurs on old terraces principally in the New Mexico part of the area. Slopes range from 2 to 5 percent. Because irrigation water is not available the land is used for grazing. The pasture-carrying capacity, however, is low, since vegetation is limited almost exclusively to creosotebush. The profile is as follows:

1. Pale-brown highly calcareous mellow gravelly loam about 8 inches thick.
2. Light-brown to strong-brown moderately compact lime-mottled clay loam about 20 inches thick, which breaks into angular fragments.
3. Light brownish-gray highly calcareous clay loam with lime spots and soft lime nodules to about 26 inches.
4. Very light brownish-gray slightly lime-cemented gravelly material containing heavier textured reddish lime-seamed plates of loam or clay loam about 36 inches thick.
5. Light brownish-gray or very pale-brown porous stratified sand and gravel in which lime coats the pebbles.

This soil usually occurs where the gravel capping on the terraces is thin, and the underlying lacustrine sediments frequently appear in the lower subsoil or substratum. Although the areas on which the soil occurs are usually smooth, in a few places they are cut by shallow gullies resulting from the erosion to which the mellow surface soil yields readily. Moderate sheet erosion is general. The steep terrace fronts are described elsewhere as Rough broken land, coarse materials.

Dos Cabezas gravelly sandy loam, eroded level phase.—This phase, which is of slight extent, occurs in a few small scattered places. In general it is similar to the eroded undulating phase, but its relief is flatter (nearly level to 2 percent).

Dos Cabezas gravelly sandy loam, eroded undulating phase.—This phase resembles the eroded gently sloping phase in most features except in its slopes, which are shorter and cause the land to have an undulating appearance. Sheet erosion is moderate. The land has fewer gullies than the eroded gently sloping phase, but it is less easily irrigated owing to the irregular relief (2 to 5 percent).

Dos Cabezas sandy loam, eroded phase.—A large part of this soil lies on alluvial fans northwest of Franklin; the rest, northwest of Duncan. Slopes range from nearly level to 2 percent, but some areas are included with slopes of 2 to 5 percent. The soil material is friable and highly subject to erosion, which is responsible for numerous shallow gullies. This soil retains moisture well and has good internal drainage. There are no toxic concentrations of salts. The profile is as follows:

1. Light brownish-gray mellow calcareous sandy loam to a depth of about 6 inches with scattered gravel and commonly a thin vesicular surface crust sometimes sprinkled with small lime nodules or caliche fragments.
2. Pale-brown or light yellowish-brown calcareous mellow plastic loam to about 12 inches.
3. Pale-brown firm heavy loam or clay loam to about 28 inches, breaking into angular fragments, some of which have a colloidal coating; threadlike concentrations of lime present.
4. Very pale-brown or light brownish-gray compact loam or clay loam, continuing to about 40 inches with lime specks, threads, and ¼-inch lime nodules.
5. Light brownish-gray firm but friable fine sandy loam with similar lime concentrations and a few caliche fragments and lime-coated pebbles.

This soil has developed upon calcareous alluvial fan material derived largely from old lacustrine sediments. The harder caliche fragments were probably eroded from caliche strata in these lake clays.

Use and management.—None of Dos Cabezas sandy loam, eroded phase, is farmed. The native vegetation is almost wholly creosotebush, hence the value of the soil even for grazing is low. The area lying above the canals has a gently sloping fan relief, which can be irrigated by pumping. Under good management, including proper rotation with alfalfa, the soil would probably be fairly productive without the irrigation-laid silt. Applications of phosphate, however, probably would be necessary for good alfalfa yields, since the soil has a relatively high lime content.

Gila clay loam (silted).—This soil has been silted somewhat more and therefore is slightly darker and heavier than other Gila soils. Practically all of it is farmed, its excellent structure, tilth, and ready permeability to both roots and water making it suitable for a wide variety of crops. Slopes range from nearly level to 2 percent.

This soil is closely associated with Pima silty clay loam, which it resembles in manner of distribution and relief. It usually lies nearer the river than the Pima soil but has good underdrainage and few salty areas. The soil has the following profile:

1. Pale-brown very friable clay loam or loam about 10 inches thick; somewhat heavier where deeply silted but excellent granulation.
2. Pale-brown friable permeable loam or clay loam to a depth of about 20 inches.
3. Pale-brown to light brownish-gray stratified fine sandy loam, very fine sand, silt, and coarser sediments of variable thicknesses.

The coarser sediments in the substratum permit free water movement. The soil is calcareous throughout.

Use and management.—The same crops are grown on Gila clay loam (silted) as on Pima silty clay loam. Its yields of cotton and small grains are commonly somewhat lower, but in general it is more favorable than the Pima soil for alfalfa, grain sorghums, and most varieties of potatoes. Methods of cultivation are similar for both soils.

Gila fine sandy loam.—Most of this soil occurs as long narrow belts on the nearly level flood plain of the Gila River and is so high it is covered only by exceptionally severe floods. Underdrainage is good, and toxic concentrations of salts uncommon. Slopes range from nearly level to 2 percent.

This soil is stratified; the different layers vary in thickness and texture, but in general their materials are medium to light and are moderately to very permeable. Following is a typical profile:

1. Calcareous pale-brown friable fine sandy loam 10 to 14 inches thick, modified to some extent by irrigation-laid silt.
2. Friable permeable and mildly calcareous pale-brown to light brownish-gray stratified materials ranging from silt loam to loamy fine sand to a depth of 30 to 36 inches.
3. Porous rapidly permeable mildly calcareous light brownish-gray stratified material, ranging from fine sandy loam to sand to 72 inches or more

In places the substrata are very gravelly and porous. The moisture-holding capacity ranges from medium to low.

Use and management.—Nearly all of Gila fine sandy loam is under cultivation. Cotton and potatoes are the main cash crops, although alfalfa, corn, and hegari also are important. It is somewhat less productive for cotton than are the heavier soils, as, for example, Pima silty clay loam, and the heavily silted soils, like Imperial silty clay loam (silted), but is especially well adapted to alfalfa and potatoes. Yields of cotton average 1 to 1½ bales an acre; potatoes, 275 to 325 bushels; alfalfa, 3½ to 5½ tons; corn, 40 to 70 bushels; and hegari, 3,000 to 4,000 pounds. Small grains are used both for pasture and for grain. Oats average about 50 bushels an acre; wheat, 25 bushels; and barley, 40 bushels.

This soil can be plowed and cultivated easily and under a wider range of moisture conditions than the heavier soils, such as Pima silty clay loam. It has moderately good moisture-holding capacity. To maintain its rather high fertility it is essential to grow alfalfa in the crop rotation and to use barnyard manure where available. Green-manure crops of grain and barnyard manure are plowed under in preparing the land for potatoes and other cash crops.

Gila fine sandy loam, channeled phase.—In general this phase is similar to the normal phase, with which it is associated. The chief differences are its more sandy texture and the presence of numerous channels cut by swift-moving waters in periods of high water. Slopes range from nearly level to 2 percent. Some leveling usually is necessary before the phase can be irrigated and cultivated.

Gila fine sandy loam, channeled low-bottom phase.—Although this phase is similar to the channeled phase it occurs at lower levels in association with the low-bottom phase. Nearer to the main channel of the river than the channeled phase, it is subject to more frequent and deeper inundation by floodwater. It is less suitable for irrigation and cultivation than either the channeled or low-bottom phases because of its greater dissection by channels and its larger percentage of coarse sandy material. Bank cutting and channel shifting go on constantly. Slopes range from nearly level to 2 percent.

Gila fine sandy loam, low-bottom phase.—This soil occupies long narrow belts of low land along the Gila River that are inundated whenever the river is at flood stage. Slopes range from nearly level to 2 percent. Although predominantly sandy, the soil varies greatly in texture and stratification within short distances.

Dense thickets of water motie, arrowweed, scattered cottonwoods, and willows check erosion to a considerable extent. Dikes and channel-protection works also aid somewhat in stabilizing the river channel, but bank cutting and channel shifting are not uncommon. Only in a few areas adjacent to the higher lying Gila soils has farming been attempted. The soil is fertile and would be rather highly productive if it could be effectively protected from floods, but because of the ever-present flood hazard the best use of the land is pasture. Browse and pasture, however, are of poor quality, and the carrying capacity is low.

Gila loam, channeled low-bottom phase.—This phase is crossed by numerous channels cut by swift-moving floodwaters and is even less suitable for cultivation than the low-bottom phase, which it otherwise resembles. Slopes range from nearly level to 2 percent.

Gila loam, low-bottom phase.—This phase occurs in the southern part of the area in small widely scattered tracts adjacent to the Gila

River. It is flooded annually and in some localities remains water-logged throughout the year. Owing to its continued leaching, however, it has no accumulations of soluble salts.

This soil is similar to Gila clay loam (silted) but usually has a slightly lighter textured surface soil. Slopes range from nearly level to 2 percent. Its low-lying position for the most part makes it unsuited to cultivation. In a few places, however, dikes afford some protection from small floods, and in such areas small grains are grown for pasture and hegari and corn for grain. The native vegetation consists largely of dense growth of water motie and a scattering of cottonwood and willow, which with annual weeds and occasional water-tolerant grasses provide some pasture. Except where permanent flood-protection measures are taken, farming is very hazardous on this soil.

