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Minimum Tillage
In the Southwest

By

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Some tillage practices now used in the irrigated areas of the Southwest have little or no value; others may be harmful. This bulletin describes the beneficial and harmful effects of some common tillage practices and discusses means of minimizing necessary but compacting operations.
Summary

1. Tillage and traffic cause compaction on most soils.

2. Reduced pore space caused by compaction may reduce yields by decreasing water intake, air movement, and root penetration.

3. Overtilling increases production cost.

4. Compacted soil should be broken up, allowed to dry out if possible, and traffic over the soil kept to a minimum. A light harrowing between plowing and planting may be all that is necessary to attain a desirable seedbed.

5. Soil plowed below compacted layers is in an ideal condition for transmitting water into the plant root zone and for leaching salts.

6. Soil should be cultivated only when necessary to control weeds.
Effects of Farm Mechanization

EXCESSIVE TRAFFIC

The essentially complete mechanization of farms has not been accomplished without creating problems, especially on the irrigated farms of the Southwest. Mechanization has introduced implements that can cause serious soil compaction.

When the rubber-tired tractor, for example, was substituted for the horse, excessive traffic over the land ensued. Working the soil with modern equipment during seedbed preparation and cultivation compacts the soil, creating so-called tillage pans, which in turn reduce water intake, root penetration and air movement.

Slow water intake is considered by many irrigation authorities to be the primary problem associated with the management of irrigated land.

COMPACTION PROBLEMS

Compaction, a result of particle reorientation, can be caused by wind, water, and equipment traffic. Since it takes special practices to control wind, and the soil must be wetted throughout the root zone by irrigation for best production, effort must be directed toward reducing compaction caused by equipment.

This does not mean that we must return to the horse era. It is advocated, rather, that tillage practices be kept to a minimum and that those practices be used that are least destructive to soil structure.

The consequences of compaction are demonstrated in many ways. Some are:

1. The necessity to run water longer for each irrigation set.
2. Excessive waste of water and sometimes fertilizer from irrigation runoff at the lower end of fields.
3. Insufficient leaching of harmful salts.
4. Reduce root penetration.
5. Inability to store adequate quantities of water in root zone.
6. Unequal distribution of irrigation water.
8. Increased production costs.

Tillage - Its Meaning and Its Hazards

Tillage as considered in this bulletin refers to all of the mechanical manipulation of soil by man.

Certain tillage practices are necessary to incorporate crop residues into the soil; to "break-up" compact, residual soil masses; and to prepare land for irrigation. Preparing the seedbed, planting, cultivating, and other operations involving the application of fertilizer, insecticide, and weedicide further increase the traffic through the cultivated area.
Various tillage practices compact the soil at different depths in the soil profile, depending on the implement use. Such compact layers are referred to as pressure pans or "tillage pans."

A tillage pan is generally considered to be a relatively narrow band of soil whose particles have been pressed or oriented into a smaller volume. This band of compact soil generally is located just below the area of pressure application.

Tillage pans are usually found less than 10 inches deep; however, in newly leveled land or when "mudding-out" harvesting operations are used, deeper pans can be created. Plow shares, disk blades, cultivators and disk-harrows drawn through the soil create stresses that result in pans. These pans are more pronounced when tillage operations are repeated at the same depth. (See Figures 1 and 2 on page 7 at right).

Vibration of the soil, as well as direct pressure by some types of farm equipment also causes tillage or pressure pans. Regardless of how they are formed, tillage pans reduce air space, infiltration rate, and root penetration. (See Figures 3 and 4 on page 8).

MINIMUM TILLAGE DESCRIBED

Some tillage is unavoidable, but it can be minimized. The expression "rough tillage" is commonly used in the Southwest. It is usually associated with (1) plowing to a depth below compact layers and at a soil moisture content at which the soil will turn up cloddy, (2) irrigating, and then (3) using the least tillage possible to develop a seedbed.

FIGURE 1. Tillage pan 6 inches below surface restricts root growth of cantaloups in clay loam soil. Note mass of roots on top of compact layer; only a few roots penetrate the layer.

FIGURE 2. Cantaloups growing in clay loam soil, free from a tillage pan. Roots are distributed throughout the soil mass.
FIGURE 3. Soil compacted by a combination of tillage operations and irrigation water. Soil on left is a coarse sandy loam; soil on right is a silt loam.

FIGURE 4. Compaction reduces the rate of water movement through a soil. Dense compaction on this soil was between 6- and 11-inch depth.
Minimum tillage is a group of soil preparations in which the number of operations and trips over the field are fewer than the conventional practices. Minimum tillage does not imply that seeds should be planted in the clods, but a preplanting irrigation on clods will develop better soil tilth than working the soil while dry. (See Figure 5.)

