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Olton Soils:

Distribution, Importance, Variability, and Management

The Texas Agricultural Experiment Station
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College Station, Texas
in cooperation with
United States Department of Agriculture
Agricultural Research Service
Soil Conservation Service

Contents

Olton Soils—Distribution, Importance, Variability and Management[1]

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Introduction

Area Occupied by Olton Soils

Olton soils[2] have been mapped extensively in twelve counties in the Southern High Plains of Texas and one county in eastern New Mexico (Figure 1) and to a lesser extent in three additional counties in Texas and one county in New Mexico (Figure 2; Tables 2 and 3). The portions of different counties occupied by Olton soil range from 1.2 to 46.4 percent (Table 2). The area of Olton soils is bounded by the area of Pullman soils on the north and east, Yellowhouse Creek on the south, the Caprock escarpment at the High Plains-Rolling Plains boundary on the southeast, and Blackwater Draw from near Earth, Texas, to Portales, New Mexico, on the southwest. Within this roughly crescent shaped area, Olton soils occupy about 19 percent of the land surface.

The area of Olton soils ranges from about 101°10' to 103°50' West longitude and about 32°50' to 35°40' North latitude. Elevation of the surface of Olton soils ranges from about 2,600 to 4,200 feet above mean sea level. The area is in a semiarid climatic zone where average annual precipitation ranges from about 17 inches at the western edge to about 21 inches at the eastern edge (Table 3). Also listed in Table 3 are the average length and dates of the frost-free period, average daily maximum and minimum temperatures, and average precipitation in counties in which Olton soils are found.

Olton soils occupy about 1.26 million acres of land (Table 2) and are among the most extensive arable soils in Texas. Olton soils also occupy a small area of New Mexico. Other major arable soils in Texas are Pullman with 3.8 million acres, Amarillo with 2.5 million acres, and Houston Black with 1.5 million acres.

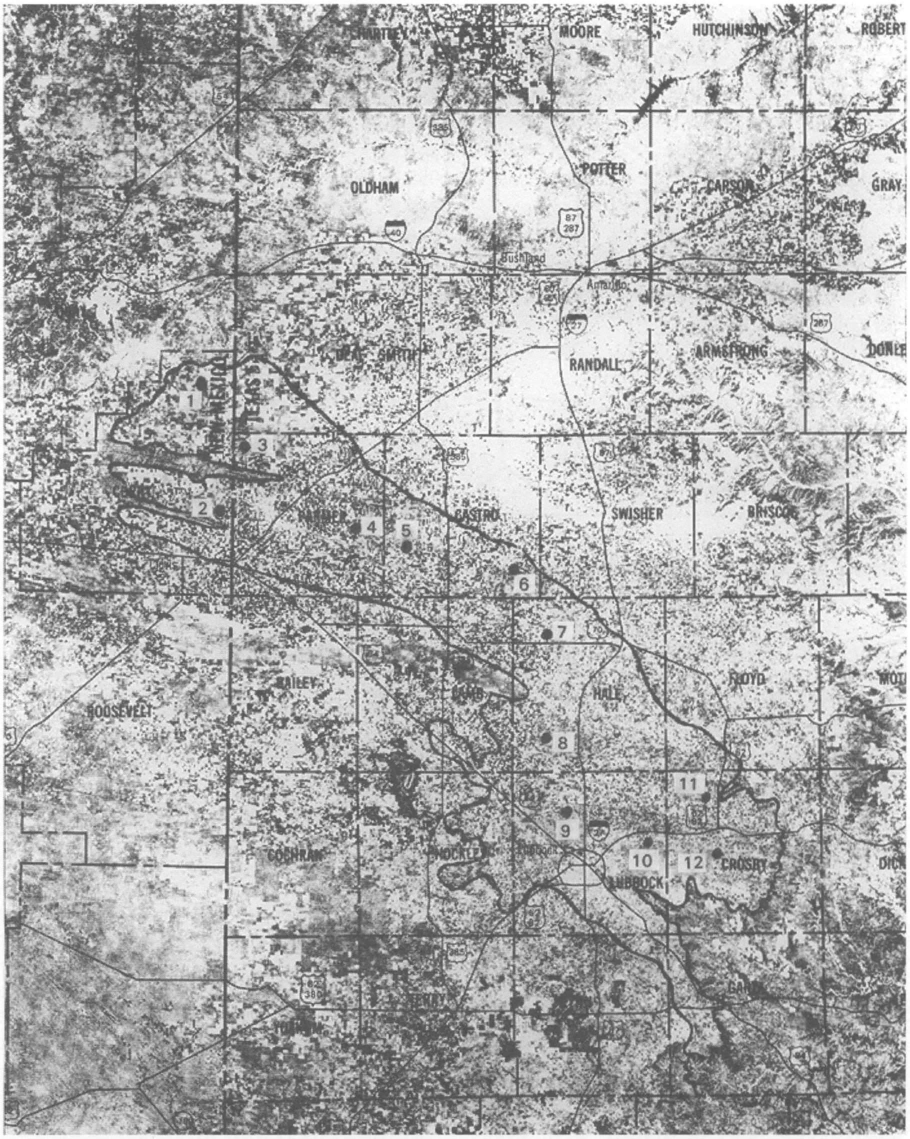

Figure 1. The approximate areas where Olton soils have been mapped extensively are delineated by the solid line. The approximate locations of sampling sites are indicated by the numbered dots.

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[1] Contribution from the USDA, Agricultural Research Service, P.O. Drawer 10, Bushland, Texas 79012, and the USDA, Natural Resources Conservation Service, Amarillo, Texas 79121.

[2] See Table 1 for classification of soils mentioned in this report.

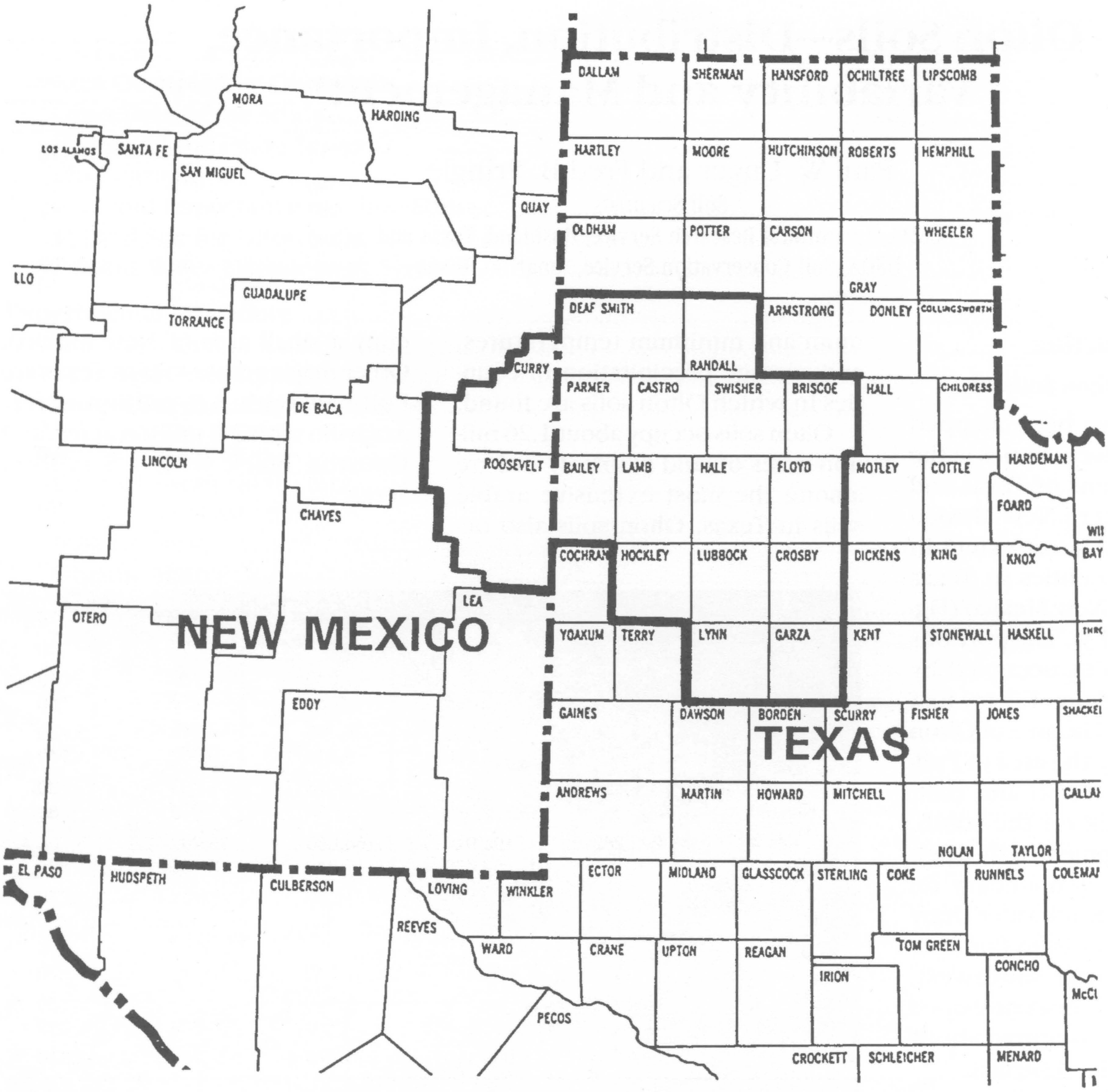

Figure 2. Counties of Texas and New Mexico in which Olton soils have been mapped are within the solid, heavy-lined area.

Objectives of the Study

Olton soils vary considerably in profile properties across the area. One property is depth to the calcic horizon, which varies from 34 to 54 inches. Because profile depth strongly influences plant rooting depth and thus the effective depth for storing water, a knowledge of profile depth along with a characterization of other profile properties is important for improved water and crop management. The objective of this study was to determine the variation in depth, texture, bulk density, organic matter content, calcium carbonate

Table 1. Classification of soils mentioned in the text and figures.

Series	Classification
Acuff	Fine-loamy, mixed, superactive, thermic, Aridic Paleustolls
Amarillo	Fine-loamy, mixed, superactive, thermic, Aridic Paleustalfs
Berda	Fine-loamy, mixed, superactive, thermic, Aridic Ustochrepts
Bippus	Fine-loamy, mixed, superactive, thermic, Cumulic Haplustolls
Drake	Fine-loamy, mixed (calcareous), thermic, Typic Ustorthents
Estacado	Fine-loamy, mixed, superactive, thermic, Calciargidic Paleustolls
Houston Black	Fine, montmorillonitic, thermic, Udic Pellusterts
Mansker	Fine-loamy, carbonatic, thermic, Calciargidic Paleustolls
Mobeetie	Coarse-loamy, mixed, superactive, thermic, Aridic Ustochrepts
Olton	Fine, mixed, superactive, thermic, Aridic Paleustolls
Pep	Fine-loamy, mixed, superactive, thermic, Aridic Calciustolls
Posey	Fine-loamy, mixed, thermic, Calciorthidic Paleustalfs
Potter	Loamy, carbonatic, thermic, shallow, Ustic Haplocalcids
Pullman	Fine, mixed, superactive, thermic, Torretic Paleustolls
Randall	Fine, smetitic, thermic, Ustic Epiaquerts
Richfield	Fine, smetitic, mesic, Aridic Argiustolls

Table 2. Areas occupied by Olton soil.

County, State	Slope	Mapping unit area	Portion of County	Total series area[1,2]	Total cropland[3]	Irrigated cropland	Rangeland	Other land[4]
	%	acres	%	acres				
Bailey, TX	0-1	6,310	1.2	6,310	5,670	710	470	170
Briscoe, TX	0-1	4,440[5]	0.7	11,380	2,280	540	2,050	110
	1-3	6,940	1.2		3,540	850	3,360	140
Castro, TX	0-1	132,030	23.4	163,930	104,300	68,840	24,430	3,300
	1-3	31,230	5.5		24,670	16,280	5,780	780
	3-5	670	0.1				660	10
Crosby, TX	0-1	109,810	18.8	124,770	87,850	45,680	19,220	2,750
	1-3	14,960	2.6		11,970	6,220	2,620	370
Curry, NM	0-1	80,000[6]	8.9	120,000	63,200	32,860	14,800	2,000
	1-3	40,000[6]	4.4		31,600	16,430	7,400	1,000
Deaf Smith, TX	0-1	44,150[6]	4.6	67,930	35,760	18,600	7,290	1,100
	1-3	23,770[6]	2.4		19,260	10,210	3,930	590
Floyd, TX	0-1	10,450	1.6	21,280	8,360	3,350	1,830	260
	1-3	10,830	1.7		8,660	3,470	1,900	270
Garza, TX	0-1	55,920[5]	9.6	59,860	50,880	4,070	3,540	1,500
	1-3	3,940[5]	0.7		3,350	270	510	80
Hale, TX	0-1	84,600	13.5	125,500	63,450	38,070	19,030	2,120
	1-3	40,900	6.5		30,680	18,410	9,200	1,020
Hockley, TX	0-1	21,100	3.7	21,100	16,880	8,780	3,690	530
Lamb, TX	0-1	75,680	11.5	81,080	77,780	39,940	900	2,040
	1-3	5,400	0.8		2,180	2,860	220	150
Lubbock, TX	0-1	109,420	19.2	123,850	84,530	38,040	19,510	3,720
	1-3	14,430	2.5		8,360	3,340	5,500	1,240
Lynn, TX	0-1	7,130[6]	1.2	9,500	5,920	1,270	1,150	130
	1-3	2,380[6]	0.4		2,510	380	560	60
Parmer, TX	0-1	227,840	41.4	225,280	195,940	166,080	26,200	5,700
	1-3	27,440	5.0		23,600	17,840	3,160	690
Randall, TX	0-1	10,120	1.7	25,430	4,770	1,550	5,100	250
	1-3	14,150	2.4		4,480	790	9,320	350
	3-5	1,160	0.2		140		1,000	20
Roosevelt, NM	0-1	24,680	1.6	24,680	8,140	2,040	16,160	370
Swisher, TX	0-1	4,900	0.8	20,270	3,870	1,240	910	120
	1-3	15,380	2.7		8,610	2,760	6,380	380
Total		1,262,160		1,262,160	1,003,190	571,770	227,780	33,320

[1] Includes total area for all slopes and conditions.
[2] Totals for the different slopes and conditions may not equal the total for the series because values are rounded to the nearest 10 acres.
[3] Includes land in Conservation Reserve Program (CRP).
[4] Includes land in roads, towns, and other nonagricultural uses.
[5] Calculated from General Soils Map.
[6] Tentative.

equivalent, pH, cation exchange capacity, and water retention of the different horizons of Olton soils as affected by location in the region. Water infiltration at locations selected also was determined. The data obtained are discussed relative to managing the soil for efficient and effective water use for optimum crop production.

History of the Olton Series

The Olton series was established in the Soil Survey of Lamb County, Texas, in 1960 (Soil Conservation Service, 1962). It was named after the town of Olton in Lamb County. Before 1960, Olton soils were included in other series, mainly the Amarillo, Pullman, and Richfield series. The processes of inventorying and classifying soils on the High Plains began with publication of the Reconnaissance Soil Survey of the Panhandle Region of Texas in 1910. In this survey, Olton soils were called Richfield clay loam. The Richfield series was established in this survey and included all nonreddish silty clay loams and clay loams on the Southern High Plains.

As soil surveys and investigations continued, differences in the physical and chemical properties of soils were noted. This led to the recognition of other soil series. Early soil surveys of Dickens, Lubbock, and Wheeler counties of the Texas High Plains included these soils in both the Amarillo and Richfield series. Further investigations plus the implementation of soil taxonomy resulted in refinements to series criteria. The Olton series was established for those soils of the South-

Table 3. Elevation and climatic features in counties having Olton soils.