Glenbar loam, level gravelly subsoil phase.—This soil, which occurs chiefly above the canals, is derived from old lake-laid clays and their overlying gravelly materials. For the most part it occupies the smooth flood plains of the numerous washes, which usually are incised gullies. The slopes rarely exceed 2 percent. Soluble salts in toxic concentrations are uncommon. Following is a description of the profile:

1. Very pale-brown to very light-brown mellow platy loam or fine sandy loam about 6 inches thick, containing occasional pebbles.
2. Very pale-brown to very light-brown friable loam that breaks into soft angular clods to about 18 inches.
3. Pale-brown or light-brown sand and gravel about 4 inches thick.
4. Very light-brown massive and moderately compact silty clay loam with occasional gravel to about 40 inches.
5. Light brownish-gray sand and gravel to about 48 inches.
6. Very light-brown or pale-orange silt loam or silty clay loam, somewhat plastic when wet but friable when dry.

This soil is extremely variable in stratification, but moderately heavy-textured thick subsoil strata are predominant. The entire profile is calcareous, and lime coatings on the gravel are not uncommon.

The small part of this soil that is irrigated by the canals is being farmed and is slightly silted by irrigation sediments. This soil is usually more permeable than other nongravelly Glenbar soils. Fair yields are obtained on a few small farmed areas, but these areas have not become deeply silted. Native vegetation is largely creosotebush, mesquite, chamiza, scattered grasses, and flowering annuals. The carrying capacity of pasture is low.

Glenbar loam, gullied level gravelly subsoil phase.—This soil is similar to the level gravelly subsoil phase except that it has suffered moderate to severe erosion. Sheet erosion is moderate, and most areas have numerous gullies of varying depth. Some areas have been practically destroyed by deep gullies; others have only occasional gullies. Slopes range from nearly level to 2 percent. Suitability for use is less than that of the level gravelly subsoil phase, in direct proportion to the severity of erosion.

Glenbar loam, gullied gently sloping gravelly subsoil phase.—This phase is similar to the gullied level gravelly subsoil phase except that it occurs on slightly strong slopes (2 to 5 percent). Gullies are numerous, and sheet erosion is moderate to severe. Because of its stronger slope and faster runoff, it erodes more rapidly and consequently is less suitable for use than the gullied level gravelly subsoil phase.

Glenbar sandy clay loam.—This soil type occurs as small bodies in widely scattered areas in association with Glenbar silty clay loam, level phase. The texture of the surface soil, which in many places is on overwash of coarser materials, is lighter than that of the associated soil. Slopes range from nearly level to 2 percent, but a few gently sloping areas (2 to 5 percent) are included. Very little of the soil is farmed. The vegetation and the carrying capacity under grazing are about the same as that of Glenbar silty clay loam, level phase. Following is a profile description:

1. Friable calcareous pale-brown to light-brown sandy clay loam or sandy loam about 6 inches thick with a pale-orange tinge.
2. Light-brown to pale-orange massive clay loam that breaks into irregular angular clods, continuing to about 18 inches.
3. Light-brown to pale-orange silty clay loam with vertical cracks that give rise to angular massive pillars to about 46 inches.
4. Light-brown to pale-orange silty clay loam or silty clay, containing fine threads and seams of soluble salts, other than lime, and vertical fractures that form poorly defined prisms 1 to 1½ inches in diameter; extends to about 65 inches.
5. More friable laminated and stratified layers of light-brown or pale-orange clay loam, silty clay loam, and silty clay.

Under cultivation this soil, which is calcareous throughout, would probably require the same treatment as Glenbar silty clay loam, level phase. The yields also would be similar.

Glenbar sandy clay loam, gullied phase.—This phase is similar to the normal phase except that it has lost varying quantities of surface soil through moderate sheet and gully erosion. This erosion has decreased its value for grazing as well as for cultivation, where it can be irrigated. Slopes range from nearly level to 2 percent.

Glenbar silt loam, gravelly subsoil phase.—Although this soil is not extensive, it occurs with other Glenbar soils in many places along the numerous washes entering the valley. It usually occupies smooth stream plains cut by numerous steep-walled gullies. Slopes range from nearly level to 2 percent, but a few gently sloping areas (2 to 5 percent) are included.

Since most of the soil lies above the irrigation canals, very little of it is farmed. The native vegetation, largely mesquite, chamiza, creosotebush, and a scattering of tobosa grass, affords some pasture.

The profile characteristics are similar to those of Glenbar silty clay loam, level phase, except that the texture is somewhat lighter and strata of gravel and sand occur below about 30 inches. These make the soil considerably more permeable than the silty clay loam. Fine-textured materials are interstratified with sand and gravel.

This phase is relatively free from toxic concentrations of salts except in a few areas near irrigated fields where the underdrainage is poor.

Glenbar silt loam, eroded gravelly subsoil phase.—For the most part this phase is similar to the associated gravelly subsoil phase except that it has lost varying quantities of the surface soil by moderate sheet erosion and has been subject also to occasional gullying. Slopes range from nearly level to 2 percent.

Glenbar silt loam, gullied gravelly subsoil phase.—This phase is similar to the gravelly subsoil phase and to the eroded gravelly subsoil phase, but it has been subject to more or less severe erosion, which has produced numerous gullies and moderate sheet erosion. The phase is associated with the gravelly subsoil phase. Slopes range from nearly level to 2 percent.

Glenbar silty clay loam, level phase.—This phase is widely distributed throughout the Arizona section of the area, chiefly on the smooth flood plains or bottom lands along the many tributary washes. Its slopes range from nearly level to 2 percent but rarely exceed 1 percent. The streams or washes crossing areas of this phase are usually deeply incised and confined between vertical banks that are sometimes 10 feet or more above the stream flow. Deep fissures promote additional rapid lateral gully erosion along the steep banks.

The vegetation is more diversified than on the Imperial soils but consists largely of chamiza, mesquite, and a scattering of alkali sacaton and tobosa grass. Barren areas are not uncommon but may be covered by flowering annuals in spring. The carrying capacity of the soil for livestock is low. A representative profile of the virgin soil is as follows:

1. Light-brown to light pinkish-brown calcareous silty clay loam, which is platy at the surface and granular below, sticky and plastic when wet, but friable when dry; about 4 inches thick.
2. Light-brown to pale-orange compact calcareous silty clay loam or silty clay, which breaks into angular clods to about 12 inches
3. Compact calcareous silty clay with vertical cracks giving rise to 1- to 3-inch angular prisms to about 36 inches.
4. Light-brown or pale-orange silty clay or silty clay loam somewhat more friable than the material above but cracked vertically into large-size prisms, continuing to about 64 inches.
5. Similar but slightly lighter textured laminated and stratified material, silt loam or silty clay loam, which, though compact, breaks into floury material, continuing to about 80 inches.
6. Lighter textured stratified materials.

This soil contains some soluble salts retained from the parent lacustrine sediments. It is somewhat plastic and appears to be highly dispersed, but its alkalinity is low. The highest salt concentrations occur along the lower ends of the washes and low terrace fronts along the Gila River flood plain. Some of the salt concentrations have resulted through unfavorable underdrainage caused by the irrigation of higher lying soils.

Use and management.—Most of Glenbar silty clay loam, level phase, that is cultivated is more or less silted by deposition of irrigation sediment and improved by leaching. Crop yields are more or less unsatisfactory until the soil is built up by irrigation sediments and any soluble salt is leached out. This soil is more readily reclaimed than the Imperial soils.

Glenbar silty clay loam, eroded level phase.—This phase, which occurs near the terrace fronts along the Gila River flood plains and the deeply incised tributary streams and washes, differs from the level phase with which it is associated in places in having had varying quantities of its surface removed by sheet erosion. Slopes range from nearly level to 2 percent but usually are about 2 percent.

Glenbar silty clay loam, gullied level phase.—This soil is similar to the level phase, but in addition to suffering some sheet erosion, it is moderately to severely gullied. It occurs in association with the eroded level phase along the terrace fronts and deeply incised tributary streams and washes. Slopes range from nearly level to 2 percent.

Glenbar silty clay loam, level phase (silted).—Widely distributed areas of this phase under irrigation have been silted. A few are included that probably were Glenbar sandy clay loam in the virgin state but have been similarly silted. Slopes range from nearly level to 2 percent.

Although the depth of silting is variable it usually exceeds 1 foot, and depths greater than 2 feet are not uncommon. Silting has made this soil very productive. It has been further improved by irrigation, which has removed toxic salts from the root zone. Most of the crops of the area produce high yields on this soil. Yields of cotton and small grains are especially good. In a few small areas along the Gila River flood plain, reclamation has been less successful, largely owing to poor subdrainage, which in some cases has been aggravated by irrigation.