MINIMUM TILLAGE
FOR ALL FIELD OPERATIONS

Plowing is perhaps the most important phase of tillage. The tillage required between plowing and seeding will vary with crop, size of seed, kind of soil, kind of equipment used, and the amount of soil moisture.
On many soils in the Southwest, the only period during the growing season that irrigation water will move freely into the soil is immediately after plowing and before additional tillage is undertaken. This preplant irrigation leaches out harmful salts, softens layers not opened by tillage equipment, and stores water for later use.

Cultivation and field operations that necessitate traffic with rubber-tired equipment—such as weed eradication, insect control, and fertilizer placement—aggravate the compaction problem. Breaking up compact layers and minimizing the number of trips over the soil are the keys in developing a soil-root zone conducive to plant growth.

**Tillage — Objectives**

**MAJOR OBJECTIVES**

A farmer should have two major objectives when he starts preparing the soil for planting: first, to break up impermeable soil layers, and second, to provide an adequate seedbed. If these two objectives are attained with a minimum number of tilling operations, the maximum favorable soil structure will be maintained at a minimum cost. How much tillage will be required, and the equipment that will be needed, will depend on the kind of soil, organic-matter content, crop, method of irrigation, time of year, size of seeds, salt concentration in soils, and soil moisture.

**Tillage Principles**

**PLOW AT DIFFERENT DEPTHS**

Continuous plowing or disking at a fixed depth causes tillage pans to form that inhibit root growth. Special tillage practices are necessary to control pan formation and eliminate pans already formed.

Excellent results have been obtained by plowing below pans on clay loam soils at Mesa, Arizona. This was followed by a preplanting irrigation (usually at least 1 foot of water), after which seedbeds were prepared by leveling clods—usually with a light harrowing. Seed such as small grain, sorghum, peas, corn or cotton were then planted. (See Figure 6.)

When small seeds such as carrots, beets, cabbage, or cauliflower are to be planted, a more precise tillage practice is required.

**ALLOW SOIL TO DRY THOROUGHLY TO ACHIEVE MAXIMUM INTAKE RATE**

Slow-drying, saline, Grabe silty clay loam soils on The University of Arizona farm at Safford, are plowed, harrowed, and planted to crops such as small grain or sorghum in dry soil. A heavy irriga-
FIGURE 6. Irrigating rough-plowed land without smoothing or breaking up clods.

tion (at least 1 acre-foot of water) is then applied. In a plowed status, this soil takes in water and leaches, even though the irrigation water is saline.

If the soil is worked from a cloddy to fine condition when dry, however, intake rates are reduced, preventing salts from being washed through.

CONSTRUCT FAVORABLE SEED BED

If furrow-irrigated crops are desired, the beds can be constructed on the plowed soil and then irrigated. Afterwards, harrows, clod removers, or rotary harrows are used to expose the moist soil on which the seeds are planted.

Minimum Tillage Pays

SAVINGS IN LABOR AND MACHINERY

Yields may not always be reduced immediately on some well-developed soils if excess tillage is practiced; however, the total cost of tillage operations will be high compared with minimum tillage. Minimum tillage pays, not only in eventual higher yield, but in immediate savings in labor and machinery.
BETTER WATER UTILIZATION

On some soils, excess tillage has decreased the infiltration rate to a point where water cannot be managed well enough to obtain high irrigation efficiency and still get adequate water into the soil to leach salts or to satisfy plant growth. Compacted layers cause the water to move over the soil faster. Thus, the water arrives at the end of the field faster, runoff starts quicker. The irrigator gets the mistaken idea that moisture deficiency in the root zone has been satisfied, and cuts the water off.

In effect, the moisture deficiency has not been corrected and water should be run longer. A better method is to maintain high infiltration rates by minimum tillage.

On other soils having compacted layers—such as sands—water penetration may be adequate, but the compacted layers restrict root development and thus reduce yield. Scalding may also occur if water is held on the land too long.

Research Shows Detrimental Effects of Compaction

EFFECTS ON CROP YIELDS

Alfalfa and Cotton

In 1954, a six-year rotation was set up on The University of Arizona farm at Mesa, Arizona, to test the effects of various tillage practices. The rotation consisted of four years of cotton and two of alfalfa. Two years of barley preceded the rotation. Tillage treatments were as follows:

1. Plow, irrigate, and plant.
2. Plow, disk, drag, irrigate, disk, and plant.
3. Plow, disk, irrigate, and plant.
4. Plow, irrigate, disk, and plant.
5. Plow, irrigate, disk, irrigate, disk, and plant.

Each plot was carefully leveled so it had no slope, and each received the same quantity of water. Though the time for water to penetrate varied, no plant scalding was observed. Differences between tillage treatments were due to factors other than quantity of water available for plant use.

Though no great differences in alfalfa yield occurred, the infiltration rates were considerably reduced by excessive operations. (See Table 1.) Intake rates on the minimum tilled plots, Treatment 1, remained higher throughout the two years of alfalfa in spite of considerable traffic during the harvesting operations.