County, state, station	Elev.	Average annual lake evaporation	Average growing season		Average daily temperature[1] Max.	Min.	Average annual precip.[1]
	ft	in	days	period	°F	in	
Bailey, TX, Muleshoe	3760	69	187	Apr 17–Oct 21	72.3	40.9	16.84
Briscoe, TX, Silverton	3280	68	189	Apr 15–Oct 20	71.0	42.6	21.67
Castro, TX, Dimmitt	3860	—	178	Apr 23–Oct 17	71.3	40.4	17.94
Crosby, TX, Crosbyton	3010	—	209	Apr 3–Oct 29	73.1	45.3	22.57
Curry, NM, Clovis	4290	—	192	Apr 16–Oct 24	71.4	42.2	17.44
Deaf Smith, TX, Hereford	3820	67	185	Apr 18–Oct 20	70.6	41.5	17.17
Floyd, TX, Floydada	3220	69	203	Apr 10–Oct 29	72.1	44.2	20.44
Garza, TX, Post	2550[2]	71	225	Mar 29–Nov 9	75.1	48.1	20.92
Hale, TX, Plainview	3370	69	206	Apr 3–Oct 26	72.1	45.3	19.96
Hockley, TX, Levelland	3550	70	200	Apr 10–Oct 27	73.8	43.2	19.47
Lamb, TX, Littlefield	3510	70	200	Apr 7–Oct 24	72.4	43.6	19.07
Lubbock, TX, Lubbock	3250	69	210	Apr 5–Oct 31	73.4	46.7	18.66
Lynn, TX, Tahoka	3120	69	213	Apr 2–Nov 1	74.3	45.6	19.72
Parmer, TX, Friona	4030	68	187	Apr 16–Oct 20	70.9	41.7	16.88
Roosevelt, NM, Elida	4350	72	178	Apr 21–Oct 16	72.2	42.1	14.52
Swisher, TX, Tulia	3500	68	205	Apr 10–Nov 1	72.9	42.6	17.24

[1] Average values for monthly maximum and minimum temperatures and precipitation are available in most published soil surveys.

[2] Recording station not located in Olton series area of occurrence.

ern High Plains that have dark colored surfaces and reddish brown subsoils with clay contents ranging from 35 to 40 percent, and a mean annual soil temperature greater than 59°F at a 20-inch depth.

Physiography

The topography consists of nearly level to gently sloping, smooth, treeless plains (Figure 3). Surfaces are plane to convex and slopes range from 0 to 5 percent, but are mainly 0 to 2 percent. These broad plains are interrupted only by the numerous playas, or shallow lakes, containing other soils. Except for playas, the surface is remarkably smooth. Playas range from a few square yards to several square miles in surface area, and from a few inches to more than 50 feet in depth. The average grade of the High Plains is about 10 feet per mile to the southeast. Runoff follows a poorly defined pattern. Water flows mainly into the playas, from which there is rarely an outlet. Much of the water collected in shallow playas is lost by evaporation, but some is used for irrigation. In deeper playas, water percolates to depths greater than 80 inches and perhaps adds small amounts of water to the underlying aquifer.

Other soils associated with the Olton series in its area of occurrence include Acuff, Amarillo, Drake, Estacado, Mansker, Pep, Pullman, and Randall (Figures 4, 5, 6, and 7). Acuff soils are similar in appearance to Olton but have less than 35 percent clay in the upper 20 inches of the subsoil. They occur on the same general landscape and in close association with Olton soils, but surfaces are slightly more convex. Amarillo soils have light colored, typically fine sandy loam surfaces and are found on

Figure 3. Aerial photo showing the typical topography of the Olton soil region.

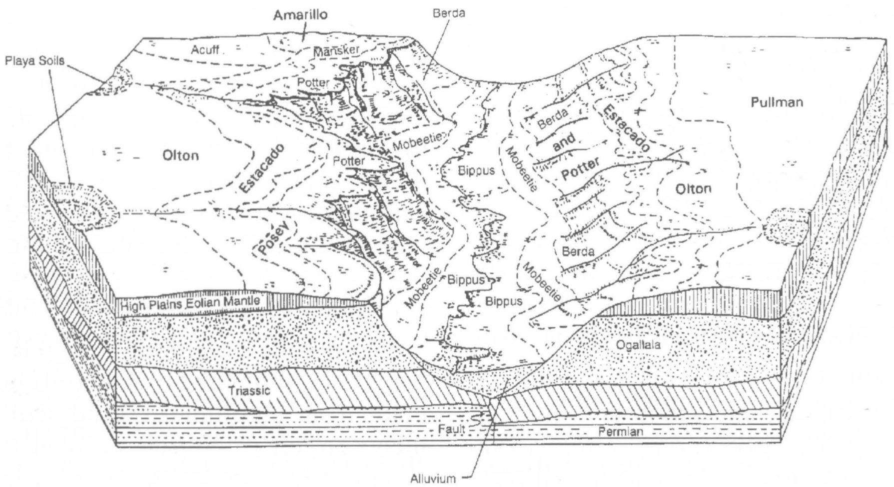

Figure 4. Illustration of the major soils and underlying formations in the area occupied by Olton soils.

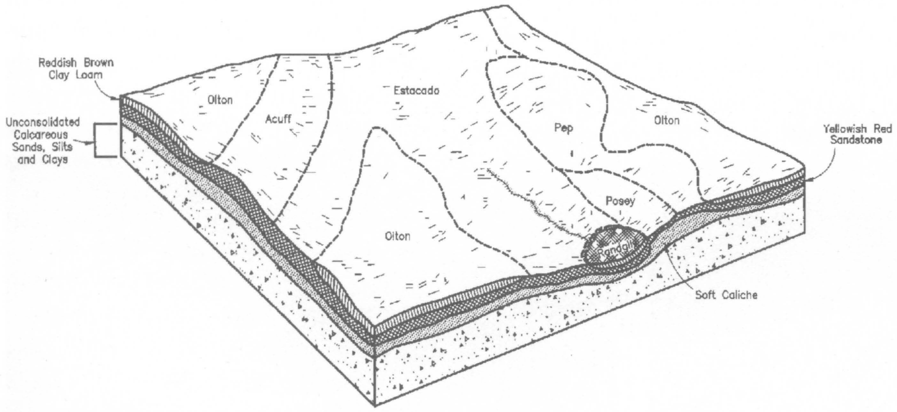

Figure 5. Soil pattern on erosional surfaces near major drainageways in the northern area of occurrence for Olton soils.

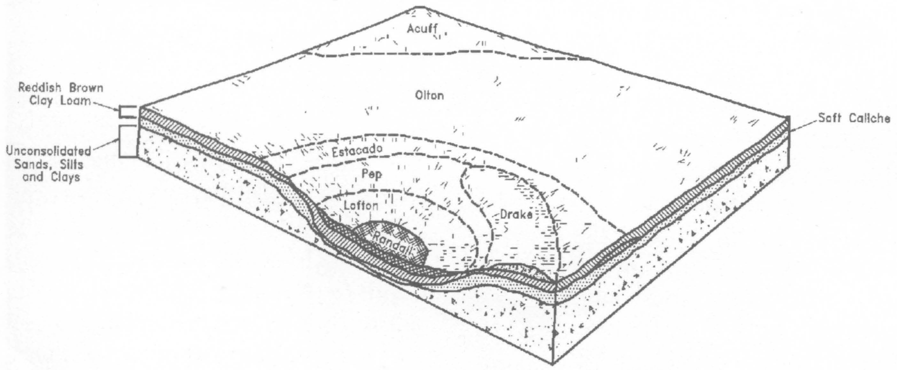

Figure 6. Typical soil pattern in the central area of occurrence for Olton soils.

the same general landscape and in close association with Acuff soils. Estacado, Mansker, and Pep are calcareous, loamy soils on low convex ridges, on sideslopes around playas, and along draws. Pullman soils are on nearly level smooth plains and are similar in appearance to Olton. However, the Bt horizon of Pullman soil is dark brown, has a clay texture, and is less permeable. Randall soils are dark gray, have clay textures throughout, and occur on playa bottoms. Drake soils are weakly developed, calcareous, have loam or clay loam textures, and are more permeable. They occur on convex knolls or crescent-shaped dunes on the eastern rims of playas.

Differences in morphological properties of the Olton series are related to geographic location and landscape position. These differences determine water storage capacity, which in turn affects water management on these soils. The morphological features are depth to strong calcic horizon [>30 percent calcium carbonate ($CaCO_3$)], depth to a layer of strongly contrasting material, soil texture, and permeability. An analysis of soil survey field notes for nine counties and additional recent profile observations revealed that depth to a strong calcic horizon ranges from 34 to more than 54 inches. Observations by soil and plant scientists indicate that calcic horizons containing at least 30 percent lime ($CaCO_3$) inhibit root development of most crops. Based on laboratory determinations using a simple volume calcimeter, the average $CaCO_3$ content in the Btk horizon of Olton soils is about 45 percent.

To present a clearer understanding of these soils as they relate to geographic location, it is convenient to describe the landscape positions on which they are found. In the northern part of the region, Olton soils are on erosional plains adjacent to major drainageways that dissect the High Plains. These include Frio Draw, Tierra Blanco Creek, and Tule Creek in Castro, Deaf Smith, Parmer, Randall, and Swisher Counties in Texas. Also included are erosional surfaces along the margins of the High Plains in Briscoe, Randall, and Swisher Counties. Slopes are nearly level to gently sloping (Figure 5), and surfaces are smooth and slightly convex. In this part of the High Plains, Olton soils are intermingled with areas of Estacado, Mansker, Pep, Pullman, and Randall soils. Pullman soils occupy the same general landscape position as Olton soils, although the surfaces of Pullman are less sloping. Estacado, Mansker, and Pep soils are on low convex ridges, sideslopes around playas, and along draws. Within the area of occurrence, Olton soils comprise about 35 percent of the total area; Pullman soils comprise

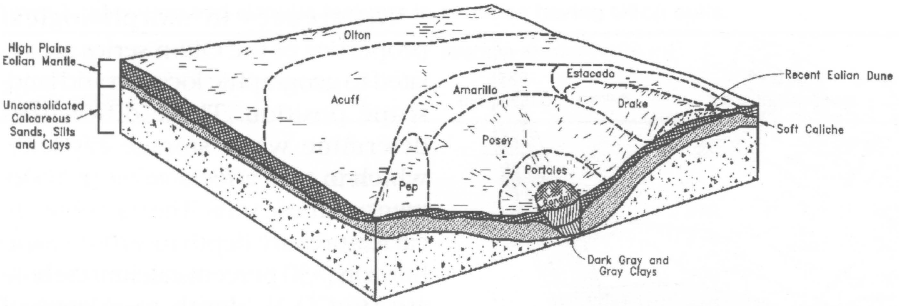

Figure 7. Typical soil pattern in the western area of occurrence for Olton soils.

35 percent; and Estacado, Mansker, Pep, and Randall soils comprise the remaining 30 percent. Where Olton soils are closely associated with Pullman soils, their clay contents of the upper subsoil are similar. They range from 35 to 42 percent and average about 39 percent. The depth to a strong calcic horizon averages about 49 inches. The $CaCO_3$ content of this layer ranges from 35 to 56 percent and averages about 45 percent.

The primary area of occurrence for Olton soils includes the area south and west of a line extending from the High Plains escarpment on the Texas-New Mexico state line to White River Lake in Crosby County, Texas. It includes parts of Bailey, Crosby, Deaf Smith, Garza, Hale, Hockley, Lamb, and Lubbock Counties in Texas. Also included are parts of Curry and Roosevelt Counties in New Mexico. Slopes of Olton soils in this region are nearly level to gently sloping. The smooth surfaces are planar to slightly convex (Figures 6 and 7). Olton soils comprise about 25 percent of the total area. The remainder is mainly Acuff, Amarillo, Drake, Estacado, Mansker, Pep, Posey, and Randall soils. Acuff, Amarillo, and Estacado soils are on smooth plains with slightly convex surfaces. Mansker, Pep, and Posey soils are on sideslopes around playas and along draws. Drake soils are on low Aeolian dunes on the eastern rims of playas. Randall soils are on playa floors. When Olton soils are closely associated with Acuff soils, clay contents of the upper subsoil range from 33 to 40 percent and average about 36 percent. Surface textures of some pedons reflect the influence of winnowing by wind erosion. The depth to a strong calcic ranges from 34 to 54 inches, averaging about 43 inches. Calcium carbonate content of the calcic horizon ranges from about 35 to more than 55 percent and averages about 42 percent.

Uses and Importance of Olton Soils

Olton soils are used primarily for agriculture with about 79 percent of their area being used for crop production and about 18 percent in rangeland. The remaining area is in roads, towns, and other nonagricultural uses. Of the cropland area, about 45 percent is irrigated and 55 percent is dryland (Table 2). The area of irrigated Olton soil represents about 11 percent of all irrigated cropland in Texas (Texas Dept. Agric., 1995). Cotton (*Gossypium hirsutum* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], corn (*Zea mays* L.), and wheat (*Triticum aestivum* L.) are the major field crops (Texas Dept. Agric., 1995). Other crops grown on smaller areas are oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), sugar beet (*Beta vulgaris* L.), soybean (*Glycine max* L.), forage sorghum (*Sorghum* sp.), alfalfa (*Medicago sativa* L.), sunflower (*Helianthus annuus* L.), and vegetables.

Because Olton soils are located in a semiarid region, yields of dryland crops are relatively low. Irrigation from the Ogallala Aquifer greatly increases yields, but the water supply is limited and is being depleted. Although the cost of energy for pumping water has decreased since the mid 1980s, it is still a major variable crop production cost. Surface water for irrigation is negligible. It is, therefore, essential that water be used as efficiently as possible so that economic crop production can be maintained and the eventual return to dryland crop production can be delayed as long as possible. When dryland farming replaces irrigated farming, even if only on the Olton soils, a significant percentage of the total irrigated crop production in Texas will be lost.

Typical Site for Olton Soils

Olton soils developed in a relatively cool, subhumid to semiarid climate from medium-textured sediments largely or entirely of Aeolian origin. They occupy smooth areas that are nearly level to gently sloping. Surface slopes range from 0 to about 5 percent toward the playas or shallow basins, and on erosional surfaces along draws. Although largely cultivated, the typical native vegetation on Olton soils was short- grasses, principally blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*). Profiles of Olton soil are shown in Figures 8 and 9.

The surface layer of a typical Olton soil is a brown to dark brown clay loam, but the texture ranges from loam to sandy clay loam. Thickness of the surface layer usually ranges from 6 to 8 inches, at which depth there is a clear boundary to a brown, reddish brown, or dark reddish brown clay loam with moderate blocky structure. The soil may contain buried horizons of older soils at 3 to 5 feet below the surface. The buried horizons usually have a clay loam or sandy clay loam texture. The upper boundary of the calcic layer is clear and wavy. Although depth to the calcic layer often is considered the effective depth of a soil for crop production purposes, winter wheat and especially sunflower use water from well into the calcic layer, based on observations and measurements on a similar soil (Pullman clay loam) at Bushland, Texas (O. R. Jones, Bushland, Texas, unpublished data; Unger, 1978a).

Present Water Management Systems

It is desirable to have a soil filled to capacity with water at planting time, especially for dryland crops, because of limited and erratic precipitation during the growing season in semiarid regions such as where the Olton soils occur. When the soil is filled to capacity at planting time, crops usually experience less water stress during the growing season than when it contains a limited amount of water. Crop yields usually are higher when growing season water stress is not severe.

Based on data from the Texas A&M University Agricultural Research and Extension Center at Lubbock–Halfway and values published in soil surveys of Hale and Lubbock Counties, Texas (Soil Conservation Service, 1974, 1979), the Olton soil at these locations has a total water storage capacity of about 10.1 and 13.4 inches to 3- and 4-foot profile depths, respectively. Of the total, about 5.4 and 7.2 inches, respectively, are available for plant use. The remainder (4.7 and 6.2 inches to 3- and 4-foot depths, respectively) is held at tensions (energy levels) greater than those at which plants can extract the water.

Although irrigation can provide water to crops, soil water content at planting is still important because any water stored from precipitation reduces the amount required from irrigation. When water storage from precipitation is low, a preplant or emergence irrigation often is used to increase the soil water content. Because the Olton soil is moderately slowly permeable, relatively short periods of water application must be used to avoid incurring deep drainage losses. With furrow irrigation (Figures 10 and 11), considerable tailwater runoff is usually permitted so that adequate water is stored at the lower end of the field. Unless an effective tailwater recovery system (Figure 12) is used, tailwater runoff reduces the efficiency of water use.

In recent years, many center-pivot sprinkler systems (Figure 13) have been installed on Olton soils. These systems, when properly designed and operated, reduce runoff amounts compared to furrow irrigation, but require considerably more energy input than furrow systems. With all farming systems on both dryland and irrigated land, a knowledge of the water-holding capacity of the soil profile (Figure 14) is important for effective water management.