Use and management.—The heavy character of Glenbar silty clay loam, level phase (silted), makes it best suited to cotton and small grains. Yields of cotton usually average 1¼ to 1½ bales an acre, but much higher yields are reported. When grown for grain, oats yield 50 to 60 bushels an acre; wheat, 25 to 30; and barley, 40 to 45. Corn yields about 50 bushels an acre; and hegari, which often follows the small-grain crops the same year, 2,500 to 2,800 pounds. Alfalfa yields only 3 to 4 tons an acre, but it is grown because the deep-root system increases the permeability of the heavy subsoil.

As with the silted Imperial soils, care must be taken not to plow and cultivate the soil when wet and thereby destroy the natural granulation of the silt. The moisture range for successful tillage is not so wide as on the lighter textured soils.

Glenbar silty clay loam, gently sloping phase.—This phase is similar to the level phase except that it has slightly stronger slopes (2 to 5 percent). Its suitability for cultivation is about the same as that of the level phase, although it is more subject to erosion and may not receive as much silt when irrigated.

Glenbar silty clay loam, gently sloping phase (silted).—This phase is similar to the level phase (silted), but the slopes are slightly stronger (2 to 5 percent) and the silt deposited by irrigation is not so deep.

Glenbar silty clay loam, gullied gently sloping phase.—This phase is similar to the gently sloping phase except that it is more eroded. Both sheet and surface erosion are active but vary greatly in intensity. In most places sheet erosion is moderate, but in some it is severe. Gullies are numerous in the majority of areas, but in others they occur only occasionally. The suitability of the phase for agriculture is not so good as that of the gently sloping phase and in general may be said to vary according to the severity of erosion and the number of gullies. Slopes range from 2 to 5 percent.

Glenbar silty clay loam, gravelly subsoil phase (silted).—This soil is widely distributed within the area served by irrigation canals. Some areas are included that originally were probably Glenbar loam, level gravelly subsoil phase. A large part of the phase is nearly level or very gently sloping; only a few small areas have slopes exceeding 2 percent.

The uniformity of slope on this soil has tended to equalize the silting, the average depth of which is probably about 1 foot. Depth up to 2 feet or more, however, is not uncommon at the lower end of irrigated fields. The presence of a sand and gravel strata makes the soil somewhat more permeable than is usual in a soil of such heavy character.

Use and management.—All of Glenbar silty clay loam, gravelly subsoil phase (silted), is farmed and is suitable for most crops of the area. The yields are high. Cotton, the principal cash crop grown, averages 1 to 1½ bales an acre but may yield up to 2 bales or more; oats, 50 to 60 bushels; wheat, 25 to 30; barley, 40 to 50; and corn, 55 to 60. Hegari, usually grown following these crops, produces 2,700 to 3,000 pounds an acre. This phase is more suitable for alfalfa than the unsilted Glenbar soils and the yields average 3½ to 4½ tons an acre.

The use of alfalfa in the crop rotation aids in maintaining fertility and prevents compaction, which normally accompanies deep silting. Although the silted soil may have an excellent structure under optimum conditions, it is plastic and slick when wet and should not be plowed and cultivated until drier if good tilth is to be maintained. Toxic concentrations of salts do not occur.

Imperial silty clay, level phase.—Less than half the original area of this soil was still unirrigated and unsilted in 1939. Most of it lies east of Franklin, outside and above the elevation of the area served by the canals. In its virgin state the soil supports only salt-tolerant vegetation, mostly chamiza and alkali sacaton. Extensive areas are barren. Slopes range from nearly level to 2 percent.

Although this soil varies considerably as to texture and thickness of strata, a characteristic profile is as follows:

1. Pale-brown or light brownish-gray silty clay, after saturation forming a glazed crust about ¼-inch thick
2. Material of similar color and texture but of granular structure, open and permeable, about 2 inches thick.
3. Pale-brown or light brownish-gray calcareous silty clay, massive and relatively dense and slowly permeable, breaks into large angular clods, low in organic matter, about 8 inches thick.
4. Pale brown dense calcareous silty clay with an indistinct coarse prismatic structure, about 18 inches thick.
5. Very pale-brown or light brownish-gray calcareous silty clay continuing to about 46 inches, massively or coarsely prismatic—the prisms about 12 inches in diameter
6. Very light brownish-gray or light olive-gray calcareous massive vertically fissured clay or silty clay with fine white threads or flecks of lime and salt.

This soil is relatively calcareous, lime being more or less evenly distributed throughout all the layers. When wet the soil is sticky and plastic; when dry, hard, though somewhat crumbly. The substratum is often stratified and only moderately permeable. Water penetration is generally slow. The cracks formed in dry weather are probably partly responsible for its particular susceptibility to gully erosion. A long time is required to reclaim this soil.

Use and management.—Unirrigated areas of Imperial silty clay, level phase, have only low value as livestock range. When the land is first irrigated it is not very productive. Crop yields are not satisfactory until some of the salt is leached out and a layer of silt deposited over the surface. The smooth nearly level to very gently sloping surface, however, is favorable to the even distribution of irrigation water and facilitates both silting and leaching.

Imperial silty clay, eroded level phase.—In general this phase resembles the level phase, with which it is associated. The surface soil, however, is considerably thinner, being badly worn down by sheet erosion caused by runoff waters from nearby higher lying lands. The higher salt content may also have contributed to erosion. Lacking water, most of the soil is barren of vegetation. Reclamation through irrigation would in all probability require a longer time and prove more costly than on the level phase. Slopes range from nearly level to 2 percent.

Imperial silty clay, gullied level phase.—This phase is similar to the eroded level phase except that it has been subject to moderate to severe gullying. Because of the gullies, it is much more difficult to reclaim for cropping under irrigation than the level and eroded level phases with which associated. Some areas may be so severely gullied as to make reclamation impracticable. Slopes are from nearly level to 2 percent.

Imperial silty clay, eroded gently sloping phase.—This phase is similar to the eroded level and gullied level phases but occurs on slightly stronger slopes (2 to 5 percent). Some areas are only moderately sheet eroded; others suffer from both sheet erosion and gullying, which in places may be severe. The use of this phase is conditioned by the severity of erosion, including the number and depth of the gullies.

Imperial silty clay loam (silted).—This soil occurs as an almost continuous body in the vicinity of Franklin. Under irrigation it has become deeply silted, the depth ranging from a few inches to more than 2 feet. The soil is productive in proportion to the depth of silting and downward leaching of the salts. While irrigation is building up a fertile surface soil of excellent granular structure, the continued leaching reduces the salt content in the root zone. Thus an artificial soil, or made land, with a fertile surface soil and a subsoil of high moisture-holding capacity is gradually produced. Slopes range from nearly level to 2 percent.

Use and management.—Most of Imperial silty clay loam (silted) has been successfully reclaimed and is producing high yields of cotton and small grains. Areas having excessive accumulations of harmful salts or unfavorable subdrainage have not been so successfully reclaimed. Most of such areas are near the washes or the low terrace fronts along the Gila River flood plain. In this section idle or abandoned fields are constantly becoming worse as, without cultivation, the movement of the salts is reversed and they concentrate at the surface.

This soil is proving well adapted to the production of cotton, small grains, and other crops. On the deeply silted soil, yields of cotton equal to those on Pima silty clay loam are reported, but the average is probably 1 to 1½ bales an acre; oats yield 45 to 55 bushels; wheat, 25 to 30; and barley, 40 to 45. Pasture and grain crops, especially barley, can be grown to good advantage during the period of reclamation. Hegari, which is planted the same season following these crops, also can be grown to good advantage and yields 2,500 to 2,700 pounds. Corn averages 45 bushels an acre. Alfalfa does not give such good results on this soil as on others, probably yielding 3 to 3½ tons, but it is favored, since as a deep-rooted crop it is excellently adapted to breaking up the compact subsoil and thereby increases its permeability.

Pima silty clay loam.—Occupying long narrow belts or strips on the valley floor, this soil occurs in the southern part of the area, where it runs roughly parallel, although not immediately adjacent, to the Gila River. In this type there is deep dark-colored river alluvium even below the irrigation silt, making it unusually fertile and one of the most important irrigated soils of the valley. Free root penetration is afforded by its depth, granular structure, and friable consistence.

Although the type has a smooth nearly flat to very gently sloping surface (nearly level to 2 percent), the underdrainage is sufficient to prevent waterlogging or accumulations of soluble salts. The profile of the soil varies, but the following description is representative:

1. Friable granular brownish-gray silty clay loam, dusky brown when moist, to about 12 to 15 inches.
2. Brownish-gray silty clay loam, moderately compact, with irregularly fine blocky structure to about 24 inches.
3. Stratified or laminated layers of pale-brown to weak-brown mellow and friable silty clay loam, loam, and clay loam with occasional more sandy and silty seams to about 40 inches.
4. Friable stratified pale-brown material ranging from fine sandy loam to silty clay loam to about 70 inches.
5. Coarser material.

Underdrainage is free. The soil is rich in lime but has no definite lime concentration in any layer.