Excessive tillage on short-staple cotton reduced lint yields an average of 131 pounds per acre for the years 1954, 1956, and 1957, (See Table 2.) The minimum-tillage plots not only yielded more cotton, but at least $10 per acre was saved in tillage expense.

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TABLE 1. ALFALFA YIELD AND WATER INFILTRATION RATE

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<th>Treatment</th>
<th>1958</th>
<th>1959</th>
<th>Mean</th>
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<td>1.16</td>
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<tr>
<td>5</td>
<td>0.31</td>
<td>9.51</td>
<td>1.16</td>
</tr>
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</table>

TABLE 2. YIELD OF LINT COTTON, MESA, ARIZONA

<table>
<thead>
<tr>
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<th>1956</th>
<th>1957</th>
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<tr>
<td></td>
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<td>Lbs/A</td>
<td>Lbs/A</td>
</tr>
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<td>1558</td>
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</table>

The minimum tilled Treatment 1 outyielded an average of Treatments 2, 3 and 5 by 131 pounds. This represents about $40 per acre. In addition, at least $10 per acre was saved in tillage expense.

* Hail damage affected yields

Soybeans

Another experiment was conducted at The University of Arizona Agricultural Experiment Station farm at Mesa on Laveen clay loam. The experimental field had been planted to lettuce in the spring, mudded out, then planted to soybeans. One plot was merely disked and another was plowed before planting.

The diskig treatment did not break up the residual compaction of the soil, and the pore space was 21 percent less in the 2- to 4-inch soil zone on the disked plot than on the plowed treatment. Soybean yield was reduced 36 percent from 1400 to 900 pounds by inadequate soil preparation.

Guar

Growth of guar on Laveen silty clay loam at The University of Arizona Valley Farm at Yuma varied from good to no growth, when pore space was reduced as much as 30
percent in the 6- to 9-inch zone. Very little growth occurred when the pore space was reduced 15 percent in the 3- to 6-inch soil zone.

Salt problems existed here and the compacted soil did not allow the salts to be properly leached, thus plant growth was reduced.

EFFECTS OF COMPACTION ON PHYSICAL PROPERTIES OF SOILS

During 1959 and 1960, 7,200 volume-weight measurements were made at The University of Arizona Experiment Farm at Mesa to evaluate the effects of tractor wheels on plowed soil.

For the two years, tractor wheels reduced the pore space an average of 8.5 percent in the 2- to 12-inch soil profile, and 13 percent in the 2- to 6-inch zone. The average final infiltration rate under wheels was 0.21 inch per hour, whereas non-wheel areas averaged 0.49 inch per hour.

Tillage Implements to Use on Irrigated Land

LEVELING

Irrigated lands generally are leveled in such a way as to expedite the movement of irrigation water. It is desirable that tillage equipment have the ability to maintain this originally designed degree of leveling. If so, leveling equipment is needed only when the design of the irrigation system is changed or a more precise leveling is desired to control water.

For example, if an area is irrigated on a grade of 4 inches per 100 feet, a furrow method of irrigation will control water without precise leveling. However, if border irrigation is to be used, minor leveling or floating may be needed to assure uniform distribution throughout a border.

The land plane shown in Figure 7 is a useful and essential implement when used as intended. This

![FIGURE 7. Land plane.](image-url)
equipment should be used only as a means of leveling land to aid in distributing irrigation water, and to erase small irregularities that develop with normal farming operations.

Its use should not be necessary more than once every 4 or 5 years. Excessive use results in additional soil compaction, but even more serious is soil structure deterioration due to the pulverizing action of the bucket-blade.

**PLOWING**

A **two-way moldboard** plow is shown in Figure 8. The principal advantage of this plow over the conventional one-way plow is that dead furrows can be eliminated. This plow will turn crop residues under, operate equally well in either direction turning the soil always in one direction, and will not take the field “out-of-level.”

The **two-way disk plow** shown in Figure 9 serves the same purpose and has the same advantage as a two-way moldboard plow.

Another implement that can be used in the tillage pan-breaking operation is a **ripper with sweeps**, shown in Figure 10. This ripper arrangement also has the advantage of keeping the cultivated soil surface level, although it cannot incorporate crop residue from the surface into the soil.

**One-way disk plows** are used extensively in many areas of the Southwest. They can break up plow pans and incorporate surface residue but, unfortunately, do not leave the soil surface in a level condition.
HARROWING

The disk harrow in Figure 11 is used mainly to pulverize crop residues on the soil surface before plowing. This operation helps maintain a level area. Pulverizing the residues aids in their even distribution and decomposition. The use of this equipment on plowed land pulverizes unnecessarily.

A spike-tooth harrow in Figure 12 is probably the least publicized but the best piece of equipment to use for seedbed preparation, after the tillage pan is broken. Since the harrow requires very little power, 20- to 30-foot widths can be pulled and only one set of wheel marks are involved to compact the soil.