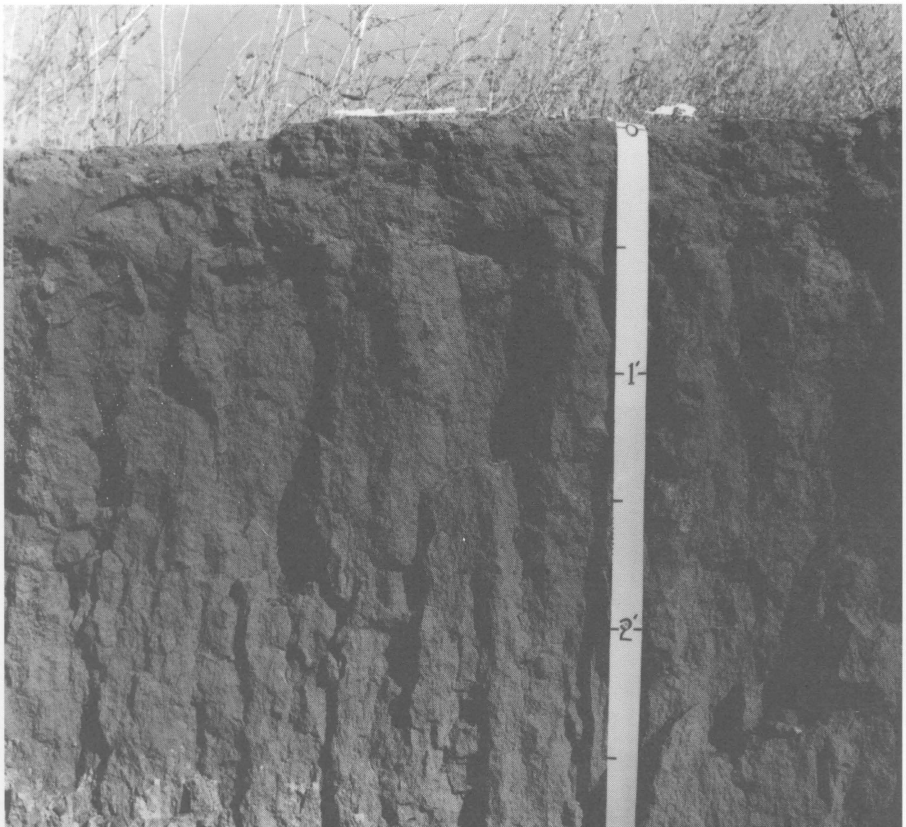

Figure 8. A relatively deep Olton soil profile from Hale County, Texas (USDA-NRCS photo).

Experimental Procedure

Site Selection

To obtain samples that would represent a near-complete range in the expected variation in soil properties, sites were selected at 12 widely separated locations across the region. The sampling sites were in Castro, Crosby, Hale, Lubbock, and Parmer Counties in Texas; and Curry County in New Mexico (Figure 1). Although the locations were widely separated, samples were not obtained near the margins of the region to avoid zones of transition to other soils. Likewise, locations of transition to other soils within the region were avoided. Sampling was restricted to "typical" Olton soil sites for the particular region. Brief descriptions of the locations are given with the profile descriptions in the Results and Discussion section. Sites 2, 4, 5, 6, 7, 8, 9, 10, 11, and 12 were in irrigated fields, and Sites 1 and 3 were in dryland fields. All sites

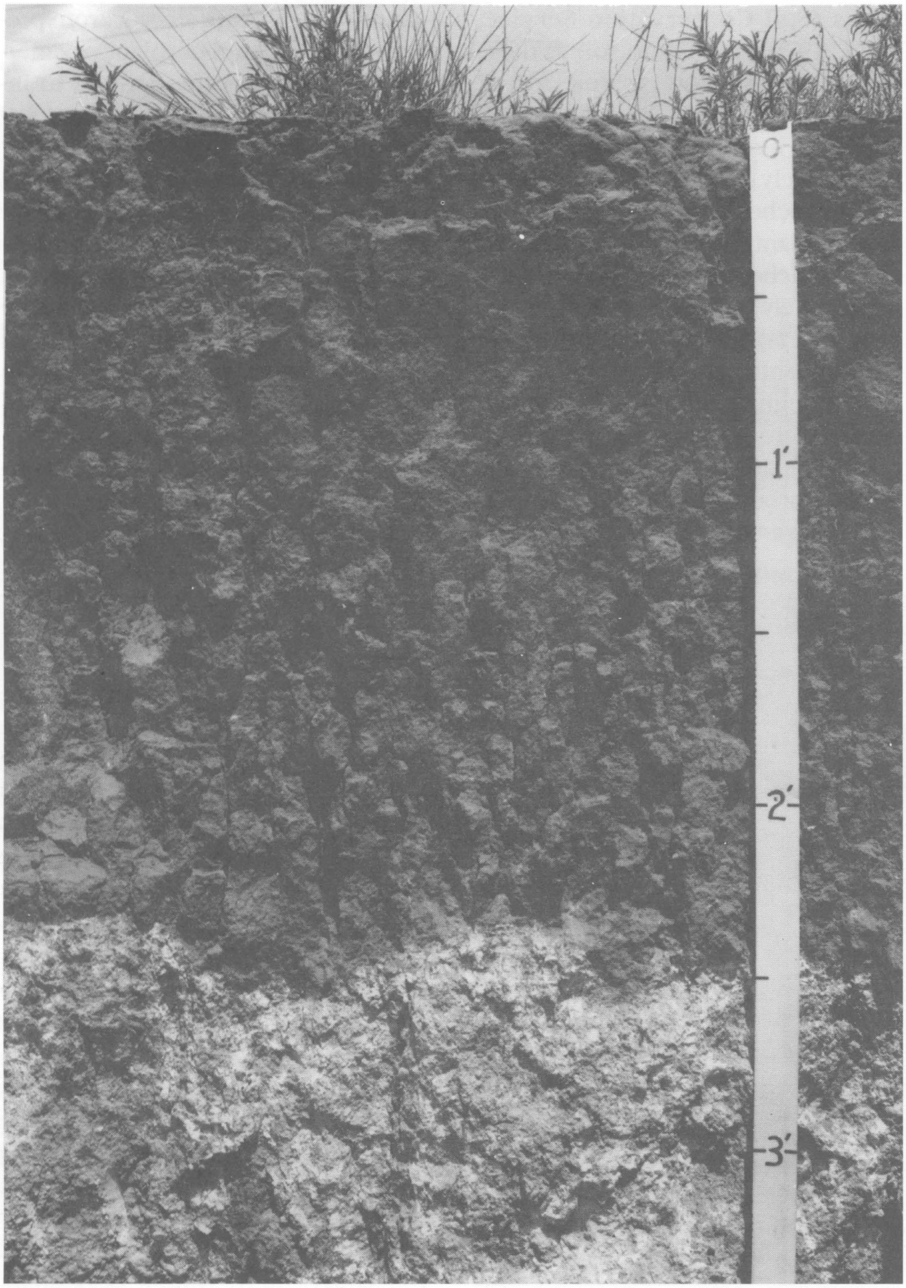

Figure 9. A relatively shallow Olton soil profile from Hale County, Texas (USDA- NRCS photo).

were on nearly level uplands of the High Plains.

Sampling Techniques

At each site, loose soil of the plow layer, usually to the depth of the Ap horizon, was removed before obtaining core samples with a hydraulically-operated, pickup-mounted core sampler. The inside diameter of the cutting tip was 1.625 inches. Two cores at each location were used for profile description. Several other cores were taken and separated into depth segments based on thickness of the different horizons to provide adequate material from each depth for determining bulk density, particle size distribution, organic matter content, pH, and cation exchange capacity. Also, two bulk samples of surface soil were collected at each site. At a different time, three water infiltration determinations were made at each site using recorder-equipped, constant head, double-ring infiltrometers (Haise et al., 1956). The rings were seated into the most restrictive subsurface layer, and a 1.5-inch head of water was maintained for the duration of the test. Water surfaces were covered to prevent evaporation. Placement of individual infiltrometers was determined after examining the field to determine tillage zone conditions at the time of testing.

Sample Preparation and Analyses

Bulk density was determined by drying the cores at 105°C, then weighing them. Soil from these cores was retained and ground to pass a 2-mm sieve. Subsamples of this sieved soil were then used to determine organic matter content by the Walkey-Black method (Jackson, 1958), pH (1:1 soil:water ratio), particle size distribution (mechanical analysis) by the hydrometer method (Day, 1965), and cation capacity by the USDA-SCS procedure (Soil Conservation Service, 1984). Sand retained from the particle size distribution analyses was subsequently sieved to determine the size distribution of the sand fraction. Soil water retention at -1/3 and -15 bars matric potentials was calculated by equations developed by Unger (1975).

Samples of surface soil were air-dried, ground, and passed through a 2-mm sieve. Subsamples of the soil were used to determine particle size distribution, organic matter content, pH, cation exchange capacity, and water retention by the methods outlined above.

Relationships among various Ap, Bt1, and Bt2 horizon characteristics; total water infiltration in 10 minutes and 20 hours; and infiltration rates at these times were investigated by multiple linear regression analyses. Horizon characteristics investigated were thickness; sand, silt, clay, and organic matter content; and bulk density. For Ap, Bt1, and Bt2 horizons, actual values were used, except that densities of Ap and Bt1 horizons were measured in the field where infiltration

Figure 10. Furrow irrigation through gated pipes with 'socks' attached to the gates to reduce furrow erosion.

Figure 11. Furrow irrigation from an open ditch using syphon tubes. Water losses often are high when open ditches are used to deliver the water.

measurements were made. Besides the partial regression coefficients and the coefficient of correlation (R^2), standardized partial regression coefficients and *t*-values were also calculated (Ezekial and Fox, 1959; Steel and Torrie, 1960). Based on the standardized coefficients, the independent variables were ranked numerically in order of their relative importance for influencing total infiltration or infiltration rates. All independent variables were used in the initial analysis for each set of data. In subsequent analyses, the lowest-ranking variable was excluded, which resulted in the last analysis being a simple linear regression analysis if only one variable was significant.

Results and Discussion

Profile Descriptions

This section describes the profiles at the 12 sites and their locations. The descriptions are based on examination and determinations made in the field immediately after extracting the cores. Although data in subsequent sections are based mainly on horizons above the calcic horizon, the calcic horizon is included in the profile descriptions.

Site No. 1

Soil Type: Olton loam

Location: Curry County, New Mexico; in a cultivated field 150 feet south of paved county road, 3.6 miles west and 6.0 miles north of N.M. Highway 241 at Bellview, 3.7 miles west of the Texas/New Mexico State line.

Pedon description:
Sample No. S90NM009-1-(1-5)

Ap—0 to 8 inches; brown (7.5YR 4/2) loam, dark brown (7.5YR 3/2) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1—8 to 23 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; thin continuous clay films; neutral; gradual smooth boundary.

Bt2—23 to 31 inches; brown (7.5YR 5/4) clay loam, dark brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—31 to 38 inches; reddish brown (5YR 5/4) clay loam, yellowish brown (5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads, films, small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk—38 to 80 inches; pink (5YR 8/4) clay loam; pink (5YR 7/4) moist; moderate medium blocky structure; very hard,

Figure 12. A lake pump in the tailwater recovery pit recycles runoff water to the cropland (USDA-NRCS photo).

Figure 13. A sprinkler irrigation system equipped with drop hoses that deliver the water close to the soil surface, thus reducing evaporation.

friable; common fine pores; about 53 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 2
Soil Type: Olton loam

Location: Curry County, New Mexico; in a cultivated field 2150 feet west of paved county road, 14.2 miles north of U.S. Highway 84, and 1.1 miles west of the Texas/New Mexico State line in Texico, New Mexico.

Pedon description:
Sample No. S90NM009-2-(1-5)

Ap—0 to 7 inches; brown (7.5YR 4/3) loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1—7 to 20 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; thin continuous clay films; neutral; gradual smooth boundary.

Bt2—20 to 28 inches; reddish brown (5YR 5/4) clay loam, reddish brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—28 to 39 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads, films, small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk—39 to 70 inches; pink (5YR 8/4) clay loam; pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 53 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 3
Soil Type: Olton clay loam

Location: Parmer County, Texas; in a cultivated field 700 feet south of unpaved county road, 0.7 miles west of Farm Road 2013, 7.4 miles northwest of its intersection with Farm Road 1731, 9.7 miles west of Friona.

Pedon description:
Sample No. S90TX369-1-(1-5)

Ap—0 to 6 inches; brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

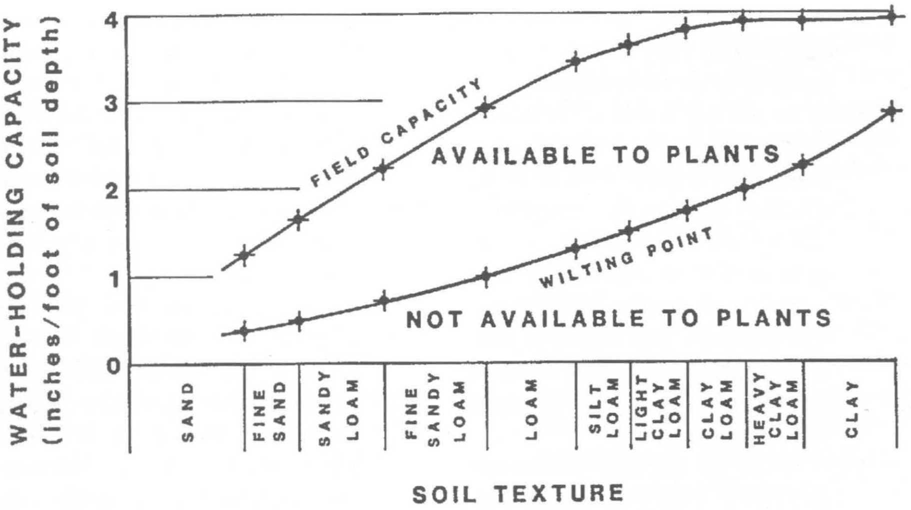

Figure 14. Typical water-holding capacities of soils with different textures (adapted from USDA, 1955).

Bt1–6 to 16 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; thin continuous clay films; neutral; gradual smooth boundary.

Bt2–16 to 25 inches; reddish brown (5YR 5/3) clay loam, reddish brown (5YR 4/3) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3–25 to 41 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads, films, small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk–41 to 72 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 57 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 4

Soil Type: Olton clay loam

Location: Parmer County, Texas; in a cultivated field 1800 feet south of unpaved county road, 1.9 miles west of Texas Hwy 214, 8.0 miles south of Friona.

Pedon description:
Sample No. S90TX369-2-(1-5)

Ap–0 to 8 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1–8 to 24 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; thin continuous clay films; neutral; gradual smooth boundary.

Bt2–24 to 37 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3–37 to 48 inches; yellowish red (5YR 5/6) sandy clay loam, yellowish red (5YR 4/6) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk–48 to 72 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 55 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 5

Soil Type: Olton clay loam

Location: Castro County, Texas; in a cultivated field 300 feet north of Farm Road 145, 7.5 miles west of its intersection with Farm Road 168 in Hart.

Pedon description:
Sample No. S90TX069-1-(1-5)

Ap–0 to 6 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1–6 to 17 inches; dark brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; weak coarse prismatic structure, parting to weak medium blocky structure; hard, friable; common fine roots; few fine pores; thin patchy clay films; neutral; gradual smooth boundary.

Bt2–17 to 33 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; moderate medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads and films of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Bt3–33 to 45 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; moderately alkaline; clear smooth boundary.

Btk–45 to 70 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 46 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 6
Soil Type: Olton clay loam

Location: Castro County, Texas; in a cultivated field 2800 feet north of Farm Road 145, 1.1 miles west of its intersection with Farm Road 168 in Hart.

Pedon description:
Sample No. S91TX069-2-(1-5)

Ap–0 to 7 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1–7 to 20 inches; dark brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; hard, friable; common fine roots; few fine pores; thin patchy clay films; neutral; gradual smooth boundary.

Bt2–20 to 38 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; moderate medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads and films of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Bt3–38 to 49 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; moderately alkaline; clear smooth boundary.

Btk–49 to 70 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 46 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 7
Soil Type: Olton clay loam

Location: Hale County, Texas; in a cultivated field 600 feet north of unpaved county road, 0.35 mile west and 1.0 mile north of U.S. Hwy 70; 3.0 miles west of its intersection with Farm Road 2284; 4.0 miles west of Halfway.

Pedon description:
Sample No. S90TX191-1-(1-5)

Ap–0 to 7 inches; dark brown (7.5YR 4/2) clay loam, dark brown (5YR 4/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1–7 to 18 inches; dark brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; thin continuous clay films; neutral; gradual smooth boundary.

Bt2–18 to 32 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; neutral; gradual smooth boundary.

Bt3–32 to 42 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk–42 to 72 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 35 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 8
Soil Type: Olton clay loam

Location: Hale County, Texas; in a cultivated field 1200 feet south of Farm Road 37, 4.0 miles west of Farm Road 179 in Cotton Center.

Pedon description:
Sample No. S91TX191-2-(1-4)

Ap–0 to 7 inches; reddish brown (5YR 4/3) loam, dark reddish brown (5YR 3/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1–7 to 24 inches; dark reddish brown (5YR 4/3) clay loam, dark reddish brown (5YR 3/3) moist; moderate medium blocky structure; very hard, firm; common fine roots; few fine pores; thin continuous clay films; neutral; gradual smooth boundary.