Variation in the rate of flow of irrigation water has caused segregation of the silt and consequently a variation from loam to silty clay in the texture of the surface soil of individual fields, although the dominant texture appears to be silty clay loam. The soil is granular and friable in spite of its high clay content. It should not be cultivated when wet, however, as it becomes sticky and plastic and may have its tilth injured. It is one of the most deeply silted soils in the area as a result of its long-time irrigation and location on nearly flat or on very gently sloping areas, where silt from the irrigation water settles readily. The stratified materials in the subsoil range from fine sandy loam to silty clay loam and are usually somewhat lighter below 2 or 3 feet. The soil is relatively high in organic matter and holds moisture effectively for long periods.

Use and management.—Nearly all of Pima silty clay loam is farmed. Only one small area, near York, is not cultivated, because of toxic concentrations of salts or alkali.

Cotton is the principal crop, and because of the high fertility of the soil, which is continuously replenished by silting, this crop can be grown many years in succession with little if any decline in yield or deterioration in fiber. The yields may reach as much as 3 bales an acre, but 1½ to 2½ bales are more common.

Small grains are grown extensively and give excellent yields. Occasionally oats yield 100 bushels or more to the acre, but under average management the yields are 65 to 70 bushels. Wheat yields 30 to 35 bushels, and barley, 35 to 55. Small grains commonly grazed before being allowed to mature supply considerable pasture. Grain sorghums, principally hegari, which average 3,000 to 3,500 pounds of grain, are planted the same season following the small grains (pl. 1, *B*). When the small grains are used for winter pasture and plowed in spring, they are followed by corn, which proves a satisfactory crop to complete the seasonal rotation. Almost all corn varieties other than Mexican June will mature on this soil and produce heavy yields. Although yields as high as 100 bushels are reported, the average is 50 to 60.

This soil is almost too heavy for potatoes, but good yields of varieties like Chippewa can be obtained by plowing under green-grain crops, barnyard manure, and alfalfa and by following other good management practices. Excellent yields of head lettuce can be obtained by similar practices.

Alfalfa is an excellent crop to grow in the rotation, especially where the soil has a heavy texture and is deeply silted, since the roots open up the soil and increase its permeability. There is a tendency, however, for the crowns to be injured by the deposits of silt on land as flat as this. Alfalfa yields 3½ to 5 tons an acre annually with five cuttings.

Riverwash.—This land type occupies the channels and stream beds of the Gila River and its numerous tributaries. Washed from a wide variety of rocks, it consists of unstable intermingled fine sediments, sand, gravel, cobbles, and stones. Along the Gila River it consists chiefly of washed sands with occasional lenses and streaks of gravel and stone. The surface is eroded and channeled and is swept at irregular intervals by floodwaters. Along many of the numerous tributary washes dikes have been constructed to confine the stream to its channels. The surface materials usually are too unstable to support vegetation. Slopes on this land type range from nearly level to 2 percent.

Rough broken land, coarse materials.—This soil material occurs on steep gravelly or stony escarpments rising from the alluvial valleys to the high surrounding plains. Its location is similar to that of Rough broken land, fine-textured materials, but its components are coarser, consisting of thin mantles of colluvial rubble overlying lacustrine sediments, which are exposed in places. Slopes are more than 15 percent.

Rough broken land, fine-textured materials.—This land type occurs on rough broken areas and steep escarpments rising from the alluvial valleys to the high surrounding plains. The slopes are occasionally precipitous and seldom less than 15 percent. The eroded lake-laid materials are largely gravel-free silts and clays that are more or less stratified with marly lime and coarser textured materials. Gravel beds are rare.

Native vegetation consists of a variety of desert shrubs and some little grass. The only agricultural value of this land type is for scanty pasture.

Stacy clay loam, level phase (silted).—Most of this phase occurs in the New Mexico part of the area and forms an important part of the land under cultivation. In general the slope is smooth (nearly level to 2 percent) and favorable for irrigation.

This phase is similar to Stacy sandy loam, although it has a heavier textured surface soil because of silting. For the most part, the water requirement is higher than on the majority of cultivated lands in the area. The open character of the subsoil is conducive to free drainage, and therefore toxic salts have not accumulated.

The silted layer is less than 1 foot deep on the average, but the lower ends of irrigated fields are usually more deeply covered and as a consequence are the most productive. Where washes have overflowed and left coarse sediments the silting may be shallow and uneven, with gravelly areas not uncommon.

Use and management.—Although cotton is grown widely on Stacy clay loam, level phase (silted), the well-drained and well-aerated soil makes it well adapted also to potatoes, which are the principal cash crop. By plowing under green crops or manure and adding alfalfa to the rotation, even better yields of potatoes and other crops are obtained. The yield from the two crops of potatoes grown in a season averages about 300 bushels an acre. Alfalfa, which is cut five times a year, usually yields an average of 3½ to 4½ tons an acre and cotton, about 1 bale. The average yields of hegari are about 2,500 to 3,000 pounds, and of corn, about 45 to 50 bushels. Small grains are grown for pasture and grain. Oats have an average yield of 40 to 50 bushels; wheat, 20 to 25; and barley, 30 to 40.

Stacy clay loam, gently sloping phase (silted).—In general this phase is similar to the level phase (silted), with which it is associated. It differs in several respects, however, having stronger slopes (2 to 5 percent) and a more gravelly and porous subsoil. Furthermore, because the silt deposit in the surface is generally thinner and of more variable depth than that of the level phase (silted), there is considerable variation in surface texture in parts of individual fields, which may have a loam or clay loam at the upper shallow-silted end and a clay at the lower end, which is deeper silted.

Areas of this phase are generally on the higher parts of the fans. The more gravelly subsoil, steepness of slope, and thinner silting make it more droughty than the level phase (silted). A few areas that have numerous gullies and slight sheet erosion are included in the map. Erosion in the irrigation furrows frequently exposes the unsilted soil.

Stacy gravelly clay loam, gently sloping phase (silted).—This soil is similar to the level phase (silted), except that it occupies stronger slopes (2 to 5 percent). Some areas with slopes of 5 to 10 percent are included. Silt deposits are thinner than on the level phase (silted), and in general this soil is less well suited to irrigation and crop production.

Stacy gravelly clay loam, level phase (silted).—This soil is inextensive, occurring as small bodies widely scattered throughout the irrigated part of the area. The silt deposit is only a few inches thick in most places, and the soil retains much of its original droughty character. The crops are similar to those grown on Stacy clay loam, level phase (silted), but the yields are much lower. Cultivation is difficult because of the gravel in the soil. Slopes range from nearly level to 2 percent.

Stacy gravelly sandy loam, level phase.—Most of this soil lies above the canals and consequently is farmed in only a few small areas. It occurs on alluvial plains, nearly level to 2 percent slope, along the numerous lateral washes throughout the valley. Shifting deeply entrenched intermittent streams traverse this phase, subjecting it to erosion and depositing coarse sediment, including gravel and cobbles, on the surface. The soil profile is described as follows:

1. Pale-brown calcareous gravelly sandy loam to about 18 inches.
2. Pale-brown or light brownish-gray calcareous stratified gravelly sandy loam and loamy sand with occasional threads or seams of lime and lime coatings on some of the gravel but no compaction or structure to about 36 inches.
3. Light brownish-gray open porous stratified sand and gravel with lime coatings on some of the pebbles to 80 inches or more.

The lime content gives this soil a definite gray color when dry; the igneous gravel tends to make it appear brown when wet. Since the soil has been eroded from the lime-cemented gravel capping overlying the old lake clays of the high terraces, much of the gravel probably was coated with lime before being deposited. Some areas have moderate sheet erosion and occasional gullies.

Use and management.—With low water-holding capacity and low fertility, Stacy gravelly sandy loam, level phase, is not very productive and little of it is under cultivation. A few small areas that have been irrigated and silted are described as Stacy gravelly clay loam, level phase (silted). In its virgin state it supports a rather wide variety of plants, including creosotebush, mesquite, catclaw, Mormon-tea, crucifixion thorn, squaw bush, lotebush, broom snakeweed, cactus, annual grasses, and flowering herbs. Its carrying capacity under grazing is low.

Stacy gravelly sandy loam, gullied level phase.—This soil is similar to the level phase, except that it is susceptible to moderate sheet erosion and gullying. In places, the content of gravel and cobbles is so great that the soil is worthless for agriculture. Slopes range from nearly level to 2 percent.

Stacy gravelly sandy loam, gently sloping phase.—This soil is similar to Stacy gravelly sandy loam, level phase, except that it occurs on stronger slopes. Although 2 to 5 percent slopes usually prevail, in places the slopes are 5 to 10 percent. The soil occurs on higher alluvial fans, principally in the New Mexico part of the area, where the concentration of lime in the subsoil is greater than elsewhere. Some of the higher fans have an exceptionally high content of cobbles and stones. Moderate sheet erosion and some gullying is going on in places. This phase is less well suited to cultivation than the level phase.

Stacy gravelly sandy loam, gullied gently sloping phase.—This phase is similar to the gently sloping phase except that the soil is slightly to moderately sheet eroded and in most areas has numerous gullies. The soil occupies the upper part of slopes, which range from 2 to 5 percent and in a few areas from 5 to 10 percent. Some areas are cobbly. The phase, in general, is less well suited to cultivation than the gently sloping phase.

810440—50——3

Stacy sandy loam.—This soil is widely distributed, largely in the Arizona part of the area. It occurs mostly within smooth gently sloping alluvial fans on bottom lands along the more deeply entrenched washes in the northern part of the area. It therefore contains more old lacustrine material than the other soils of this series. The light-brown color and relatively fine texture of much of the stratified material also points to its lacustrine origin. In many places this soil is cut by gullies but not so deeply as the heavier soils of the area. Considerable sediment is deposited by the intermittent streams, which occasionally shift their courses, but there are no accumulations of toxic salt. Slopes range from nearly level to 2 percent. Although this soil varies considerably in profile, the following description is fairly representative:

1. Light-brown platy mellow calcareous sandy loam or loam with scattered pebbles, about 3 inches thick.
2. Similarly colored friable calcareous sandy loam breaking into soft clods, about 13 inches thick.
3. Lighter brown to light brownish-gray stratified loam, sandy loam, and loamy sand, about 30 inches thick, containing some gravel and having threadlike deposits of lime slightly more concentrated than at the surface.
4. Light brownish-gray gravel and sand strata with faint lime seams and some lime-coated fragments.
5. Light brownish-gray open porous stratified sand and gravel to 70 inches or more.

The fragments of the subsoil are thinly coated with lime, which tends to give them a light color. When wet, however, the material is darker, owing to the rhyolite, andesite, and basalt, from which it is largely derived. The presence of rounded accretionary lime fragments washed from the lake deposits and thick lime coatings on some pebbles indicate that this soil was eroded from the gravelly terrace capping. The substratum is usually increasingly porous and gravelly. Some areas of this soil have slight sheet erosion and occasional gullies.

Use and management.—None of Stacy sandy loam is under cultivation. The native vegetation is largely creosotebush, mesquite, broom snakeweed, yucca, and cactus, although scattered annual grasses and flowering annuals provide some grazing.

Stacy sandy loam, eroded phase.—This soil is similar to the normal phase except that part of the surface soil has been removed by moderate sheet erosion and occasional to numerous gullies have developed in some areas. The dominant slopes are from nearly level to 2 percent, but slopes reaching 5 percent are included.

Teague gravelly sandy loam, eroded undulating phase.—This soil occurs in widely scattered bodies on the high terraces at the outer margins of the area. None of the phase is farmed, but its scanty vegetation provides some grazing. Slopes are 2 to 5 percent on most areas, but a few are 5 to 10 percent. Following is a profile description:

1. Light-brown to moderate-brown noncalcareous gritty or sandy loam to about 6 inches, the surface layer constituting a desert pavement of water-worn gravel and having a thin vesicular crust.
2. Weak reddish-brown noncalcareous highly colloidal tough plastic gritty clay with scattered gravel to about 14 inches, breaking into irregular prisms or angular blocks.
3. Light-brown to strong-brown plastic clay or gritty loam about 6 inches thick, less colloidal than layer above, faint lime seams and some gravel.

4. Variegated light-brown heavy coarse sandy loam or gritty clay loam to about 26 inches, lime seams and some gravel and cobbles present.
5. Light-gray conglomeratelike lime hardpan, in some places only a foot or less thick and underlain by loose or softly cemented gravel and cobbles, in others, continues to great depth.

This soil borders the steep terrace fronts and the numerous deep and shallow drainage channels that are being cut back into the flat mesa tops. The gravelly and cobbly character of the upper soil and the hardpan in the interstream areas help to resist erosion. Large areas near the terrace fronts and adjacent to the drainage channels, however, have a calcareous surface soil, which has eroded deeply enough to expose the hardpan. The steep areas along the terrace fronts are mapped as Rough broken land.

Teague gravelly sandy loam, eroded level phase.—This phase occurs in a few scattered areas on a gradient of 0 to 2 percent. It has less slope than the eroded undulating phase and no gullies.

PRODUCTIVITY, USE, AND MANAGEMENT OF THE SOILS

The chief factors influencing productivity are temperature, moisture supply, soil, and lay of the land. Crop yields over a long period of years, however, furnish the best available index of soil productivity.

The estimated average acre yields that may be expected from the principal crops grown on the soils of the area under the prevailing system of irrigation farming are given in table 5. Under natural desert conditions these soils have practically no agricultural value, but under irrigation many of them are highly productive. Potential yields of soils that can be cultivated as soon as gravity irrigation is available are estimated on the basis of the yields from irrigated soils of similar chemical composition. Others, because of steepness or roughness, have little value even for grazing.

Ordinary management practices include the use of legume crops and barnyard manure. Farmers in the area seldom purchase commercial fertilizer or lime. Unirrigated pasture and range customarily do not receive applications of any kind of fertilizer.

With the productivity of many of the soils gradually being increased by the deposition of silt from irrigation water and by the leaching of salts, irrigated sections of the area will become even more productive.

The productivity of the soils may be considered relatively permanent as compared with transitory economic conditions. It is important to realize, however, that productivity in terms of yields is not the only consideration that determines the relative value of a soil for growing crops. Inherent fertility, ease of tillage, and maintenance of yields at a given level, susceptibility to erosion, and, in this area, the ease of distribution and efficiency of use of water for irrigation likewise are factors that influence the general suitability of a soil for agricultural use.

Each soil is placed in one of five classes on the basis of its suitability for irrigation, as shown in table 5.

The first group includes soils well suited to irrigation and comprises almost the entire area under cultivation. These soils have a high fertility either natural or acquired through deep silting by irrigation sediments. They are ideally suited to effective distribution and efficient

TABLE 5.—*Estimated average acre yields of the principal crops on the soils of the Duncan area, Arizona-New Mexico*

[Blank spaces indicate that the soil is not irrigated and therefore is not under cultivation]

Soil	Cotton lint	Alfalfa hay	Oats	Wheat	Barley	Grain sorghums	Corn	Potatoes	Rotation pasture [1]	Range pasture [2]	Irrigation suitability group [3]
	Lb.	*Tons*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Cow-acre-days* [4]	*Cow-acre-days* [4]	
Cavot gravelly sandy loam:											
Eroded sloping phase	----	----	----	----	----	----	----	----	----	10	4
Eroded undulating phase	----	----	----	----	----	----	----	----	----	10	4
Gullied rolling phase	----	----	----	----	----	----	----	----	----	7	4
Continental gravelly sandy loam:											
Eroded level phase	----	----	----	----	----	----	----	----	----	10	4
Eroded undulating phase	----	----	----	----	----	----	----	----	----	7	4
Dos Cabezas clay loam (silted)	560	4.4	45	25	36	36	48	220	110	(5)	1
Dos Cabezas gravelly sandy loam:											
Eroded gently sloping phase	----	----	----	----	----	----	----	----	----	7	4
Eroded level phase	----	----	----	----	----	----	----	----	----	10	4
Eroded undulating phase	----	----	----	----	----	----	----	----	----	7	4
Dos Cabezas sandy loam, eroded phase	----	----	----	----	----	----	----	----	----	10	2
Gila clay loam (silted)	700	5.0	60	29	42	46	55	270	135	(5)	1
Gila fine sandy loam	540	5.0	50	25	40	44	53	280	125	(5)	1
Channeled phase	----	----	----	----	----	----	----	----	----	15	3
Channeled low-bottom phase	----	----	----	----	----	----	----	----	----	10	3
Low-bottom phase	----	----	----	----	----	----	----	----	----	20	3
Gila loam:											
Channeled low-bottom phase	----	----	----	----	----	----	----	----	----	15	3
Low-bottom phase	----	----	----	----	----	----	----	----	----	25	3

Glenbar loam:											
Gullied gently sloping gravelly subsoil phase										10	4
Gullied level gravelly subsoil phase										10	4
Level gravelly subsoil phase										10	2
Glenbar sandy clay loam										10	2
Gullied phase										7	4
Glenbar silt loam:											
Eroded gravelly subsoil phase										10	2
Gravelly subsoil phase										10	2
Gullied gravelly subsoil phase										7	4
Glenbar silty clay loam:											
Eroded level phase										10	2
Gently sloping phase										10	2
Gently sloping phase (silted)	640	4. 0	50	28	40	38	48	210	115	([5])	1
Gravelly subsoil phase (silted)	600	4. 8	53	26	40	40	53	250	120	([5])	1
Gullied gently sloping phase										7	4
Gullied level phase										8	4
Level phase										12	2
Level phase (silted)	640	4. 0	50	28	40	38	48	210	115	([5])	1
Imperial silty clay:											
Eroded gently sloping phase										7	2
Eroded level phase										10	2
Gullied level phase										7	4
Level phase										10	2
Imperial silty clay loam (silted)	600	3. 6	48	26	40	38	45	200	110	([5])	1
Pima silty clay loam	800	4. 8	65	30	44	44	55	240	150	([5])	1
Riverwash										5	5
Rough broken land:											
Coarse materials										5	5
Fine-textured materials										10	5
Stacy clay loam:											
Gently sloping phase (silted)	440	4. 6	40	21	30	38	45	250	105	([5])	1
Level phase (silted)	480	5. 0	45	24	34	42	50	270	115	([5])	1
Stacy gravelly clay loam:											
Gently sloping phase (silted)	320	3. 2	33	16	24	26	33	170	80	([5])	2
Level phase (silted)	380	3. 2	33	16	24	26	33	170	80	([5])	2

See footnotes at end of table.