Bt2–24 to 38 inches; reddish brown (5YR 4/4) clay loam, dark reddish brown (5YR 3/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Btk–38 to 70 inches; yellowish red (5YR 6/6) clay; yellowish red (5YR 7/6) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 38 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 9
Soil Type: Olton clay loam

Location: Lubbock County, Texas; in a cultivated field 2200 feet east of Farm Road 2528, 1.35 miles south of its intersection with Farm Road 1729, 6.0 miles west of Interstate Highway 27 at New Deal.

Pedon description:
Sample No. S91TX303-1-(1-4)

Ap–0 to 11 inches; dark brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; moderate medium blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; mildly alkaline; abrupt smooth boundary.

Bt1–11 to 26 inches; dark brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; moderate medium blocky structure; hard, friable; common fine roots; few fine pores; thin continuous clay films; mildly alkaline; gradual smooth boundary.

Bt2–26 to 47 inches; reddish brown (5YR 5/3) clay loam, reddish brown (5YR 4/3) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Btk–47 to 80 inches; reddish yellow (5YR 6/6) clay; reddish yellow (5YR 7/6) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 38 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 10
Soil Type: Olton clay loam

Location: Lubbock County, Texas; in a cultivated field 150 feet east of unpaved county road, 0.5 mile south of U.S. Highway 82, 4.5 miles east of Farm Road 400 in Idalou.

Pedon description:
Sample No. S90TX303-2-(1-5)

Ap–0 to 7 inches; dark brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; weak medium subangular structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1–7 to 23 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; weak coarse prismatic structure, parting to weak medium blocky structure; very hard, firm; common fine roots; few fine pores; thin patchy clay films; mildly alkaline; gradual smooth boundary.

Bt2–23 to 33 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; calcareous; mildly alkaline; gradual smooth boundary.

Bt3–33 to 42 inches; yellowish red (5YR 5/8) clay loam, yellowish red (5YR 4/6) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk–42 to 70 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 55 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 11
Soil Type: Olton clay loam

Location: Crosby County, Texas; in a cultivated field 950 feet south of a field turnrow, 0.85 miles south of curve in Farm Road 651, 1.85 miles south of its junction with Farm Road 1471 at Big Four.

Pedon description:
Sample No. S91TX107-1-(1-5)

Ap–0 to 10 inches; brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; mildly alkaline; clear smooth boundary.

Bt1–10 to 22 inches; brown (7.5YR 4/4) clay loam, dark brown (7.5YR 3/4) moist; weak coarse prismatic structure, parting to weak medium blocky structure; very hard, very firm;

common fine roots; few fine pores; common continuous clay films; mildly alkaline; gradual smooth boundary.

Bt2—22 to 33 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; common clay films; mildly alkaline; gradual smooth boundary.

Bt3—33 to 42 inches; red (2.5YR 4/6) clay loam, dark red (5YR 4/3) moist; weak medium blocky structure; very hard, firm; few fine roots; few fine pores; thin patchy clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk—42 to 72 inches; reddish yellow (5YR 6/8) silty clay loam, yellowish red (5YR 5/8) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 44 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Site No. 12

Soil Type: Olton sandy clay loam

Location: Crosby County, Texas; in a cultivated field 1700 feet west of FM 651, 1.1 miles south of Texas Highway 82 in Crosbyton.

Pedon description:
Sample No. S91TX107-2-(1-5)

Ap—0 to 9 inches; brown (7.5YR 4/2) sandy clay loam, dark brown (7.5YR 3/2) moist; weak medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common fine and medium pores; neutral; abrupt smooth boundary.

Bt1—9 to 22 inches; brown (7.5YR 4/4) clay, dark brown (7.5YR 3/4) moist; weak coarse prismatic structure, parting to weak medium blocky structure; hard, firm; common fine roots; few fine pores; common continuous clay films; mildly alkaline; gradual smooth boundary.

Bt2—22 to 29 inches; reddish brown (5YR 5/4) clay, reddish brown (5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; common continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—29 to 35 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; common clay films; few threads, films, and small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk—35 to 70 inches; pink (5YR 8/4) clay; pink (5YR 7/4) moist; moderate medium blocky structure; very hard, friable; common fine pores; about 47 percent of soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

Based on the field descriptions and laboratory determination of particle size distribution, profiles at the various sites differed mainly in horizon thickness, color, and texture, and depth to the calcic horizon. Profiles present at the different sites are indicated in Table 4. The Ap, Bt1, Bt2, and Btk horizons were present at all sites, and the Bt3 horizon was present at all sites, except at Sites 8 and 9.

The Ap horizon was generally 6 to 8 inches thick at all sites, but was 9 inches at Site 12, 10 inches at Site 11, and 11 inches at Site 9. The color of dry soil was brown or dark brown at all sites, except Site 8 where it was reddish brown. The color of moist soil was dark brown at all sites, except Site 8 where it was dark reddish brown. The Ap horizon textures are clay loam at Sites 1, 4, 7, and 11; sandy clay loam at Sites 2, 3, 5, 6, 8, 9, and 12; and sandy loam at Site 10. This horizon represents mainly the plow layer. The differences in thickness and texture of this horizon could be natural because the surface texture of Olton soil varies considerably. Mixing of the upper layers by plowing and winnowing of the fine fraction by wind possibly contributed to the differences.

The Bt1 horizon was mainly 11 to 16 inches thick, but it ranged from 10 inches Site 3 to 17 inches at Site 8. The texture generally was clay loam, but was clay at Sites 1, 7, and 12; sandy clay loam at Sites 6 and 8; and sandy clay at Site 9. Colors were brown or dark brown for dry and moist soil at all sites, except Site 8 where it was dark reddish brown for both conditions.

The Bt2 horizon ranged in thickness from 7 inches at Site 12 to 21 inches at Site 9, with most sites having a different thickness of this horizon. The texture was clay loam at Sites 2, 4, 5, 10, and 11; sandy clay loam at Site 9; and clay at Sites 1, 3, 6, 7, 8, and 12. Colors were mainly reddish brown for dry and moist soil, but were brown (dry) and dark brown (moist) at Site 1, brown for both conditions at Site 7, and yellowish red for both conditions at Site 10.

The Bt3 horizon was mainly 9 to 12 inches thick, but was 6 inches at Site 12, 7 inches at Site 1, and 16 inches at Site 3. The texture was clay loam at Sites 1, 2, 3, 6, 10, 11, and 12; sandy clay loam at Sites 4 and 5; and clay at Site 7. Color was mainly yellowish red, but was reddish brown (dry) at Site 1, reddish brown for both conditions at Site 7; and red (dry) and dark red (moist) at Site 11.

Thickness of the Btk horizon ranged from 21 to 42 inches, with

9 of the 12 sites having a thickness between 28 and 33 inches. The Btk horizon started at a depth ranging from 35 inches at Site 12 to 49 inches at Site 6. The bottom of this horizon usually was at 70 or 72 inches, but was at 80 inches at Sites 1 and 9. The texture was clay at all sites, except Sites 1, 9, 10, and 11 where it was clay loam. The color generally was pink for both the dry and moist soil, but yellowish red at Site 8 for both conditions, reddish yellow at Site 9 for both conditions, and reddish yellow (dry) and yellowish red (moist) at Site 11.

Particle Size Distribution

Results of the particle size distribution analyses are included in Table 5. Weighted mean sand contents for all horizons at a site, except the Btk, ranged from 31.0 percent at Site 7 to 48.8 percent at Site 9. There appeared to be no definite trend in weighted mean sand contents due to location of the sampling sites within the region. The sand content for the Ap horizon was highest (70.4 percent) at Site 10 and lowest (42.6 percent) at Site 11. The sand content at a given site usually was highest in the Ap horizon, but it was equal or greater for the Bt2 and Bt3 at Site 4, for the Bt3 at Site 5, for the Bt1 and Bt2 at Site 9, and the Btk at Site 11. No consistent trends in sand content with profile depth were found among the different sites. For horizons above the Btk, the overall weighted mean sand content was 40.0 percent. The sand content averaged 50.0 percent for the Ap horizon, 37.2 for the Bt1, 37.5 for the Bt2, 37.9 for the Bt3 (10 sites), and 31.8 in the Btk. The higher average sand content in the Ap horizon than in the underlying horizons suggests that much of the fine material (silt and clay) has been lost from the Ap horizon due to wind erosion. The low sand content of the Btk horizon reflects the high clay content of that horizon. Had the $CaCO_3$ been removed before analysis, the clay content would have been lower and sand would have been a greater part of the remaining material.

Size distributions of the sand fraction of soil from the different sites are given in Table 6. Of the total, the percent of coarse sand (0.850-mm sieve) was low, with the highest weighted mean amount (excluding the Btk horizon) being 2.6 percent at Site 6. This site also had 5.3 percent in the Bt2 horizon, which was the highest for any horizon above the Btk. For the next smaller sieve (0.425 mm), the highest amount was 3.7 percent at Site 7, with the Bt1 horizon at that site having the highest amount (7.6 percent) for an individual horizon. The highest amount for the 0.250-mm sieve was 9.8 percent at Site 9. The Ap horizon at this site also had the highest amount (11.0 percent) for an individual horizon. For the 0.150-mm size, the highest amount was 24.4 percent at Site 9, but the highest total for an individual horizon was 36.8 percent for the Ap at Site 10. The weighted mean totals for the above size fractions (0.850, 0.425, 0.250, and 0.150 mm) ranged from 7.4 percent at Site 1 to 35.1 percent at Site 9.

At all sites, except 9 and 11, the weighted mean percent of sand on the 0.106- mm sieve was greater than the total amount on the four larger sieves. Also, the amount on the finest sieve (0.053 mm) was greater than on the next finest sieve (0.106 mm) at all sites, except 9. This site also had the lowest amount on the finest sieve (29.9 percent). The lowest amount on the 0.106-mm sieve was 16.1 percent at Site 1. Surprisingly, the highest amount on the finest sieve (76.5 percent) also was at Site 1. For individual horizons, the highest amount on the finest sieve was 78.6 percent for the Bt1 at Site 1. It was 46.2 percent for the Bt2 horizon at Site 4 on the 0.106-mm sieve. Lowest amounts for individual horizons were 14.4 percent in the Bt1 at Site 1 on the 0.106-mm sieve and 25.1 percent in the Ap at Site 10 on the 0.053-mm sieve.

Of the three soil particle sizes (sand, silt, and clay), the weighted mean percent was lowest for silt at all sites, except Site 10, where it was 0.4 percentage unit greater than for clay. The amount of silt was highest (30.4 percent) at Site 10 and lowest (19.0 percent) at Site 6. For individual horizons above the Btk, the highest amount (37.4 percent) was in the Bt3 at Site 10 and the lowest amount (13.6 percent) was in the Bt1 at Site 9. Silt contents were variable in the profiles, and no horizon

Table 4. Horizons identified in Olton soil profiles at the various sampling sites.

	Horizon				
Site, County, State	Ap	Bt1	Bt2	Bt3	Btk
1, Curry, NM	X	X	X	X	X
2, Curry, NM	X	X	X	X	X
3, Parmer, TX	X	X	X	X	X
4, Parmer, TX	X	X	X	X	X
5, Castro, TX	X	X	X	X	X
6, Castro, TX	X	X	X	X	X
7, Hale, TX	X	X	X	X	X
8, Hale, TX	X	X	X	—	X
9, Lubbock, TX	X	X	X	—	X
10, Lubbock, TX	X	X	X	X	X
11, Crosby, TX	X	X	X	X	X
12, Crosby, TX	X	X	X	X	X

Table 5. Characteristics of the Olton soil at the study sites.

Site, county and state	Horizon	Depth	Particle size distribution			USDA texture	Bulk density	Organic matter	$CaCO_3$ equiv.	pH	CEC	Water content[1]		Plant-available water			
			Sand	Silt	Clay							-0.33	-15.0				
		inches	%	%	%		g/cm^3	%	%		meg/100 g	% by volume		%	in/in	in/hor.	48-in. depth[3]
1, Curry, NM																	
	1, Ap	0–8	43.5	26.3	30.2	Clay loam	1.35[2]	2.21	—	7.2	17.2	33.12	21.80	11.32	0.113	0.90	
	2, Bt1	8–23	32.5	25.1	42.4	Clay	1.60	0.70	—	7.7	18.3	36.50	27.27	9.23	0.092	1.38	
	3, Bt2	23–31	38.4	22.0	39.6	Clay loam	1.65	0.40	—	7.9	15.4	33.39	25.11	8.28	0.083	0.66	
	4, Bt3	31–38	36.0	27.5	38.7	Clay loam	1.50	0.15	—	7.9	15.2	30.20	22.09	8.11	0.081	0.57	
	5, Btk	38–80	35.8	25.6	38.6	Clay loam	1.52	0.32	57.0	8.1	7.0	—	—	—	—	—	
	Weighted mean[4]		36.7	25.1	38.6	—	1.54	0.85	—	7.7	16.9	33.97	24.71	9.26	0.093	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	3.51	4.32
2, Curry, NM																	
	1, Ap	0–7	49.9	24.5	25.6	Sandy clay loam	1.35	1.50	—	6.6	15.9	26.21	16.64	9.57	0.096	0.67	
	2, Bt1	7–20	31.1	30.8	38.1	Clay loam	1.59	0.60	—	6.7	16.4	32.79	24.16	8.63	0.096	1.12	
	3, Bt2	20–28	36.9	28.2	34.9	Clay loam	1.50	0.58	—	7.8	18.0	29.60	21.11	8.49	0.095	0.76	
	4, Bt3	28–39	42.0	26.2	31.8	Clay loam	1.52	0.43	—	7.3	11.7	26.77	18.92	7.85	0.079	0.87	
	5, Btk	39–70	26.6	27.8	45.6	Clay	1.40	0.29	59.4	7.7	6.8	—	—	—	—	—	
	Weighted mean		38.7	27.8	33.4	—	1.51	0.71	—	7.1	15.3	29.26	20.71	8.55	0.086	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	3.42	4.13
3, Parmer, TX																	
	1, Ap	0–6	47.0	26.8	26.2	Sandy clay loam	1.35	1.98	—	7.2	17.8	29.06	18.57	10.49	0.105	0.63	
	2, Bt1	6–16	29.1	31.9	39.0	Clay loam	1.56	1.15	—	6.9	19.4	35.96	26.17	9.79	0.098	0.98	
	3, Bt2	16–25	28.1	31.0	40.9	Clay	1.54	1.26	—	7.1	15.2	37.72	27.48	10.24	0.102	0.92	
	4, Bt3	25-41	31.2	29.1	39.7	Clay loam	1.46	0.90	—	7.5	12.4	34.36	24.69	9.67	0.097	1.55	
	5, Btk	41-72	22.7	29.1	47.2	Clay	1.31	1.06	47.3	7.8	6.2	—	—	—	—	—	
	Weighted mean		32.3	29.9	37.8	—	1.49	1.20	—	7.2	15.5	34.71	24.77	9.94	0.099	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	4.08	4.76
4, Parmer, TX																	
	1, Ap	0–8	43.5	29.1	27.4	Clay loam	1.35	1.71	—	7.7	16.5	28.53	18.45	10.08	0.101	0.81	
	2, Bt1	8–24	35.4	30.0	34.6	Clay loam	1.57	1.16	—	7.8	19.1	32.90	23.57	9.33	0.093	1.49	
	3, Bt2	24–37	44.4	22.2	33.4	Clay loam	1.54	0.36	—	7.8	14.9	27.75	19.91	7.84	0.078	1.01	
	4, Bt3	37–48	53.8	14.7	31.5	Sandy clay loam	1.51	0.26	—	8.0	13.7	25.61	18.08	7.53	0.075	0.83	
	5, Btk	48–72	31.8	23.9	44.3	Clay	1.54	0.24	57.4	7.6	4.1	—	—	—	—	—	
	Weighted mean		43.4	24.2	32.4	—	1.51	0.83	—	7.8	16.3	29.11	20.47	8.64	0.086	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	4.14	4.14
5, Castro, TX																	
	1, Ap	0–6	45.0	27.3	27.7	Sandy clay loam	1.35	1.96	—	7.8	12.1	30.05	19.44	10.61	0.106	0.64	
	2, Bt1	6–17	36.8	28.3	34.9	Clay loam	1.50	1.65	—	7.2	19.1	34.99	24.57	10.42	0.104	1.14	
	3, Bt2	17–33	35.2	27.7	37.1	Clay loam	1.58	1.21	—	7.0	16.3	35.05	25.40	9.65	0.097	1.55	
	4, Bt3	33–45	45.7	21.9	32.4	Sandy clay loam	1.64	0.78	—	7.1	13.2	29.99	21.75	8.24	0.082	0.98	
	5, Btk	45–72	31.2	26.7	42.1	Clay	1.31	0.53	58.4	7.3	6.3	—	—	—	—	—	
	Weighted mean		39.7	26.2	34.1	—	1.55	1.30	—	7.2	15.6	33.02	23.43	9.59	0.096	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	4.31	4.56
6, Castro, TX																	
	1, Ap	0–7	57.3	19.3	23.4	Sandy clay loam	1.35	1.05	—	6.7	11.9	22.34	13.83	8.51	0.085	0.60	
	2, Bt1	7–20	51.2	16.4	32.4	Sandy clay loam	1.45	0.92	—	7.1	17.6	29.08	20.11	8.97	0.090	1.17	
	3, Bt2	20–38	37.1	20.2	42.7	Clay	1.51	0.69	—	7.3	20.0	35.91	26.43	9.48	0.095	1.71	
	4, Bt3	38–49	40.4	19.7	39.9	Clay loam	1.67	0.53	—	7.6	13.2	34.43	25.94	8.49	0.085	0.94	
	5, Btk	49–70	25.9	23.5	50.6	Clay	1.57	0.20	57.2	7.8	12.4	—	—	—	—	—	
	Weighted mean		44.5	19.0	36.6	—	1.51	0.77	—	7.2	16.7	31.83	22.84	9.01	0.090	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	4.42	4.34

Table 5. Continued.

Site, county and state	Horizon	Depth	Particle size distribution Sand	Silt	Clay	USDA texture	Bulk density	Organic matter	$CaCO_3$ equiv.	pH	CEC	Water content[1] -0.33	-15.0	Plant-available water			
		inches	%	%	%		g/cm^3	%	%		meg/100 g	% by volume		%	in/in	in/hor.	48-in. depth[3]
7, Hale, TX																	
	1, Ap	0–7	41.0	29.4	29.6	Clay loam	1.35	1.29	—	6.8	15.4	28.06	18.46	9.60	0.096	0.67	
	2, Bt1	7–18	28.0	31.1	40.9	Clay	1.55	0.74	—	7.6	20.1	35.19	25.91	9.28	0.093	1.02	
	3, Bt2	18–32	34.5	24.9	40.6	Clay	1.57	0.60	—	7.7	17.2	34.44	25.50	8.94	0.089	1.25	
	4, Bt3	32-42	22.4	36.7	40.9	Clay	1.40	0.43	—	7.8	13.2	32.35	23.26	9.09	0.091	0.91	
	5, Btk	42-72	25.9	28.6	45.6	Clay	1.34	0.40	61.0	7.9	8.3	—	—	—	—	—	
	Weighted mean		31.0	30.1	38.9	—	1.49	0.71	—	7.5	16.7	33.08	23.90	9.18	0.092	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	3.85	4.40
8, Hale, TX																	
	1, Ap	0–7	62.8	14.1	23.1	Sandy clay loam	1.35	0.84	—	7.4	15.0	21.07	12.96	8.11	0.081	0.57	
	2, Bt1	7–24	48.7	17.9	33.4	Sandy clay loam	1.54	0.74	—	7.5	16.9	29.66	21.14	8.52	0.085	1.45	
	3, Bt2	24–38	39.3	18.9	41.8	Clay	1.56	0.43	—	7.7	15.4	34.37	25.58	8.79	0.088	1.23	
	4, Btk	38-70	38.3	19.6	42.1	Clay	1.55	0.43	41.0	7.9	8.2	—	—	—	—	—	
	Weighted mean		47.8	17.6	34.6	—	1.51	0.55	—	7.6	16.0	29.81	21.27	8.54	0.085	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	3.25	4.13
9, Lubbock, TX																	
	1, Ap	0–11	47.7	30.5	26.8	Sandy clay loam	1.35	0.25	—	6.7	14.3	20.79	13.36	7.43	0.074	0.81	
	2, Bt1	11–26	48.0	13.6	38.4	Sandy clay	1.61	0.90	—	7.3	17.8	34.69	25.54	9.15	0.092	1.38	
	3, Bt2	26–47	50.0	16.9	33.1	Sandy clay loam	1.56	0.18	—	7.6	12.6	26.79	19.36	7.43	0.074	0.81	
	4, Btk	47–80	39.0	21.4	39.6	Clay loam	1.48	0.28	36.8	7.8	7.7	—	—	—	—	—	
	Weighted mean		48.8	17.9	33.3	—	1.53	0.43	—	7.3	14.7	27.91	19.93	7.98	0.080	—	
	Profile total—in.		— —	—	—	—	—	—	—	—	—	—	—	—	—	3.00	3.07
10, Lubbock, TX																	
	1, Ap	0–7	70.4	15.3	14.3	Sandy loam	1.35	0.96	—	7.6	10.9	15.29	7.88	7.41	0.074	0.52	
	2, Bt1	7–16	34.0	31.7	34.3	Clay loam	1.61	0.85	—	7.3	19.2	31.46	22.82	8.64	0.086	1.38	
	3, Bt2	16–33	34.0	32.6	33.4	Clay loam	1.44	0.55	—	7.4	16.1	27.85	19.42	8.43	0.084	0.84	
	4, Bt3	33–42	32.0	37.4	30.6	Clay loam	1.66	0.35	—	7.9	12.4	26.68	19.46	7.22	0.072	0.65	
	5, Btk	42–70	24.0	37.0	39.0	Clay loam	1.50	0.31	47.3	7.2	9.0	—	—	—	—	—	
	Weighted mean		39.6	30.4	30.0	—	1.51	0.69	—	7.5	15.6	26.28	18.23	8.05	0.081	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	3.39	3.82
11, Crosby, TX																	
	1, Ap	0–10	42.6	20.3	37.1	Clay loam	1.35	1.59	—	6.6	13.2	35.01	24.09	10.92	0.109	1.09	
	2, Bt1	10–22	41.8	23.0	35.2	Clay loam	1.58	1.10	—	6.7	18.8	33.12	23.86	9.26	0.093	1.12	
	3, Bt2	22–33	38.0	22.7	39.3	Clay loam	1.48	0.79	—	7.9	15.3	33.68	24.31	9.37	0.093	1.02	
	4, Bt3	33–42	34.0	29.8	36.2	Clay loam	1.41	0.42	—	7.3	12.6	28.98	20.41	8.57	0.086	0.77	
	5, Btk	42–72	43.7	17.0	39.3	Clay loam	1.47	0.28	39.9	7.6	7.5	—	—	—	—	—	
	Weighted mean		39.3	23.7	36.9	—	1.46	0.99	—	7.1	15.2	32.83	23.29	9.54	0.095	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	4.00	4.52
12, Crosby, TX																	
	1, Ap	0–9	49.0	22.6	28.4	Sandy clay loam	1.35	1.70	—	7.5	12.8	29.25	19.03	10.22	0.102	0.92	
	2, Bt1	9–22	29.4	27.9	42.7	Clay	1.51	1.29	—	7.5	19.1	38.93	28.37	10.56	0.106	1.38	
	3, Bt2	22–29	34.0	25.1	40.9	Clay	1.61	0.95	—	7.9	16.3	36.76	27.25	9.51	0.095	0.67	
	4, Bt3	29–35	41.6	20.7	37.7	Clay loam	1.52	0.42	—	6.9	13.2	31.00	22.56	8.44	0.084	0.50	
	5, Btk	35–70	31.7	26.5	41.8	Clay	1.61	0.43	38.8	7.6	9.1	—	—	—	—	—	
	Weighted mean		37.5	24.7	37.8	—	1.49	1.18	—	7.5	15.9	34.65	24.75	9.90	0.099	—	
	Profile total—in.		—	—	—	—	—	—	—	—	—	—	—	—	—	3.47	4.56

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[1] Water contents at the -1/3 and -15 bar matric potentials were calculated by Equations 1 and 2, respectively, in Table 7, of Unger (1975).

[2] Bulk density of the Ap horizon was based on a value obtained from another study on Olton soil because this horizon was the loosened tillage layer and core sampling was not possible when the samples were obtained for this study.

[3] Adjusted to 48-inch depth for all horizons by adding or subtracting plant-available water based on water retention of the horizon above or the horizon occurring at the 48-inch depth.

[4] The calcic horizon (Btk) was not included in the weighted mean calculations. For water content, weighted means were calculated only to the depth to which data are presented.

had the lowest or highest amount in all cases. Also, trends for silt content generally were opposite the trends for sand content. The overall weighted mean silt content was 24.7 percent. For individual horizons, silt content averaged 23.4 percent for the Ap, 25.6 for the Bt1, 24.4 for the Bt2, 26.4 for the Bt3 (10 sites), and 25.6 for the Btk. While silt content varied considerably among horizons at a given site, average silt contents for the horizons were remarkably uniform, ranging from 23.4 percent for the Ap to 26.4 percent for the Bt3.

Weighted mean clay contents varied less among sites than those for sand and silt, ranging from 30.0 percent at Site 10 to 38.9 percent at Site 7. Excluding the Btk horizon, clay content usually was highest in the Bt1 or Bt2 horizon and lowest in the Ap horizon. For individual horizons above the Btk, clay content was lowest (14.3 percent) in the Ap at Site 10 and highest (42.7 percent) in the Bt2 at Site 6 and the Bt1 at Site 12. The overall weighted mean clay content was 35.4 percent. Clay contents averaged 26.7 percent in the Ap horizon, 37.2 in the Bt1, 38.1 in the Bt2, 35.9 in the Bt3 (10 sites), and 43.0 in the Btk. The $CaCO_3$ was not removed before determining the particle size distribution for the Btk horizon. The trends in average clay content for the different horizons are opposite the trends for sand.

Bulk Density

Bulk density of the Ap horizon was not determined because this horizon was disturbed by tillage and generally remained in a loosened condition when sampling occurred. Other studies, however, have shown that type and recency of tillage greatly affect the density of this horizon. Therefore, for this study, we assumed the bulk density to be 1.35 g/cm^3 (Table 5), which was the bulk density for the Ap horizon of Olton soil in Lamb County (B. L. Allen, Lubbock, Texas, personal commu-

Table 6. Content and size distribution of sand in Olton soil.

				Sand retained on sieves with openings of (mm)					
Site, county, and state	Horizon	Depth	Total sand	0.850 (#20)	0.425 (#40)	0.250 (#60)	0.150 (#100)	0.106 (#140)	0.053 (#270)
		in				%			
1, Curry, NM	Ap	0-8	43.5	0.5	1.1	2.3	3.4	17.6	75.1
	Bt1	8-23	32.5	1.2	1.3	1.0	3.5	14.4	78.6
	Bt2	23-31	38.4	2.5	2.2	1.4	3.0	14.8	76.1
	Bt3	31-38	31.0	0.9	1.6	0.9	3.2	19.3	74.1
	Btk	38-80	36.0	1.4	1.9	1.7	2.6	15.8	76.6
	Weighted mean[1]		35.8	1.3	1.5	1.3	3.3	16.1	76.5
2, Curry, NM	Ap	0-7	49.9	2.2	2.3	1.3	2.9	27.7	63.6
	Bt1	7-20	31.1	4.8	2.7	2.0	4.3	33.2	53.0
	Bt2	20-28	36.8	1.1	3.6	2.7	4.6	35.3	52.7
	Bt3	28-39	42.0	1.1	3.0	2.6	4.6	34.2	54.5
	Btk	39-80	26.6	1.8	4.2	3.3	5.3	34.4	51.0
	Weighted mean		38.7	2.5	2.9	2.2	4.2	32.9	55.3
3, Parmer, TX	Ap	0-6	47.0	2.1	0.7	0.8	2.8	27.1	66.6
	Bt1	6-16	29.1	0.4	0.8	0.7	2.4	19.5	76.2
	Bt2	16-25	29.9	1.3	1.5	1.1	2.3	18.3	75.5
	Bt3	25-41	31.7	3.2	2.6	2.9	2.4	20.9	68.0
	Btk	41-80	22.7	7.4	4.5	2.3	4.2	23.0	58.6
	Weighted mean		32.9	1.9	1.6	1.7	2.4	20.9	71.4
4, Parmer, TX	Ap	0-8	43.5	0.4	1.4	1.1	4.0	30.7	62.4
	Bt1	8-24	35.4	0.2	1.3	1.2	7.1	43.2	47.0
	Bt2	24-37	44.4	2.4	1.5	1.5	7.1	46.2	41.3
	Bt3	37-48	53.8	0.3	1.5	1.5	11.8	41.3	43.6
	Btk	48-80	31.7	7.9	4.5	3.5	11.4	29.2	43.5
	Weighted mean		43.4	0.9	1.4	1.3	7.7	41.5	47.2
5, Castro, TX	Ap	0-6	45.0	0.1	0.3	0.4	7.2	26.1	60.6
	Bt1	6-17	36.8	0.2	1.1	2.7	16.5	32.5	47.0
	Bt2	17-33	35.2	1.0	2.0	2.0	20.6	34.0	40.4
	Bt3	33-45	45.7	0.5	0.9	1.8	18.3	33.0	45.5
	Btk	45-80	31.2	1.2	1.8	2.3	23.1	32.7	38.9
	Weighted mean		39.7	0.6	1.3	1.9	17.3	32.5	46.4
6, Castro, TX	Ap	0-7	57.3	1.0	1.1	5.0	10.1	32.7	50.1
	Bt1	7-21	51.2	1.7	1.1	4.2	10.3	31.4	51.3
	Bt2	21-38	37.1	5.3	1.0	2.2	7.1	22.3	62.1
	Bt3	38-49	40.4	0.4	0.8	2.9	6.7	32.4	56.8
	Btk	49-72	25.9	3.1	1.2	2.7	7.4	25.5	60.1
	Weighted mean		44.8	2.6	1.0	2.7	8.4	28.7	56.1
7, Hale, TX	Ap	0-7	41.1	4.1	0.8	2.4	6.3	27.0	59.4
	Bt1	7-18	30.5	2.1	7.6	2.0	9.4	32.3	46.6
	Bt2	18-32	35.0	1.6	2.1	2.6	6.6	39.7	47.4
	Bt3	32-42	22.7	3.6	3.7	4.6	8.3	31.9	47.9
	Btk	42-72	25.9	—	—	—	—	—	—
	Weighted mean		31.9	1.8	3.7	2.9	7.7	33.8	4.93
8, Hale, TX	Ap	0-7	62.8	0.1	0.8	8.0	20.3	28.3	42.5
	Bt1	7-24	48.7	0.1	0.8	5.1	14.5	25.9	53.6
	Bt2	24-38	39.3	0.5	1.4	7.8	11.0	21.0	58.3
	Btk	38-72	38.3	1.5	2.7	6.8	11.6	20.2	57.2
	Weighted mean		47.8	0.6	1.0	6.6	14.3	24.4	53.1
9, Lubbock, TX	Ap	0-11	47.7	0.2	0.3	11.0	27.0	32.3	29.2
	Bt1	11-26	48.0	0.2	0.4	8.6	22.2	34.6	34.0
	Bt2	26-47	50.0	0.5	0.8	10.1	24.5	36.7	27.4
	Btk	47-80	39.0	1.4	1.8	9.6	20.3	32.7	34.2
	Weighted mean		48.4	0.3	0.6	9.8	24.4	35.0	29.9
10, Lubbock, TX	Ap	0-7	70.3	0.0	0.3	10.8	36.8	27.0	25.1
	Bt1	7-23	34.0	0.4	0.6	4.2	11.6	33.6	50.6
	Bt2	23-33	35.1	0.9	1.0	4.3	10.0	34.6	49.2
	Bt3	33-42	32.0	2.4	2.4	7.3	14.9	37.8	35.2
	Btk	42-72	24.0	5.3	4.8	7.4	12.0	33.0	37.5
	Weighted mean		39.9	0.9	1.0	6.0	16.1	33.6	42.7

Table 6. Continued.

Site, county, and state	Horizon	Depth	Total sand	Sand retained on sieves with openings of (mm) 0.850 (#20)	0.425 (#40)	0.250 (#60)	0.150 (#100)	0.106 (#140)	0.053 (#270)
		in	%						
11, Crosby, TX	Ap	0-10	42.6	0.2	0.5	6.0	23.1	28.0	42.2
	Bt1	10-22	41.8	0.2	0.1	6.2	22.9	29.4	41.2
	Bt2	22-33	38.0	0.5	0.8	5.7	20.3	27.3	45.4
	Bt3	33-42	34.0	3.9	6.6	8.1	18.3	26.4	35.3
	Btk	42-72	42.6	0.6	1.1	5.8	20.4	28.8	43.3
	Weighted mean		39.4	1.1	1.8	6.4	21.3	27.9	41.3
12, Crosby, TX	Ap	0-9	49.0	0.4	0.9	3.3	13.1	22.2	60.1
	Bt1	9-22	29.4	0.3	0.6	4.4	14.5	28.5	51.7
	Bt2	22-29	34.0	0.7	1.0	4.2	14.1	26.2	53.8
	Bt3	29-35	41.6	0.6	1.0	4.3	14.8	26.2	54.0
	Btk	35-72	31.7	1.9	2.8	5.7	15.2	26.4	48.0
	Weighted mean		37.5	0.5	0.8	4.1	14.1	26.0	54.7

[1] The calcic (Btk) horizon was not included in calculation of the weighted means.

nication, 1997). A value was needed to calculate the available water content of the Ap horizon in a later section.