TABLE 5.—*Estimated average acre yields of the principal crops on the soils of the Duncan area, Arizona–New Mexico*—Con.

[Blank spaces indicate that the soil is not irrigated and therefore is not under cultivation]

Soil	Cotton lint	Alfalfa hay	Oats	Wheat	Barley	Grain sorghums	Corn	Potatoes	Rotation pasture [1]	Range pasture [2]	Irrigation suitability group [3]
	Lb.	*Tons*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu*	*Cow-acre-days* [4]	*Cow-acre-days* [4]	
Stacy gravelly sandy loam:											
Gently sloping phase	------	------	------	------	------	------	------	------	------	10	4
Gullied gently sloping phase	------	------	------	------	------	------	------	------	------	9	4
Gullied level phase	------	------	------	------	------	------	------	------	------	8	4
Level phase	------	------	------	------	------	------	------	------	------	12	4
Stacy sandy loam	------	------	------	------	------	------	------	------	------	12	2
Eroded phase	------	------	------	------	------	------	------	------	------	8	2
Teague gravelly sandy loam:											
Eroded level phase	------	------	------	------	------	------	------	------	------	12	4
Eroded undulating phase	------	------	------	------	------	------	------	------	------	8	4

[1] Irrigated pasture.

[2] Unirrigated natural pasture.

[3] Group 1 includes soils well suited to irrigation; group 2, soils fairly well suited; group 3, soils poorly suited, group 4, soils generally unsuited; and group 5, soils unsuited.

[4] Cow-acre-days, used to express the carrying capacity of pasture land, is the product of the number of animal units carried per acre multiplied by the number of days that animals can be grazed without injury to pasture, for example, a soil that supports 1 animal unit per acre for 360 days rates 360; a soil supporting 1 animal unit on 2 acres for 180 days rates 90, and a soil supporting 1 animal unit on 4 acres for 100 days rates 25.

[5] Soil used entirely for irrigated crops.

use of irrigation water and are highly productive when adequately irrigated.

The second group includes soils that, with two exceptions, are unsilted. Most of them are uncultivated at the present time. For the most part they occur above the level of gravity irrigation water but in places where they might possibly be irrigated by pumping. In their natural state they are only fairly fertile, and several, as the Glenbar and Imperial soils, commonly contain toxic concentrations of salts. If these soils were to be irrigated with water from the river, however, they would become silted and eventually acquire the fertile properties of the silted soils in the first group. Stacy gravelly clay loam, level phase (silted), is only slightly silted and in addition is gravelly and droughty. Some areas are not effectively protected from overflow from desert washes.

Although the general lay of the land is suitable for effective distribution of irrigation water, it has many irregularities, including gullies, sags, and swells. These would require leveling before irrigation could be efficient and economical. In places protection is afforded by detention dams and storm dikes. Similar protection is necessary in many other places before all the soils of this group can be used for cultivated crops. The Glenbar and Imperial soils are highly erodible and are frequently traversed by deep uncrossable gullies with deep lateral fissures rapidly being widened and deepened by accelerated erosion.

The third group is composed of Gila soils that occur adjacent to the Gila River and are rather frequently flooded. They are traversed by numerous channels and have sandy hummocks and irregularly laid sediments that make them unsuitable for irrigation unless considerably leveled. A few areas, protected by low dikes, are farmed at least a part of the season. Where effective permanent flood protection is feasible, these soils are suitable for irrigation and many of them prove highly productive. Some of the soils, however, are underlain at shallow depths by gravel or coarse sand and would be droughty under cultivation.

The soils of the fourth group, which includes gravelly soils for the most part unsuited to irrigation, have little if any potential value for cultivation. All the soils of the group except the Stacy occur high on terraces where only pumped water is available. Depth to water at this point, moreover, makes the cost of this type of irrigation prohibitive for such poor quality soils. Areas of Stacy gravelly sandy loam occurring where gravity water is available possibly could be used for cultivation.

The Rough broken lands and Riverwash, which comprise the fifth group, are unsuited to irrigation and are used principally as range land. Rough broken land, composed of fine-textured materials, has a very steep and broken relief; and Rough broken land, composed of coarse materials, is more or less littered with stone and cobbles. Riverwash consists of unstable shifting sand and gravel in or near stream channels.

WATER CONTROL ON THE LAND

The irrigated part of the Gila River valley, which is the part immediately adjacent to the river, furnishes the principal problems of irrigation and drainage and of control of runoff, erosion, and deposition. About 11 percent of the area, or approximately one-fourth of the land occurring within the range of the numerous irrigation canals, cannot be cultivated, because it is subject to floods, the deposition of coarse sandy and gravelly materials, or severe gullying and bank cutting.

Destructive floods in 1916 temporarily forced many settlers from the low-lying lands along the Gila River, and in September 1941 [5] a flow of approximately 41,700 second-feet caused a flood that inundated about 2,800 acres of cultivated land, severely damaging crops. Unfortunately such floods cannot be controlled locally, owing to their unpredictable character and rapid rise.

Floods from discharges up to 25,000 second-feet occur from time to time but affect only the low areas along the river, many of which are uncultivated. Estimates by the Soil Conservation Service indicate that discharges of 5,000 second-feet will probably occur once in 4 years, and that a flow as high as 9,000 second-feet discharge will take place only once in 8 years. On the basis of the area under cultivation in 1941, 400 and 800 acres, respectively, would be inundated by such discharges. The construction of low dikes often gives these lower cultivated lands temporary protection, especially against small sporadic floods in the growing season.

Land along the numerous sidewashes is in constant danger of flash floods carrying heavy loads of sand, gravel, and cobbles, which frequently spread in sheets over the adjacent cultivated acreage. The canals themselves afford some protection along the outer margin of the cultivated area, and retaining dams and dikes have been constructed recently with government aid.

In other sections the lateral washes are deeply incised in alluvial plains and fans of heavy-textured soils. Deep-spreading cracks in these soils promote rapid gully erosion and destruction of adjacent lands. In the cultivated area uncontrolled waste irrigation water often contributes to accelerated erosion.

Drainage does not constitute so great a problem in this area as control of runoff and floods. Only in the narrow low-lying areas adjacent to the immediate stream bed of the Gila River are waterlogging and the concentration of salts serious problems; but unless the river is diked and the channel straightened, such areas probably cannot be successfully drained.

CONTROL OF RUNOFF, EROSION, AND DEPOSITION

In the New Mexico part of the area the problem of protecting cultivated land from overflow and detrimental deposition of gravel and sand by the lateral washes is greater than that of controlling gully formation, although there are places where fissures are rapidly becoming deep gullies. Dikes, which have been constructed with government aid, effectively confine floodwaters to the straightened channels running directly to the river, and detention dams, placed well back in these washes, tend to check and equalize the water load carried in times of rapid runoff. Similar detention dams in the Arizona section tend to reduce overflow, accelerated erosion, and gullying and bank cutting on Glenbar, Imperial, and other heavy-textured soils of the

[5] As reported by the U. S. Geological Survey.

alluvial flats and fans. At the present time such flood-protection works are probably more complete in the New Mexico part of the area.

In the uncultivated lands along the outer margin of the area, which consists of high terraces with steep broken fronts and alluvial fans and flats along the numerous lateral washes, accelerated erosion is common, and even pronounced in many places. At the same time the destructive force of accumulated water in the lower reaches of the washes has caused numerous deep gullies and sheet erosion; this occurs, especially above the canals, on the heavy-textured soils in the flood plains of the more deeply incised lateral valleys of the Arizona side. To prevent such rapid runoff and erosion, numerous gully check dams and rock and gravel contour dams have been laid, and in addition, detention dams and dikes for checking accumulated water in the lower reaches of the washes have been constructed.

On the whole, erosion on individual farms is well controlled, although some of the steeper slopes are subject to erosion by irrigation water. The constant addition of sediment in the irrigation water offsets some of the erosion losses. Most farmers level their land as completely as possible for more effective distribution and efficient use of water. Perhaps the most destructive erosion occurs along or near incised stream channels and terrace fronts where waste irrigation waters are not controlled. Dikes and dams along the margins of the streams serve as some protection, but on the Imperial, Glenbar, and other heavy clayey soils these measures may not be effective, owing to the numerous deep cracks that penetrate into the subsoil.

Much of the area covered by the low-bottom phases of the Gila soils could probably be farmed if it could be protected by dikes along the Gila River. There is the danger, however, that the dikes might be destroyed by heavy floods. The river is constantly shifting its course and in some areas is destroying valuable bordering fields. The area involved is relatively small, however, and the cost of flood protection might exceed the value of benefits derived.