Weighted mean bulk densities for horizons above the Btk were relatively constant and ranged from 1.46 g/cm^3 at Site 11 to 1.55 g/cm^3 at Site 5. The bulk density for the Bt1 horizon was lowest (1.45 g/cm^3) at Site 6 and highest (1.61 g/cm^3) at Sites 9 and 10. The density was lowest (1.44 g/cm^3) at Site 10 and highest (1.65 g/cm^3) at Site 1 for the Bt2 horizon. For the Bt3 horizon, densities ranged from 1.40 g/cm^3 at Site 7 to 1.67 g/cm^3 at Site 6. The largest difference between the lowest and highest densities was in the Btk horizon, for which the lowest (1.31 g/cm^3) was at Sites 3 and 5 and the highest (1.61 g/cm^3) was at Site 12.

At most sites, bulk density was highest in the Bt1 or Bt2 horizon, indicating that some soil compaction had occurred. Based on studies conducted by Taylor and Gardner (1963), however, the densities were not high enough to prevent plant root penetration if the soil contains adequate water, but some reduction in root penetration could occur. Root penetration is affected by soil strength, which is a function of soil bulk density and water content (Taylor and Gardner, 1963). Their study with Amarillo fine sandy loam, for example, showed that some roots penetrated the soil when the bulk density was 1.75 g/cm^3 if the soil matric potential was -1/2 bar or higher (wetter). At a drier soil condition (-2/3 bar matric potential), some root penetration occurred when the bulk density was 1.65 g/cm^3 or less. The maximum density at the Olton soil sites sampled was 1.67 g/cm^3 (Bt3 horizon, Site 6). Such density could reduce root penetration as the soil becomes drier. However, resistance to root penetration at similar soil water contents and bulk densities may not be the same in Olton soil as in the Amarillo soil. Also, the method of obtaining samples for bulk density determination may influence the results obtained. For this study, core sampling was used for which the bulk density represents an average density of the sampled volume, including the soil and the shrinkage cracks that develop as the soil dries. When clod sampling is used, shrinkage cracks are excluded and the measured bulk density generally is higher than with core sampling. If shrinkage cracks develop as the soil dries, roots may grow through those cracks, even if the soil density is high. Therefore, no definite conclusions regarding effects of measured bulk densities on root penetration are warranted.

Organic Matter

At all sites, except Site 9, the organic matter content was highest in the Ap horizon (Table 5). The extremely low content at Site 9 (0.25 percent) possibly resulted from tillage that inverted the surface layer of soil. For the remaining sites, the organic matter content in the Ap ranged from 0.84 percent at Site 8 to 2.21 percent at Site 1. For the Bt1 horizon, organic matter contents ranged from 0.60 percent at Site 2 to 1.65 percent at Site 5. It ranged from 0.18 percent at Site 9 to 1.26 percent at Site 3 for the Bt2 horizon and from 0.15 percent at Site 1 to 0.90 percent at Site 3 for the Bt3 horizon. The Btk horizon contained less than 0.50 percent organic matter at all sites, except at Site 3 where it was 1.06 percent and Site 5 where it was 0.53 percent.

The weighted mean organic matter content, which does not include the Btk horizon, was lowest (0.43 percent) at Site 9. This site had the lowest content in the Ap and Bt2 horizons, but its content in the Bt2 horizon was not greatly different from that of the Bt1 horizon at most other sites. The weighted mean was highest (1.30 percent) at Site 5 and next highest (1.20 percent) at Site 3. At both sites, the three upper horizons contained more than 1.00 percent organic matter.

Calcium Carbonate ($CaCO_3$) Equivalent

The $CaCO_3$ equivalent was determined for the calcic (Btk) horizon of the profiles. The values ranged from 36.8 percent at Site 9 to 61.0 percent at Site 7 (Table 5). High percentages occurred also at Sites 1 (57.0), 2 (59.4), 4 (57.4), 5 (58.4), and 6 (57.2). The $CaCO_3$ equivalent refers to the neutralizing power of the material. However, although the $CaCO_3$ equivalent was above 50 percent in the Btk horizon at some locations, the material is considered low in value for liming purposes (Lawton and Kurtz, 1957).

pH

Soil pH (Table 5) was lowest in the Ap horizon in most cases and generally increased with soil depth. The reason for the exceptions is not known. Although some different trends occurred, differences among horizons at a given site were relatively small. Differences ranged from 0.4 pH unit at Site 4 to 1.3 pH units at Site 11. The weighted means ranged from 7.1 at Sites 2 and 11 to 7.8 at Site 4.

The soil was near neutral or moderately alkaline (pH 6.6 to 8.0) in horizons above the Btk and mildly to moderately alkaline (pH 7.2 to 8.1) in the Btk at all sites, as indicated by the profile descriptions. In most cases, the pH was near or above 7.0. The lowest pH was 6.6 in the Ap horizon at Sites 2 and 11. In no horizon above the Btk was the pH at a level that appears detrimental to growth of field crops. As previously mentioned, however, the Btk horizon apparently restricts root growth of some crops. Also, sensitive plants could be affected by the alkaline conditions throughout the profile, which may require special treatment of the soil for good plant growth.

Cation Exchange Capacity (CEC)

The CEC of a soil refers to the sum of exchangeable cations that a soil can adsorb at a specific soil pH (Soil Science Society of America, 1987), and is important with regard to retaining nutrients in soil for later uptake by plants. The weighted mean CEC was relatively constant, ranging from 14.7 meq/100 g of soil at Site 9 to 16.9 meq/100 g at Site 1 (Table 5). For individual horizons above the Btk, low values were 10.9 for the Ap at Site 10, 16.4 for the Bt1 at Site 2, 12.6 for the Bt2 at Site 9, and 11.7 for the Bt3 at Site 2. High values were 17.8 for the Ap at Site 3, 20.1 for the Bt1 at Site 7, 20.0 for the Bt2 at Site 6, and 15.2 for the Bt3 at Site 1. The higher CECs generally were associated with the higher clay contents, both for the entire profiles (weighted mean values) and for individual horizons at a given site. The CECs were low for the Btk horizon, although the indicated clay contents generally were high. Included in the reported clay percentages for the Btk horizon, however, were the clay-sized carbonate particles that do not contribute to the CEC.

Water Retention

Water contents at matric potentials of -1/3 and -15 bars (Table 5) were calculated by equations developed by Unger (1975). The equations are based on the bulk density, organic matter content, and clay content of the individual horizons. These equations were selected because they are considered appropriate for the entire range of organic matter contents involved. Also considered were equations developed by Otto Baumer (unpublished report) at the Natural Resources Conservation Service (formerly, Soil Conservation Service) Laboratory at Lincoln, Nebraska. Those equations, however, are reported to be appropriate only for soils with less than 1.0 percent organic carbon (about 1.72 percent organic matter), which is less than the amount in some horizons at some sites of this study. The calculated values should be valid because correlation coefficients associated with the equations used were significant at the 0.1 percent level (P = 0.001 level).

Water contents in Table 5 are given on a volume basis. The plant-available water (PAW) contents are differences between the -1/3 and -15 bar values and are also given on a volume basis. These values represent the amount of water that can be stored in the soil for use by plants, and are equivalent to the PAW storage capacities of the soils. The -1/3 bar value is the upper limit of water retained in a soil that drains freely. In practice, however, some water above the -1/3 bar value can be used by plants if they are actively growing when water is added by rain or irrigation. Values of PAW in Table 5 for individual horizons were obtained by multiplying the horizon thickness by the determined water content for the given horizon (inches/inch). Totals for a given site are summations of the values for the individual horizons.

Plant-available water storage capacities were calculated only for horizons above the calcic (Btk) horizon because roots of most crops do not grow into nor extract water from the calcic horizon. At 8 of the 12 sites, the total PAW storage capacity was 4.00 inches or less. The low storage capacities were associated mainly with shallow soil depths above the calcic horizon. Low water retention for individual horizons was a contributing factor.

Water storage capacity was lowest (3.25 inches) at Site 8 and highest (4.42 inches) at Site 6. Depth to the Btk horizon was 38 inches at Site 8 and 49 inches at Site 6. In addition, the weighted mean water storage capacity was 0.090 inch/inch of profile depth at Site 6, but only 0.080 inch/inch at Site 8. The weighted mean was the lowest at Site 8 and equally high (0.099 inch/inch) at Sites 3 and 12.

Water storage capacity differences among sites were greatest for the Ap horizon, ranging from 0.074 inch/inch at Sites 9 and 10 to 0.113 inch/inch at Site 1. The capacities ranged from 0.085 inch/inch at Site 8 to 0.106 at Site 12 for the Bt1 horizon, from 0.074 at Site 9 to 0.102 at Site 3 for the Bt2, and from 0.072 at Site 10 to 0.097 at Site 3 for the Bt3.

To obtain a better comparison among sites, the water holding capacity of all profiles was adjusted to a 48-inch depth with the assumption that the calcic horizon held as much water (inch/inch) as the horizon immediately above it. On this basis, water storage capacity was lowest at Site 9 (3.07 inches). At all other sites, except at Site 10 where it was 3.82 inches, total water storage capacity of the profile was above 4.00 inches, with the highest (4.76 inches) being at Site 3.

Water storage capacities differed among sites, with the lowest (3.00 inches) being at Site 9. For all other sites, the maximum difference was 1.03 inches. These results suggest that no major differences in management are needed in most cases to use the soil as a reservoir to store water for later extraction by crops. However, when managing these soils, several points should be taken into consideration. First, the values given should serve only as a guide because the actual amount of water stored and later extracted by plants is influenced by many soil, crop, and climatic conditions. As a result, field values of soil water storage and use seldom correspond with values obtained under laboratory conditions. Second, some crops with well-developed root systems often extract soil water to values below the reported -15 bar value, thus obtaining more water from the soil than the amount indicated by the water storage capacity. Third, an undetermined amount of water is made available to crops due to upward capillary movement of water from underlying horizons as plants use water from (dry out) the overlying horizons. Also, as previously mentioned, some water initially held above the -1/3 bar value may be used if plants are actively growing when rain occurs or an irrigation is applied. Probably the most important factor regarding a soil's water holding capacity is that the soil be managed in a way that results in refilling the storage reservoir with water whenever precipitation occurs or irrigation is applied. Such management requires maintaining conditions that result in effective water infiltration into the soil. Soil management is further discussed in a subsequent section.

Water Infiltration

Measurements of cumulative water infiltration at 10 minutes and 20 hours and of infiltration rates at times ranging from 10 minutes to 20 hours were made under varying conditions at the different sites as indicated by the remarks included with the data in Table 7. The different conditions resulted in major cumulative infiltration and infiltration rate differences, both among sites and at a given site. Data for a rangeland site are included also, but will not be included in the general discussion of water infiltration.

At 10 minutes, no measurable infiltration had occurred during one test at Sites 6 and 11 and the highest amount at one test was 2.64 inches at Site 3. At Site 6, the surface was compacted following corn harvest. Before measuring infiltration at Site 11, the soil was wetted and stirred to disperse the surface aggregates, which effectively sealed the soil surface. Such drastic treatment as at Site 11 is not natural, but intense rain on a soil with low aggregate stability can quickly cause aggregate dispersion and surface sealing. As a result, runoff can begin before 0.10 inch of rain has fallen. Other low cumulative infiltration amounts at 10 minutes were 0.12 inch at Site 4, where the measurement was made in a "packed furrow" after corn, and 0.24 inch at Site 1, where a tillage pan was present.

At Site 3, the soil was deeply ripped with a blade plow, which resulted in the highest cumulative infiltration at 10 minutes, even though the soil was near field capacity due to 9.5 inches of rain about 2 weeks before making the infiltration measurements. The next highest cumulative infiltration at 10 minutes (2.24 inches) occurred at Site 11 where the soil was loosened by plowing. Soil conditions such as at Sites 3 and 11 should be highly effective to store water in soil from an intense rain, especially if the surface is protected (for example, by residues) to prevent aggregate dispersion and surface sealing.

Cumulative infiltration at 20 hours ranged from 0.38 inch at Site 6 to 13.22 inches at Site 4. Low infiltration at Site 6 resulted from the compacted surface soil following corn. Infiltration also was low at Site 11 (1.00 inch) where the soil was wetted and stirred and at Site 9 (1.32 and 1.43 inches) where grain sorghum stubble was disked and the land was seeded to wheat. The soil was soft at Site 4 where infiltration was highest. Infiltration at 20 hours also was high (over 10.00 inches) at Site 3 (12.48 inches) where the soil was deeply ripped with a blade plow, and at Site 9 (10.73 inches) where grain sorghum stubble was disked and the land was seeded to wheat. The reason why some of the lowest and highest infiltration amounts occurred at Site 9 is not known, but these results indicate the large variation in infiltration that can occur, even within a given field.

Because of the poor soil conditions at Sites 6 and 11, infiltration rates were low initially (no measurable infiltration) and reached maximums of only 0.04 inch/hour at 10 hours at Site 6 and 0.10 inch/hour at 2 hours at Site 11. These low rates throughout the 20-hour period of measurement resulted in the low cumulative amounts at these sites. For other sites, the lowest rate at 10 minutes was 0.53 inch/hour at Site 12 where the crop was cotton. Other low rates were 0.56 inch/hour at Site 1 where a tillage pan was present, 0.59 and 0.62 at Site 9 where grain sorghum stubble was disked and the land was seeded to wheat, and 0.69 and 0.71 at Site 12 where the crop was cotton.

The measured infiltration rate was extremely high (72.00 inches/hour) at 10 minutes at Site 3, the reason for which is not known. It may have been due, however, to an unnatural soil condition such as a filled animal burrow or root channels. Other relatively high rates at 10 minutes were 3.79 inches/hour at Site 9 where grain sorghum stubble was disked and the land was seeded to wheat, 3.27 at Site 2 in a clean tilled furrow, 3.06 at Site 8 where the crop was cotton with a tillage pan present, and 3.06 at Site 10 where the soil was loose without a tillage pan.

Table 7. Cumulative amount and rate of water infiltration and related data for Olton soils.

Site, county, and state	Bulk density		Cumulative infiltration at		Infiltration rate at							Remarks
	Ap[1]	Bt1	10 min	20 hr	10 min	30 min	1 hr	2 hr	5 hr	10 hr	20 hr	
	g/cm^3		inches		inches/hr							
1, Curry, NM	1.46	1.41	0.34	4.10	1.80	1.54	0.55	0.24	0.12	0.12	0.07	Wheat stubble; undercut with sweeps at 4-inch depth
	1.61	1.56	0.24	1.68	0.56	0.05	0.04	0.04	0.08	0.08	0.03	Tillage pan present at 4-inch depth
	1.61	1.56	0.55	5.00[2]	1.29	0.35	0.32	0.51	0.18	—	—	Equipment failure at 6 hours; tillage pan present
2, Curry, NM	1.41	1.48	0.79	7.39	2.15	1.37	0.96	0.45	0.29	0.22	0.21	Clean tilled; in furrows of row-cropped grain sorghum; weak crust in place
	1.61	1.46	1.44	4.68	2.15	0.82	0.55	0.30	0.19	0.13	0.10	Clean tilled; in wheel track furrow or grain sorghum; weak crust in place
	1.25	1.46	0.67	5.86	3.27	2.28	0.90	0.63	0.40	0.27	0.21	Clean tilled; in furrow for grain sorghum; weak crust in place
3, Parmer, TX	1.32	1.44	0.94	5.78	2.25	0.74	0.73	0.50	0.33	0.21	0.19	Wheat-fallow; deep ripped with blade plow; 9.5-inch rain 2 weeks before test; soil at about 90% of field capacity; weak crust in place
	1.30	1.44	2.64	12.48	72.00	2.00	1.43	0.63	0.48	0.28	0.25	High initial infiltration, cause unknown
	1.65	*1.46*	*1.52*	*3.70*	*1.76*	*0.58*	*0.32*	*0.21*	*0.10*	*0.06*	*0.06*	*Wheel track furrow; weak crust in place*
4, Parmer, TX	1.45	1.45	0.12	5.46	0.72	0.65	0.56	0.42	0.37	0.24	0.14	Corn; packed furrow
	1.53	1.45	1.26	5.52	2.72	1.47	1.00	0.42	0.17	0.11	0.10	Packed furrow
	1.28	1.47	0.72	13.22	1.89	1.57	1.38	1.24	1.09	0.43	0.20	Soft, unpacked furrow
5, Castro, TX	1.51	1.45	1.30	7.16	2.06	1.09	0.80	0.67	0.44	0.20	0.10	Wheat stubble, underut; no crust present; initial stages of tillage plan development present
	1.32	1.45	1.22	8.50	1.87	0.78	0.56	0.41	0.56	0.34	0.25	No tillage pan present, no crust present
	1.66	1.55	1.24	3.72	1.16	0.53	0.33	0.26	0.10	0.14	0.07	Tillage pan present; no crust present
6, Castro, TX	1.82	1.68	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.04	0.01	Corn field following harvest; severe compaction caused by harvesting equipment operations
	1.45	1.47	0.28	9.94	1.16	0.89	0.57	0.57	0.39	0.25	0.14	Corn stubble, weak crust present
	1.33	1.47	0.50	9.94	1.22	0.77	0.68	0.61	0.60	0.51	0.21	No tillage pan; weak crust present
7, Hale, TX	1.58	1.53	1.59	6.19	2.40	1.33	0.71	0.56	0.29	0.14	0.11	Corn; tillage pan present; weak crust in place
	1.64	1.53	1.46	5.46	2.12	0.97	0.64	0.55	0.17	0.13	0.10	Tillage pan present; weak crust in place
	1.64	1.53	1.45	4.70	2.36	0.75	0.50	0.32	0.17	0.12	0.09	Tillage pan present; weak crust in place
8, Hale, TX	1.73	1.65	1.32	2.40	2.06	0.18	0.05	0.05	0.07	0.04	0.03	Cotton; dense tillage pan at 5-inch depth; moderate crust in place; severe compaction
	1.74	1.58	1.44	4.30	3.06	0.55	0.38	0.21	0.19	0.08	0.05	Cotton; dense tillage pan at 5-inch depth; moderate crust in place; severe compaction
	1.65	1.56	1.38	5.92	2.88	1.29	0.97	0.40	0.27	0.18	0.09	Cotton; dense tillage pan at 5-inch depth; moderate crust in place; severe compaction
9, Lubbock, TX	1.73	1.62	0.42	1.32	0.59	0.19	0.10	0.05	0.05	0.06	0.04	Grain sorghum stubble; disked, seeded to wheat; tillage pan present; severe compaction
	1.27	1.46	0.96	10.62	3.79	1.50	0.97	0.93	0.59	0.33	0.24	No tillage pan present
	1.76	1.66	0.34	1.43	0.62	0.34	0.23	0.14	0.05	0.05	0.04	Severe compaction at 4- to 6-inch depth
10, Lubbock, TX	1.28	1.45	1.50	10.73	3.06	1.45	1.20	0.84	0.47	0.35	0.27	Bulked surface; no tillage pan prsent; no crust prsent
	1.46	1.54	1.44	5.76	1.71	0.69	0.58	0.44	0.28	0.13	0.12	Bulked surface; thin tillage pan above Bt horizon; no crust present
	1.79	1.64	1.56	2.16	1.44	0.16	0.06	0.03	0.03	0.03	0.03	1.75-inch thick tillage pan above Bt horizon at 4- to 7-inch depth; no crust present
11, Crosby, TX	1.65	1.55	0.00	1.00	0.00	0.00	0.00	0.10	0.09	0.08	0.07	Soil wetted and stirred to disperse aggregates; test suggests wet crusted surface restricts infiltration and increases runoff
	1.15	1.60	1.50	6.20	2.29	0.85	0.47	0.35	0.33	0.20	0.14	Cotton; soil disturbed by plowing; site not pre-wetted
	1.15	1.67	2.26	4.68	1.62	0.48	0.42	0.28	0.11	0.04	0.08	Cotton; soil disturbed by plowing; site not pre-wetted
12, Crosby, TX	1.73	1.64	1.24	2.75	0.71	0.25	0.16	0.14	0.10	0.05	0.04	Cotton; preharvest; severe compaction; weak crust in place
	1.73	1.64	0.71	2.40	0.53	0.16	0.11	0.10	0.16	0.07	0.02	Cotton; preharvest; severe compaction; weak crust in place
	1.74	1.62	0.72	2.58	0.69	0.25	0.16	0.15	0.14	0.12	0.04	Cotton; preharvest; severe compaction; weak crust in place
Rangeland, Oldham, TX[3]	1.40	1.46	0.00	9.34	0.00	1.78	1.29	0.52	0.42	0.40	0.38	Initial water repellency caused by surface crust; about 80% grass cover
	1.35	1.46	0.00	9.46	0.00	0.00	0.00	0.43	0.50	0.56	0.45	Initial water repellency caused by surface crust; about 80% grass cover

[1] Density determined at the 4- to 7-inch depth.

[2] Estimated value so that relationships with other variables could be calculated.

[3] N.S.S.L. Rangeland infiltration/runoff research project site.

Infiltration rates dropped rapidly after 10 minutes in most cases. At 30 minutes, the greatest decline compared with that at 10 minutes was 97 percent at Site 3 where the rate was exceptionally high at 10 minutes. The two next greatest declines were 91 percent where a dense tillage pan was present at the 5-inch depth and 89 percent at Site 10 where a 1.75-inch thick pan was present. The least change (10 percent) occurred at Site 4 where the furrow was packed and the initial infiltration rate was among the lowest. Other low changes were 14 percent at Site 1 and 16 percent at Site 4. At these sites, the rates were among the highest at 30 minutes.

Further decreases in infiltration rates occurred throughout the remainder of the measurement periods, except where no measured infiltration had occurred in the early stages at Sites 6 and 11 (discussed above). The highest rate at 20 hours was 0.27 inch/hour at Site 10 where the soil was loose without a tillage pan present. Final rates of less than 0.05 inch/hour usually were associated with a tillage pan or other compacted soil condition.

High infiltration rates and amounts at 10 minutes and 20 hours as measured at some sites could cause excessive infiltration at the point of water application and, therefore, problems in obtaining uniform soil-water storage with furrow irrigation. Controlled smoothing and compacting the furrow can reduce this problem. Surge irrigation also helps to obtain more uniform water application under such conditions. The high infiltration rates should cause no problems with a well-managed sprinkler irrigation system.

Based on multiple linear regression analyses, infiltration rates and amounts at 10 minutes and 20 hours (the dependent variables) were related to few characteristics of the Ap, Bt1, and Bt2 horizons (Table 8) (only significant relationships are included in the table). Soil organic matter content, although included in the regression analyses, was not related to any dependent variable and is not included in Table 8. Infiltration amount and rate at 10 minutes were not related to any characteristic of the Ap horizon. Bulk density and clay content of the Ap, however, were related to infiltration amount and rate at 20 hours. Bulk density resulted in the highest ranking in both cases. In addition, sand content of the Ap horizon was related to the infiltration rate at 20 hours. Both relationships were highly significant (*P* = 0.001 level). Failure of infiltration amount and rate at 10 minutes to be related to any Ap horizon characteristics is attributed to the high variability of those characteristics and of measured infiltration at the sites.

Thickness of the Bt1 horizon was related (*P* = 0.05 level) to total infiltration at 10 minutes (Table 8). At 20 hours, total infiltration was related (*P* = 0.001 level) to Bt1 horizon bulk density. Infiltration rate at 10 minutes was not related to any Bt1 horizon characteristic, whereas infiltration rate at 20 hours was related (*P* = 0.001 level) only to bulk density of that horizon.

The only significant relationship involving Bt2 horizon characteristics and infiltration was between silt content and infiltration amount at 10 minutes. This relationship was significant at the *P* = 0.05 level.

For analyses involving bulk densities of the different horizons (Ap and Bt1 determined when infiltration was measured and Bt2 determined when initial sampling was done), infiltration amount and rate at 10 minutes were not related to bulk density (relationships not shown). At 20 hours, both the amount and rate of infiltration were related (*P* = 0.001 level) to bulk density of Ap and Bt1 horizons (Table 9). Bulk density of the Bt2 horizon had no effect.

Lack of effect of most soil horizon characteristics other than bulk density of Ap and Bt1 horizons on water infiltration variables suggests that management practices that change the density of those horizons will have a major impact on soil water relations of Olton soil. Because only infiltration amount and rate at 20 hours were affected, the effect of bulk density on soil water storage seems greatest with prolonged water additions, as with irrigation. The effect could be particularly critical with respect to furrow irrigation. High-density soil could restrict infiltration so that the profile is not fully recharged with water during a 'normal' period of water application. Under such conditions, mechanically loosening the soil may be needed to obtain greater infiltration. In contrast, infiltration may be excessive where the density is low. Such conditions may result in uneven distribution of water in the field, especially with furrow irrigation. It also can cause excessive water movement in soil beyond the rooting depth of plants, thus resulting in inefficient use of available water resources. Such excessive infiltration can be reduced by controlled smoothing and compacting of furrows to which irrigation water is applied, using surge irrigation, or using a sprinkler irrigation system. Because the water holding capacity of soil was around 4.00 inches at most sites, greater applications of water should be avoided in most case in order to make efficient use of water.

The measured water infiltration rates and amounts may not be representative of infiltration in all fields in the vicinity of the various sites. The major variability in infiltration may be due to past and current management on the fields such as tillage methods, crops grown, and residue management practices. As a result, producers should evaluate soil conditions on their farms and adjust their management practices accordingly. For example, if infiltration is low due to a tillage pan or other compacted soil condition, an operation such as chiseling, paratilling, deep

Table 8. Summary of multiple linear regression analyses associating total infiltration and infiltration rates at 10 minutes and 20 hours with Ap, Bt1, and Bt2 horizon characteristics of Olton soil obtained at 12 sites in Texas and New Mexico. Ranking are based on the standardized partial regression coefficients[1] and levels of significance based on the T-value follow the partial regression coefficient[2].

Soil horizon and dependent variable	Intercept	Independent variable[3] Sand	 Silt	 Clay	 BD	 HT	$R^{2,4}$
		Partial regression coefficients					
Ap							
Total infilitration in 20 hr - in	30.478	--	--	-0.189(2)**	-13.104(1)**	--	0.639***
Infiltration rate at 20 hr - in/hr	0.976	-0.003(3)*	--	-0.009(2)**	-0.309(1)***	--	0.746***
Bt1							
Total infiltration in 10 min - in	2.549	--	--	--	--	-0.116(1)*	0.169*
Total infiltration in 20 hr - in	46.641	--	--	--	-26.893(1)***	--	0.452***
Infiltration rate at 20 hr - in/hr	1.039	--	--	--	-0.606(1)***	--	0.455***
Bt2							
Total infiltration at 10 min - in	-0.460	--	0.061(1)**	--	--	--	0.217*

[1] Rankings are shown in parantheses immediately after the partial regression coefficients. Rankings in order from 1 (highest) to 3 (lowest).

[2] Levels of significance of partial regression coefficients are *(0.05), **(0.01), and ***(0.001). Independent variables included in the analyses for which the partial reression coefficients were not significant are identified by double dashes (--).

[3] Independent variables are % sand, % silt, % clay, BD (bulk density), and HT (horizon thickness).

[4] Coefficient of correlation. Levels of significance are *(0.05), and ***(0.001).

sweep plowing, or moldboard plowing may be needed to correct the problem. Where infiltration is excessive, corrective actions as discussed above may be needed to make more efficient use of available water resources and thereby achieve more economical crop production.

Implications for Management

Plant-Available Water (PAW)

The total amount of PAW retained in a profile was influenced by depth to the calcic horizon and by the water holding capacity of soil in different horizons. Total amounts ranged from 3.00 inches at Site 8 to 4.42 inches at Site 6 (Table 5). Therefore, a crop could extract about 32 percent more water from the soil above the calcic horizon at Site 6 than at Site 8. This is based on the assumption that both profiles were initially filled to capacity with water and that roots had explored and extracted water from the entire soil volume to the depth indicated (Table 5). Both conditions, however, often are not fulfilled under field conditions at all locations. The above comparison is for profiles with the lowest and highest PAW holding capacities. The differences in water holding capacities were less at other sites. When adjusted to a 48-inch profile depth, the PAW holding capacity ranged from 3.07 inches at Site 9 to 4.76 inches at Site 3, a difference of about 36 percent. Again, differences were less at other sites. Except for Site 9, these relatively small differences among sites suggest that no major differences in management are required at the different sites when only the soil water holding capacity is considered. However, factors other than water holding capacity influence the effectiveness with which a soil can be managed for crops to efficiently and effectively use available water resources to achieve optimum yields.

Based on PAW holding capacities (Table 5) and the measured infiltration rates (Table 7), soil above the calcic (Btk) horizon and to the 48-inch depth at most sites could be completely refilled with water (for example, by irrigation) in less than 20 hours, except where plowpans were present or other forms of compaction had occurred. If a plowpan is present or severe compaction has occurred, profiles would not be refilled even at 20 hrs. Excluding the extremely low amounts of infiltration at individual measurements at Sites 6 and 11 (Table 7), less than half of the required amount of water needed to refill the profile infiltrated the soil in 20 hours in some cases at Sites 1 and 9. In several other cases (at Sites 3, 5, 8, 10, and 12), infiltration at 20 hours was considerably less than the amount needed to refill the profile. Based on the infiltration rates prevailing at 20 hrs, additional time required to refill the profiles above the calcic horizon at Sites 1 and 9 would be about 62 hours. Less time would be needed where the deficit was less and the infiltration rates at 20 hours were greater. Usually, prolonging the time of irri-

Table 9. Summary of multiple linear regression analyses associating total infiltration and infiltration rates at 10 minutes and 20 hours with bulk densities of Ap, Bt1, and Bt2 horizons of Olton soil obtained at 12 sites in Texas and New Mexico. Rankings[1] are based on standardized partial regression coefficients and levels of significance[2] of the coefficients follow the rankings.

Dependent variable	Intercept	Independent variables[3] BD of Ap	 BD of Bt1	 BD of Bt2	$R^{2,4}$
Total infiltration in 20 hr - in	42.205	-0.874(2)***	-15.152(1)***	--	0.651***
Infiltration rate at at 20 hr - in/hr	0.925	-0.228(2)***	-0.304(1)**	--	0.722***

[1] Rankings are shown in parantheses immediately after the partial regression coefficients. Rankings in order from 1 (highest to 2 (lowest).

[2] Levels of significance of partial regression coefficients are **(0.01) and ***(0.001). Independent variables included in the analyses for which the partial regression coefficients were not significant are identified by double dashes (--).

[3] Independent variables are bulk density (g/cm^3) of the indicated horizons.

[4] Coefficient of correlation. Levels of significance are ***(0.001).

gation to fill the profile with water is not practical under prevailing conditions, and profiles at some sites normally would not be refilled with water, except during prolonged wet periods, or occasionally with repeated irrigations. Profiles usually would contain around 4 inches of PAW when irrigated for 20 hours (less time in some cases) and would, therefore, provide considerable water for plant use, although some profiles may not be filled to capacity.

Root penetration into soil varies with plant species and soil-water status. Sunflower roots grew into and used water from the calcic horizon on Pullman clay loam at Bushland. In contrast, sorghum generally uses water only from horizons overlying the calcic layer. Pullman and Olton soils are similar morphologically, and root proliferation would probably be similar in both soils. Therefore, although there are differences in water holding capacity and soil depth at the different Olton soil sites, management required (for example, irrigation frequency) to obtain similar yields with a given amount of water may be nearly identical at all sites, at least for crops that do not root deeply. The water application rate, however, may need to be varied because of infiltration rate differences. Crops that root deeply, tolerate stress, and deplete soil water to low levels would probably perform well on dryland and, if irrigated, would require less frequent irrigation than crops that root less deeply, are sensitive to stress, and fail to extract all PAW. Marked differences in water extraction by sunflower and grain sorghum have occurred on the Pullman soil at Bushland. When grown on adjacent fallowed plots, sunflower extracted more water from the soil at all depths than sorghum (Unger and Pringle, 1981). Similar differences probably would occur on the Olton soil.

Water Application

Furrow irrigation (Figures 10 and 11) is widely practiced on Olton soils, commonly with furrow lengths of one-quarter mile. Because of the generally low infiltration rates associated with high soil bulk densities commonly observed in clean tillage systems, it is believed that deep percolation of water can be controlled on this soil. Infiltration measurements at the various sites (Table 7), however, suggest that considerable deep percolation may be occurring at some sites. Consequently, to use irrigation water resources efficiently, a knowledge of the delivery capacity of the irrigation system and of the soil water storage capacity is required. Because of water quality concerns coupled with energy costs, deep percolation should be avoided. To evaluate irrigation practices, assistance is available through the water conservation districts and the Natural Resources Conservation Service. Where excessive deep percolation is a problem under furrow irrigation, set times may need to be shortened. Other alternatives are to use higher flow rates per furrow with shorter set times, smooth furrow bottoms for more rapid water advance, use the surge-irrigation system, or irrigate alternate packed furrows (Musick and Pringle, 1986). Additional water savings can be achieved by using underground pipelines rather than open ditches to convey water to irrigation furrows.