IRRIGATION

About 37 percent of the area is under cultivation and is supplied with water diverted from the Gila River. No storage reservoirs have been constructed, but a supplementary supply is pumped from the shallow ground water in times of drought or periods when the water in the river is low. The low-water period occurs after the spring flow from the mountains subsides and before the summer rains begin. Priority rights govern the quantity that can be drawn from the river and distributed within the area. The headings used to divert the water at favorable sites are poorly constructed and unstable. As a result they are frequently torn out by floods but are easily rebuilt and adjusted to the flow and to the diversion permitted. Most of the wells and pumps are community owned, being financed with government aid. The underground water usually is pumped into the canals and distributed in the same way as the gravity flow. Pumping materially adds to the cost of the water and is resorted to only when a supplementary supply is essential. The waste water from irrigation flows into the river and is used again farther down.

Over the greater part of the area, the relief is excellent for effective distribution of irrigation water. Many of the slopes are of less than

1 percent, and only in a few places do they exceed 3 percent. The gentleness of the slopes allows for considerable latitude in irrigation methods. Both the flooding and border methods are common for field crops, whereas the furrow method is used for row crops. In the border method small corrugations often are used to facilitate distribution.

SALTS (ALKALI)

In this area only the white alkali salts, consisting largely of sodium chloride and sodium sulfate, are common. A few areas of very heavy-textured or leached soils show indications of sodium carbonate or black alkali, but this is rarely evident at the surface as a black crust. In most areas it does not occur in sufficient quantity to affect plant growth appreciably or to impair the physical structure of the soils. Soils of the Imperial and Glenbar series, derived from the saline lake clays, appear to be slightly dispersed.

The moderately saline parent soil material derived from the lake-laid sediments underlying the gravel-capped mesas is the principal source of soluble salts in this area. The Imperial and Glenbar series, which have come from these sediments, contain in places large concentrations of salts scattered throughout the soil, subsoil, and substratum. Other soils derived from lake-laid materials also contain considerable concentrations of salts. These concentrations, due to insufficient drainage, usually occur in low areas adjacent to the Gila River. The Gila soils are those most commonly affected, but the condition is usually spotty and the salts are not very highly concentrated. A certain quantity of natural leaching occurs each year in soils subject to overflow. Salts often become concentrated at points, as along the base of a terrace where the heavy soils from the lake clays adjoin the Gila soils.

In the irrigated areas, most of the soils that were formerly saline have been reclaimed and now are less likely to contain toxic salt concentrations than other soils. Soils in this area apparently are not subject to the formation of black alkali during the process of leaching, as are many heavy-textured soils in other areas. Their relatively high gypsum content may prevent the formation of alkali carbonates. Under irrigation, reclamation is probably facilitated by the deposit by irrigation water of silt with a relatively high calcium and organic-matter content. Reclamation in this area is unique, because the sediments deposited by irrigation water form a salt-free surface soil. Moreover, if the salts are kept moving downward or kept below the root zone, crop production is not jeopardized, a fact especially true of the Imperial soils and a large part of the Glenbar, where reclamation has been efficient when accompanied by sufficient underdrainage.

Studies made of related plant, soil, and drainage conditions in order to establish the boundaries of salt-affected areas show three general grades of concentration.

1. The most strongly salt-affected areas, which have toxic salt concentrations in excess of 1 percent, are either barren or support only saltgrass, seepweed (*Suaeda* spp.), saltbush, and other salt-tolerant vegetation.

2. Areas delineated on the map as moderately salt affected have toxic salt concentrations of 0.4 to 1 percent, a condition that seriously retards or completely inhibits the growth of economic plants. Such

areas likewise are barren, or in the virgin state support only salt-tolerant vegetation, including saltbush and alkali sacaton grass.

3. Areas that are slightly salt affected have 0.2 to 0.4 percent of salt. Even this percentage is toxic to some plants and to cultivated crops, although it usually does not seriously affect cotton, hegari, and barley. Concentrations of less than 0.2 percent for the most part are not toxic, but they at times may affect the germination of seed and the growth of seedlings.

The percentage of concentration of soluble salts, determination of which was made with the electrolytic bridge, is shown on the map in the form of a fraction. The upper figure gives the concentration of salts in the soil to a depth of 1 foot, and the lower figure, the average salt concentration to a depth of 6 feet.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of weathering and development acting on the parent material deposited or accumulated by geologic agencies. The characteristics of the soil at any given point depend on: (1) The physical and mineralogical composition of the parent material; (2) the climate under which the soil material has accumulated and has existed since accumulation; (3) the plant and animal life in and on the soil; (4) the relief, or lay of the land, which influences the soil, its drainage, moisture content, aeration, susceptibility to erosion, and exposure to sun and wind; and (5) the length of time the climatic and biologic forces have acted on the material. The climate, and its influence on soil and plants, depends not only on temperature, rainfall, and humidity but also on the physical characteristics of the soil or soil material and on the relief, which in turn strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

The Duncan area, which occupies a narrow valley characterized by a hot arid climate and a sparse semidesert vegetation consisting of desert shrubs and scattered grasses, is in the zone of Red Desert and Reddish Brown soils.

Most of the soils have certain common characteristics because of their desert environment, but they vary in the nature of parent material, relief, drainage, and the time the materials have been exposed to weathering and soil development.

All the soils of the area show the presence of calcium carbonate and are relatively high in bases; a number of them have gypsum; and some, strong concentrations of sodium salts. The presence of highly oxidized and unhydrated iron is suggested by the more or less distinctly reddish tinge[6] of the soils. Little organic matter is found in any of the soils except those of the Pima and Gila series.

In the soils from the more recent alluvial deposits, which make up a large part of the area, the calcium carbonate is well disseminated, but in the more mature soils it is accumulated in a definite light-gray layer, which in places is cemented into a hardpan, or caliche. In such

[6] Although a slight reddish tinge is discernible in many of these soils, few of them, according to the color charts, are redder than light or moderate brown. The subsoil of Teague gravelly sandy loam, the reddest soil in the area, is weak reddish brown. (See: RICE, T D., NICKERSON, D., O'NEAL, A. M., and THORP, J. PRELIMINARY COLOR STANDARDS AND COLOR NAMES FOR SOILS. U. S. Dept. Agr. Misc. Pub. 425. 12 pp., illus. 1941).

soils the surface layer is usually free from calcium carbonate and is neutral to slightly acid at the immediate surface; the subsurface layer is usually neutral to slightly alkaline; and the subsoil, distinctly alkaline. The subsurface layer, or upper subsoil, usually is characterized by a comparatively high concentration of colloidal clay that increases the density and intensifies the reddish color of this zone.

The principal parent materials from which the soils have been developed have been water-borne, but some have been wind-borne. The parent materials consist of recent alluvium from a wide variety of rocks on flood plains and alluvial fans, somewhat older deposits on terraces and higher fans, and calcareous saline old lake-laid silts and clays, capped with gravelly alluvium on the highest terraces.

To the north and west of the valley the gravel is from a considerable variety of igneous formations, mainly rhyolite and basalt, whereas on the south, rhyolite is the predominant parent material. The recent alluvium along the Gila River is of varied character derived from igneous and sedimentary formations within the Gila watershed above the area. The sediments often contain organic matter eroded from grasslands in the higher parts of the watershed. The fine material in the recent alluvial fans and flood plains of the intermittent tributaries for the most part is made up of old lake sediments, and the gravel has come from gravelly soils capping the lake deposits.

Moisture and vegetation, which are active factors in the formation of soil in more humid climates, are relatively unimportant here, although the nature of the parent material and the length of time it has been in place are very important in determining the characteristics of the soils. Relief, or physiographic position, is of importance in determining the length of time the soil materials have been in place and subject to the action of soil-forming forces and in determining drainage and soil-moisture conditions. The length of time the soil materials on the high-lying terraces or mesas have been subjected to soil development is much greater than on the intermediate or lower terraces and on the valley floor, and the soils are more mature. The soils of the lower alluvial fans and flood plains are by contrast much younger and much less modified. Active natural erosion and deposition constantly influence or modify the development of the soils.

None of the soils that have acquired a mature stage of development cover any considerable area in this survey nor do they occupy positions favorable for normal development. They occur on the margins of the high terraces or mesas bordering the valley floor and have been subject to erosion. Some of them at one time may have been subject to a high ground-water level. They, therefore, do not necessarily show the normal development of soils farther from the terrace fronts.

The more mature soils are pale brown to weak reddish brown because they contain little organic matter and their decomposing iron compounds are highly oxidized and relatively unhydrated. The subsoils have a concentration of fine clay or highly colloidal reddish-brown material that probably results from the hydrolytic decomposition of certain minerals, including feldspars and hornblende in place, and from their kaolinization and subsequent dehydration.[7]

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[7] NIKIFOROFF, C. C. GENERAL TRENDS OF THE DESERT TYPE OF SOIL FORMATION. Soil Sci. 43: 105–131, illus. 1937.