On sites where infiltration is low, tailwater runoff may be high from furrow irrigation unless cutback flow rates are used. Runoff may also occur where sprinkler irrigation is used. Some runoff water can be recycled through recovery systems, but building the systems and repumping the water increases production costs.

Pumping costs are higher for sprinkler systems than for furrow irrigation because of the extra head required to pressurize the system. Labor requirements for sprinkler systems such as center-pivot systems, however, are lower than for furrow systems. With sprinklers, water can also be applied at rates compatible with infiltration rates. In an ideally designed sprinkler system, water should be applied at a rate slightly less than the soil's infiltration rate. This reduces the potential for water collecting on the surface, which could result in runoff losses.

High pressure sprinkler systems apply water over a relatively large area, thus reducing runoff problems. High pressure systems, however, are energy intensive and may result in high water losses due to evaporation from falling droplets or fine spray or due to excessive drift on windy days. Low pressure sprinklers require less energy, but apply water over a smaller area (Figure 13). Evaporative losses should be lower, but runoff losses could be higher unless special provisions are made to reduce runoff. Lyle (1979) controlled runoff and used water efficiently with a low-pressure, precision application system that included furrow dikes (Figure 15). Another possibility would be to add booms with attached nozzles at right angles to the main frame of the sprinkler, thus applying water to a larger area at the same time.

Water Infiltration Variation

Data in Table 7 show up to a 22-fold variation among observations in cumulative infiltration at 10 minutes and even greater differences in infiltration rates at most times of determination. These variations seemed most closely related to bulk density of Ap horizons determined in the field when infiltration was determined, but cumulative infiltration and infiltration rates also varied considerably among measurements at a given site in some cases. Such variation resulted from local conditions such as surface crusting and soil compaction, which suggests that soil behavior on a given field near the sampling sites may differ considerably from that indicated by the data (Table 7).

Where infiltration is much lower than expected, a compacted zone such as a plowpan may be present.

Deeper-than-normal plowing or chiseling while the soil is relatively dry is a possible remedy for overcoming infiltration problems associated with plowpans or other dense soil layers. Another possible remedy is the use of reduced- or no-tillage cropping systems, which reduce soil compaction because of less traffic across the field. The adverse soil condition (plowpan or other dense layer), however, should be corrected before a reduced- or no-tillage system is initiated because those systems are not highly effective for correcting degraded soil conditions. Those systems protect the soil surface, decrease rates of runoff, and reduce surface evaporation losses because of crop residues retained on the soil surface (Figure 16). As a result, they help maintain a favorable soil condition once it has been established. However, when residues are limited and soil crusts are left undisturbed, the crusts can become stronger and thicker with time and infiltration rates may not be improved and may even be reduced. Based on the measurements, large variations in infiltration are possible at all sites on Olton soils. Where problems are suspected, appropriate corrective measures should be taken to increase infiltration where it is too low, or decrease it where excessive deep percolation occurs.

Crop Sequences

Wheat, cotton, grain sorghum, corn, sunflowers, sugarbeets, alfalfa, and vegetable crops such as potatoes (*Solanum tuberosum*) and onions (*Allium cepa*) are adaptable and grown in some part or throughout the area of Olton soils. Much of the grain produced in the region is stored in elevators, then transported to area feedlots or to seaports for export to foreign countries. Whether crops are grown continuously or in rotations depends on factors such as crop prices; water availability; fertilizer cost and availability; weed, insect, and disease problems; and producers' preferences. When irrigated crops that do not root deeply are grown continuously, some water generally moves beyond the plant's rooting depth and, therefore, reduces water use efficiency for crop production. Unless a deep-rooted crop is later grown, such water is lost for crop production purposes unless it eventually reaches the aquifer from where it could be pumped again. Recharge (return flow) to the aquifer, however, is limited in the region.

Water losses from deep percolation can be reduced by growing deep-rooted crops in rotation with shallower-rooted crops. The effectiveness of deep-rooted crops for extracting water from deep in the profile is improved when they are grown without irrigation or with limited irrigation. In either case, adequate water must be available throughout the profile so that root growth is not restricted by a dry zone in the soil. Limited irrigation is effective for crops such as wheat and grain sorghum that can tolerate some water stress, and especially when the soil profile is filled with water at the start of the growing season (Musick and Dusek, 1971; Schneider et al., 1969).

Tillage and Cropping Practices

Concern about the steady decline of water in the Ogallala Aquifer, which supplies the water used to irrigate Olton soils, and rising production costs have triggered an interest in conservation of irrigation water. As a result, more emphasis is being placed on conservation and use of precipitation for crop production. Studies conducted on Pullman soil, which is morphologically similar to Olton soil, can aid in understanding the effects of conservation practices on Olton soils.

Under dryland conditions, more water from precipitation was stored in soil and grain yields were higher where stubble mulch tillage instead of one-way disk tillage was used in continuous wheat or wheat-fallow cropping systems (Johnson and Davis, 1972). Other practices that conserved water and increased crop yields on dryland are conservation bench terraces (Figure 17) and level bench terraces (Jones, 1975; Jones and Hauser, 1975); narrow benches, narrow conservation benches, and large contour furrows (Jones, 1981); and furrow blocking (Clark and Hudspeth, 1976; Clark and Jones, 1981) (Figure 18). These practices retained potential runoff water

Figure 15. The LEPA (Low Energy Precision Application) irrigation system applies water to furrow-diked land at a low pressure, thus resulting in energy savings, precision water application, and reduced evaporation.

where it fell or retained it on part of the field, thus increasing the amount of water available for crop use. Little benefit was obtained with respect to reduced evaporation because residues produced by dryland crops (Figures 19 and 20) generally were not adequate to greatly reduce evaporation, even when all residues were maintained on the surface in no-tillage systems (Wiese et al., 1960, 1967). Use of no-tillage on dryland, however, results in water conservation equal to or greater than that obtained with stubble mulch tillage (Jones et al., 1994). This is because the thorough soil drying that occurs when tillage loosens and/or inverts the plow layer is avoided. As a result, less water must infiltrate a no-tillage soil than a tilled soil to provide an equal amount of stored soil water.

In contrast to the limited response to surface residues for increasing water storage from precipitation in no-tillage systems on dryland, major increases in water storage occurred when residues from irrigated wheat (Figure 21) were retained on the surface with no-tillage systems compared to working them into the soil with tillage (Musick et al., 1977; Unger, 1984; Unger et al., 1971; Unger and Wiese, 1979). The additional stored water decreased the amount of irrigation water needed for grain sorghum (Musick et al., 1977) and resulted in good growth (Figure 22) and yields of dryland grain sorghum (Unger, 1984; Unger and Wiese, 1979). In a study for which wheat residues (straw) were placed on the soil surface, water storage during fallow (from the time of wheat harvest until sorghum planting) and subsequent grain sorghum yields increased as surface residues increased from 0 to about 11,000 pounds per acre (Unger, 1978b). Dryland wheat in the region often yields only about 1,500 to 2,500 pounds of residue per acre at Bushland. In contrast, irrigated wheat often yields 4,000 to 6,000 pounds of residue per acre, and amounts of 10,000 or more pounds per acre have been obtained in some years (Unger, 1977; Unger et al., 1973).

The residue amounts produced by irrigated wheat are in the range that substantially increased water storage and grain sorghum yields (Unger, 1978b). When maintained on the soil surface, residues of irrigated wheat increased water use efficiency for crop production on Pullman soils. By inference, that should also occur on Olton soils. Subsequent crops (grain sorghum, corn, and sunflower) have been successfully planted into the residues of irrigated wheat crops (Musick et al., 1977; Unger, 1981, 1984, 1986; Unger and Wiese, 1979). While large amounts of residues may cause planting problems, very little trouble was encountered when crops were no-tillage planted on the undisturbed ridges between drill rows of the previous irrigated wheat crop that was planted on ridges and in furrows.

When wheat is flat planted, as with sprinkler irrigation, more problems may be encountered in planting the next crop by the no-tillage method, especially if definite row patterns are not maintained and the interval between crops is not

Figure 16. Corn planted by the no-tillage method in wheat residues. The residues retained on the surface reduce runoff, provide for rapid water infiltration, reduce evaporation, and reduce the chance for plant injury caused by wind-blown soil.

Figure 17. Conservation bench terraces are designed to keep runoff water on the land. Runoff from the natural sloping area is trapped on the leveled area, thus providing more water for more intensive cropping on the leveled area.

adequate to allow major decomposition of residues. Weed and volunteer crop plant control may also be more difficult. However, even with relatively large amounts of residues on the surface from flat-planted wheat, grain sorghum was successfully planted in residues by planting it in a row direction at right angles to the direction of the wheat rows (Unger, personal experience). Planting in a row direction other than that of the previous crop should result in satisfactory planting in most cases. Such planting avoids placing most seed on crowns of the previous crop, thus resulting in generally better seed-soil contact for improved germination and seedling emergence.

Benefits from surface residues result from greater total infiltration and less evaporation of water. Because of their generally greater water storage capacity, profiles at Sites 3, 4, 5, 6, and 11 may derive more benefit from surface residues than those at sites having less storage capacity. Soils with less capacity are more readily filled with water because less water is required, provided water infiltration rates are sufficiently high. The greater response to surface residues on Pullman soils at a deep site at Bushland compared with a shallower site near Lubbock was verified by Baumhardt (1980), who compared effects of disk tillage and no-tillage after wheat on water storage during fallow and subsequent growth and yield of grain sorghum. Because rainfall essentially filled the low-capacity profile with water with both tillage methods near Lubbock, sorghum yields were not different due to tillage. At Bushland, where the storage capacity was greater, grain yields of sorghum were greater with no-tillage than with disk tillage when the sorghum was not irrigated. With irrigation, sorghum yields were similar with both treatments.

A benefit from lower evaporation with surface residues is the longer time the surface layer remains wet enough to beneficially influence seed germination. Whereas rapid decreases in surface soil water content due to evaporation may cause poor germination on a relatively smooth bare soil, slower evaporation on mulched soils may result in favorable germination Surface residues also reduce warm-season soil temperatures, which can be an additional benefit with respect to crop establishment and early seedling growth (Allen et al., 1975).

Figure 18. Blocked furrows (with furrow dikes) retain water on the land, thus improving water conservation. Runoff occurs from open furrows (photo provided by O. R. Jones, USDA-ARS, Bushland, Texas).

Figure 19. The amount of residue produced by dryland grain sorghum generally is low and provides little protection of the soil surface in the region where Olton soils occur.

Ranching and Livestock Production

Ranching and livestock production are important agricultural enterprises on the High Plains. Native grasses cover about 228,700 acres, or 18 percent of the total land area of Olton soils. Most ranches are cow-calf operations, although stocker steers make up a large percentage of many herds. Usually, these stocker cattle are placed in nearby feedlots for finishing.

In many cases, forage produced on rangeland is supplemented by crop stubble and small grain. In winter, the native forage is often supple-

Figure 20. The amount of residue produced by dryland winter wheat generally is low in the region where Olton soils occur.

Figure 21. An irrigated wheat crop generally produces a large amount of residues (USDA-NRCS photo).

mented with protein concentrate. Creep feeding of calves and yearlings to increase market weight is practiced on some ranches.

The native vegetation in many parts of the area has been greatly depleted by continued excessive use. Forage production now may be less than half of the original production (Natural Resources Conservation Service, 1991). Range productivity can be increased by using management practices that are effective for specific soils and range sites.

Where climate and topography are similar, differences in type of climax vegetation grown and amount of dry matter produced on rangeland are related closely to the soil type present. For effective management of rangelands, relationships among soils, vegetation, and water supplies must be considered.

The typical climax plant community and the expected percentage of each species on a typical deep hardland range site are given in Table 10. The potential total annual dry matter production in favorable, normal, and unfavorable years is about 2,000, 1,500, and 1,000 or less pounds per acre, respectively.

Besides knowing soil properties and climax plant community, range management requires evaluating the present condition of the range vegetation in relation to its production potential. Range condition on a particular site is determined by comparing the present plant community with the climax plant community for the site. The more closely the existing community resembles the climax community, the better the range condition (Figure 23). The objective in range management generally is to control grazing so that plants at a given site are similar in type and percentage composition to the climax plant community for that site. Such management generally results in maximum dry matter production, water conservation, and erosion control. Sometimes, however, a range condition somewhat below the climax meets grazing needs, provides desirable wildlife habitat, and protects soil and water resources.

The major objective of management on most rangelands is to control grazing so that the types and

Figure 22. An excellent dryland grain sorghum crop on land where residues from the previous irrigated winter wheat crop were managed on the soil surface by using no-tillage methods.

Table 10. Typical vegetation on Olton soils (deep hardland range site).

Plant name		Percentage of annual production of dry matter
Common	Scientific	
Blue grama	*Bouteloua gracilis*	40
Buffalograss	*Buchloe dactyloides*	24
Sideoats grama	*Bouteloua curtipendula*	5
Western wheatgrass	*Agropyron smithii*	5
Vine-mesquite	*Panicum obtusum*	5
Silver bluestem	*Andropogon saccharoides*	5
Tobosa	*Hilaria mutica*	5
Other perennial grasses	—	5
Other perennial forbs	—	5

Figure 23. Range grasses near climax condition provide excellent grazing for cattle (USDA-NRCS photo).

percentages of plants that make up the climax plant community can become reestablished. Controlling brush and minimizing soil erosion by wind and water also are important objectives. Aids to good range management include adequate fencing so that different tracts can be grazed on a rotation basis and strategic positioning of water and mineral supplements so that livestock will visit different parts of the tracts during their daily quest for forage, water, and minerals (Merrill, 1983). If sound range management based on soil information and rangeland inventories is applied, the potential is good for increasing the productivity of rangelands.

Summary

With a land area of 1.26 million acres, Olton soils are among the major arable soils in Texas. A small area of Olton soils also occurs in eastern New Mexico. Olton soils occupy parts of fifteen counties in the Southern High Plains of Texas and two counties in eastern New Mexico. The area of Olton soils is bounded by the area of Pullman soils on the north and east, Yellowhouse Creek on the south, the Caprock escarpment at the High Plains-Rolling Plains boundary on the southeast, and Blackwater Draw extending from near Earth, Texas, to Portales, New Mexico, on the southwest. Olton soils occupy about 19 percent of the land within the counties of occurrence. Much of the remaining land is occupied by soils having similar morphology and occupying similar landscape positions as the Olton soils.

About 79 percent of the Olton soil area is cropland, 18 percent is rangeland, and the remainder is in towns, roads, and other nonagricultural uses. Irrigation is used on about 45 percent of the cropland. Major crops are cotton, wheat, grain sorghum, and corn.

To determine the variability of soil characteristics, Olton soils were sampled at 12 widely separated locations. The profiles were described in the field at sampling time, and samples were analyzed in the laboratory for sand, silt, and clay content; bulk density; organic matter content; $CaCO_3$ equivalent; pH; and cation exchange capacity. Soil water retention was calculated with previously established equations. Plant-available water was calculated from soil horizon thicknesses and water retention values. Water infiltration was measured at the sampling sites.

The thickness of profiles to the calcic horizon was variable. It ranged from 35 inches at Site 12 in Crosby County, Texas, to 48 inches at Site 4 in Parmer County, Texas.

Cumulative water infiltration amounts and infiltration rates at 10 minutes were highly variable and seemed more closely related to bulk density of the Ap horizon when measurements were made than to any other determined profile characteristic. Excluding the two determinations for which infiltration was extremely low due to soil puddling or compaction (at Sites 6 and 11), cumulative infiltration at 20 hours ranged from 1.32 inches at Site 9 in Lubbock County, Texas, to 13.22 inches at Site 4 in Parmer County, Texas. The low cumulative infiltration in 20 hours resulted from generally low infiltration rates from 1 to 20 hours after water application, probably due to past and present management on the field. Low infiltration for some individual determinations at some other sites generally was associated with a plowpan or other compacted soil condition.

Various measurements indicated that about 20 or fewer hours of water application would fill the profile with water (about 4 inches) at most sites; up to 82 hours would be needed at others. Applying irrigation water for more than about 20 hours is not practical because tailwater runoff and/or deep percolation losses become excessive.

Because of declining supplies of water for irrigation, water conservation has received considerable attention in recent years. Practices such as conservation-bench and level-bench terraces, contours, blocked furrows, and reduced- and no-tillage systems that conserve water from rainfall are applicable to Olton soils. These practices conserve water by reducing runoff, increasing infiltration, or reducing evaporation. Crop yields have been increased where these practices were used on Pullman soils and should give similar results on Olton soils because the Olton and Pullman soils are morphologically similar. Practices for conserving irrigation water include use of improved water application techniques, tailwater recovery systems, and reduced- or no-tillage farming.

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