It seems probable that fine materials migrate downward through the coarser and more porous materials to augment further this clay concentration, and it is likely that floodwaters from higher areas contribute fine clay and colloids that filter down into the soil mass.

These older soils have a moderate to high calcium carbonate accumulation in the subsoil. The zone of lime accumulation commonly lies below the red clayey horizon, and a calcareous transitional zone is common. The lime concentrations, which occur as seams, veins, spots or nodules, or highly indurated caliche (hardpan), probably are more or less correlated with the stage of development of the soil. It seems unlikely, however, that the indurated layers were formed entirely without being influenced by a high ground-water level. There is little doubt that there has been a partial leaching of the upper part of the solum and a precipitation or deposition of lime at or near the depth of average annual penetration of moisture. In a few places where the soil has been undisturbed for a long period the upper layer is free of carbonates, but these gradually increase downward until in extreme instances they constitute a very high percentage of the soil mass.[8]

Excessive lime accumulation probably can be attributed in many instances to poor drainage, and the extreme concentrations found in some of the soils may be due to the deposit of lime in solution in the ground water and its precipitation as a distinct indurated layer of hardpan, or caliche.

The position of the Cavot soils on the lower terraces and the Continental on terraces of intermediate position seems to suggest respectively early and late stages of maturity under more normal conditions for soil development, including adequate drainage. They have been formed from gravelly alluvial materials derived largely from rhyolite, although a considerable admixture of more basic materials is not uncommon. Vegetation consists of sparse semidesert shrubs and scattered grasses. The grass cover is thicker on the more mature Continental soils. Creosotebush, which thrives on soils of high lime content, is rarely found on the Continental soils from which lime is usually deeply leached. The more characteristic vegetation includes grasses, burroweed, broom snakeweed, squawberry, lotebush, and flowering annuals. Almost all the common shrubs of the uplands of the region grow on the Cavot soils.

The following description of Cavot gravelly sandy loam, eroded undulating phase, is characteristic of the series:

0 to 6 inches, light-brown or pale-brown friable noncalcareous gravelly sandy loam with a 1½-inch platy vesicular crust.
6 to 16 inches, moderate-brown noncalcareous gravelly gritty clay loam with vertical cracks but no definite structure, probably because of the high gravel content.
16 to 30 inches, somewhat open porous stratified light-brown to moderate-brown sand and gravel with lime seams and sufficient clay to bind the material into fragile masses.
30 to 80 inches, poorly assorted porous lime-coated cobbles, gravel, and sand with occasional lenses of higher lime concentration; pebbles at lower depths have gypsum coatings on the under sides.

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[8] BREAZEALE, J. F., and SMITH, H. V. CALICHE IN ARIZONA. Ariz. Agr. Expt. Sta. Bul. 131, pp. 417–441, illus. 1930.

The more advanced stage of development is shown in the following profile of Continental gravelly sandy loam, eroded level phase, which is characteristic of the series:

0 to 6 inches, light-brown to moderate-brown noncalcareous friable gravelly gritty loam with vesicular crust and desert pavement.
6 to 14 inches, moderate-brown to weak reddish-brown plastic noncalcareous gravelly gritty clay loam that breaks into irregular masses.
14 to 28 inches, noncalcareous strong-brown or weak reddish-brown gritty gravelly clay loam that breaks into large irregular prisms with vertical cracks coated with shiny colloid.
28 to 60 inches, strong-brown to weak reddish-brown lime-seamed gravelly gritty clay loam with similar structure.
60 to 80 inches, very pale-brown or pale-orange limy horizon with slight cementation and occasional marly lenses; the materials between the lime lenses often of rusty-brown colloidal character; lime seams occur along the cracks between aggregates.

The browner surface soil and the somewhat redder and highly colloidal subsoil of the Continental series indicate more complete hydrolitic action and a high degree of oxidation and lack of hydration. The lime appears to have concentrated in a clayey horizon, in which the reddish-brown colloidal character is still retained in places. This profile probably represents the point in the normal concentration of lime beyond which increased accumulation should be attributed to deposition from lime-charged waters coming from outside sources.

The Teague soils, which occur on the high terraces along the margin of the valley trough, lie on a level with the surrounding plain and have been in place and subject to weathering and soil development over a long period. They have an indurated conglomeratelike lime carbonate hardpan, which occurs at a relatively slight depth below the surface. The lake clays, which underlie the gravel terrace capping, apparently have restricted the downward movement of water and promoted the formation of the indurated layer. The very thin surface layer and the highly colloidal clayey horizon directly over the hardpan suggest that, in addition to active hydrolysis and decomposition during the long period of formation, the solum has been truncated to a considerable degree.

The following description of Teague gravelly sandy loam, eroded level phase, is representative of the series:

0 to 6 inches, noncalcareous light-brown to moderate-brown friable gritty loam or sandy loam with desert pavement and a ¼-inch vesicular crust.
6 to 14 inches, noncalcareous weak reddish-brown heavy colloidal plastic sticky clay, which has a scattering of gravel and irregular fracture planes, largely vertical, imparting a suggestion of jagged prisms.
14 to 20 inches, light-brown to strong-brown plastic clay with a scattering of pebbles; fine threads and seams are discernible and the structure units are not so marked or coated with colloids.
20 to 26 inches, light-brown highly gritty clay, which has a scattering of gravel and cobbles and is variegated with light-gray or light reddish-gray lime concentrations.
26 inches +, light-gray massive indurated conglomeratelike lime hardpan with platy layers at the surface.

Composed of old lake sediments, the Dos Cabezas soils are also highly calcareous. They occur on relatively recent alluvial fans below the high terrace fronts. The soils lack any appreciable clay concentration or structural development in the subsoil but lime is segregated into specks and small soft nodules. The harder angular nodules that are commonly present apparently have come from the lake sediments. These soils have a light brownish-gray mellow surface soil over slightly heavier pale-brown or light yellowish-brown soils in which lime is segregated into specks, flecks, and soft nodules. Angular hard caliche fragments are common.

The Gila, Pima, Imperial, Glenbar, and Stacy soils consist of recent to young alluvial deposits in which the profile is characterized by stratification rather than by developed soil horizons. They are definitely calcareous, but the lime carbonate is usually well disseminated. The Imperial and Glenbar soils often have fine mycelialike threads of lime, gypsum, and other salts.

The Gila and Pima soils are derived from mixed materials recently deposited by floodwaters of the Gila River. They are darker than the other soils, owing to a higher content of organic matter, which for the most part has been deposited by irrigation water. This type of material is still being brought into the valley by the river and has produced the extensive fertile silted soils. The Pima soil is richer in organic matter and generally brownish gray to dark brownish gray, whereas the Gila soils are pale brown with a very slight reddish cast. Both soils are fine textured and stratified, the Pima being heavier and having thicker strata. Owing to the relatively high content of organic matter and the calcareous nature of the materials, even the heavy-textured Pima soil has excellent granulation.

The Imperial and Glenbar soils are derived from materials washed largely from silty and clayey calcareous and saline old-lake sediments and occupy recent alluvial bottoms and alluvial fans along the numerous lateral washes in the main valley depression. The Imperial and in places the Glenbar soils have a structure, usually associated with Solonchaks, that has a pronounced surface crust and granular mulch. Where the land is reclaimed this structure is not so apparent or may have disappeared.

The Imperial soils are developing from deep tough refractory pale-brown to light brownish-gray silty clay with a very slight olive tint. They usually contain large quantities of soluble salts, are slowly permeable to water, and resist root penetration. The salts usually appear as flecks or seams in the subsoil. The highly dispersed and deeply fissured condition of the material suggests sodium clay, but rarely is the alkalinity excessive. The fact that the soils are not highly alkaline may be due to their gypsum content.

The Glenbar soils differ from the Imperial soils in their more reddish or yellowish color, usually light brown or pale orange, and the more permeable character of the whole profile. The upper subsoil is often slightly more reddish, tough, and refractory than other strata of the profile. Thinly stratified or laminated layers of lighter texture and gravel may occur in the lower subsoil and substratum. Soluble salts commonly appear as specks, threads, and seams, especially in the heavier clay of the subosil. The alkalinity is rarely excessive.

The Stacy soils occur largely as alluvial fans below the terrace fronts, although they may extend well out into the alluvial flood plains of the lateral washes. The materials have been washed for the most part from the old gravelly terrace caps, which consist largely of rhyolitic material but contain a considerable admixture of basaltic, andesitic, and other gravel as well as some fine soil material from the caps and the underlying lake-laid silts and clays. The pebbles are the product of erosion from the gravelly capping, which usually is cemented by lime into a conglomeratelike lime hardpan. They are often lime coated, and the soil is highly calcareous. In fresh exposures lime concentration is usually not discernible, but old cuts often exhibit a more grayish subsoil, especially after a rainy period. This light-gray color apparently is due largely to lime, as the salt content is rarely high. The upper horizon is pale brown, whereas the subsoil is usually light brownish gray, though the thick beddings of the reddish rhyolite and darker basic gravel influence the color materially.

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