

SOIL and WATER

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Field in San Joaquin Valley with areas of excessive salinity. (Photograph provided by Blaine R. Hanson.)

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SALT MANAGEMENT

Excessive salts in the root zone of the crop or in the irrigation water will reduce crop yield.

Excessive means concentrations are high enough to reduce yield -- unless special management practices are used.

How Can We Determine If Salinity Is Excessive?

Our present data on crop tolerance comes from Maas and Hoffman (U.S. Salinity Lab - Riverside) and is given in FAO-29 and in UC-Committee of Consultants' crop tolerance tables.

If the soil salinity EC_e exceeds the EC_e tolerance shown for 0% yield decrement in these tables, for the specific crop to be grown, the salinity is excessive and if the potential yield decrement is not acceptable, corrective management practices can be used.

To determine present soil salinity, the following is a suggested procedure:

1. Estimate the depth of rooting for the mature crop.
2. Take soil samples representative of each $\frac{1}{4}$ of the root zone (4 samples).

3. Determine saturation extract soil salinity, EC_e , for each quarter of the root zone.

4. Take the arithmetical average of the 4 root zone samples as representative of the soil salinity to which the crop is responsive.

For Example: Using tomatoes as the reference crop; from the crop tolerance tables (FAO-29), it can be seen that tomatoes can tolerate a soil salinity of $EC_e = 3.5$ mmho/cm with no more than a 10% yield loss.

If by soil analysis,

EC_e of top $\frac{1}{4}$ of root zone = 2.0,

EC_e of next $\frac{1}{4}$ of root zone = 3.0,

EC_e of next $\frac{1}{4}$ of root zone = 5.0,

EC_e of bottom $\frac{1}{4}$ of root zone = 7.0,

then the average $EC_e =$

$$\frac{2+3+5+7}{4} = 4.25 \text{ mmho/cm.}$$

From the tolerance tables, expected yield decrement for tomatoes grown at the soil salinity $EC_e = 4.25$ is expected to be between 10 and 25%.

If desired a more exact expected yield loss at a determined salinity level for a specific crop can be calculated using the equation

$$Y = 100 - b (EC_e - a) \quad \text{(from Maas and Hoffman)} \quad (1)$$

where EC_e = average soil salinity of the root zone,

a = threshold soil salinity representing the maximum root zone salinity that can be tolerated by the crop without loss in yield. (% yield decrement),

b = yield decrease (%) per unit increase in soil salinity (EC_e) as salinity increases above the threshold value (a). b can be obtained from FAO crop tolerance tables using the maximum EC_e^* value (equal to a theoretical 100% yield decrease) and the threshold value (a).

$$b = \frac{100}{\text{Max } EC_e - a} \quad (2)$$

For example: Crop = Tomatoes

Soil salinity by soil analysis,

$$EC_e = 4.2 \text{ mmho/cm}$$

Max $EC_e = 12.5 \text{ mmho/cm}$ (from tables)

$$a = 2.5 \text{ mmho/cm}$$

$$b = \frac{100}{12.5 - 2.5} = 10\%$$

Using equation (1)

$$\begin{aligned} Y &= 100 - b (EC_e - a) \\ &= 100 - 10 (4.2 - 2.5) \\ &= 83\% \end{aligned} \quad (1)$$

Expected yield for tomatoes at $EC_e = 4.2 \text{ mmho/cm}$ is 83% or a yield loss of 17%.

What Can Be Done If EC_e is Excessive?

1. Do nothing -- accept the probability of a reduced yield.
2. Preplant irrigate or leach to reduce salinity to allow for good germination and growth.

*Max EC_e is used in FAO-29. Max EC_{dw} is used in UC-Committee of Consultants.

$$\text{Max } EC_e = \frac{\text{Max } EC_{dw}}{2} \quad (3)$$

3. Increase the over-all seasonal leaching fraction to control salinity within crop tolerance.

4. Irrigate more frequently to maintain lower average salinity in the upper half of root zone. Less water should be used per irrigation.

5. Change crop to one with more salt tolerance. (See tolerance tables).

The Leaching Fraction (LF)

Salts are added to soils in the water applied. If no water leaches below root zones, salts will continue to accumulate and eventually reduce yields to zero.

If water percolates through the root zone -- at any time -- leaching is taking place. The part of the water that percolates below the root zone removes some of the applied salts. The ratio of the volume of water percolating below the root zone to the volume of water entering the soil is the LEACHING FRACTION (LF),

$$LF = \frac{\text{water out}}{\text{water in}} \quad (4)$$

The leaching fraction required to control salt and maintain root-zone soil salinity low enough to produce an acceptable yield of a specific crop is the LEACHING REQUIREMENT (LR). It depends upon the salt load of the applied water (EC_w) and the salt tolerance of the crop (EC_e). Satisfying the LR is easier on light textured soils and more difficult on heavy.

There are several ways to calculate a leaching requirement for a specific crop and a given water. The method recently suggested by Dr. Rhoades of the U.S. Salinity Lab (Riverside) is easy to use and we favor it.

$$LR = \frac{EC_w}{5EC_e - EC_w}, \quad (5)$$

where LR = leaching requirement

EC_w = salinity of applied water,

EC_e = soil salinity tolerated by the crop (tolerance values for 90% yield are suggested).

For example: If a 90% yield is acceptable (for tomato $EC_w = 3.5$) and salinity of applied water is $EC_w = 1.4$ mmhos/cm,

$$LR = \frac{1.4}{5(3.5) - 1.4},$$

$$= .09 \text{ or } 9\%$$

If 90% yield is not acceptable, EC_e needed for 100% yield is $EC_e = 2.5$,

$$LR = \frac{1.4}{5(2.5) - 1.4},$$

$$= .13 \text{ or } 13\%.$$

This means that 13% of the applied water must percolate below the root zone.

Question: How much water must be applied to be sure 13% percolates below the roots? This can be calculated from:

$$Aw = \frac{ET}{1-LR} - \text{stored water} - \text{effective rainfall}, \quad (6)$$

where

Aw = applied water,

ET = crop demand for water,

LR = leaching requirement,

stored water = water in soil at start of growth,

effective rainfall = rainfall entering the soil after start of growth.

For example:

ET = 30 inches,

LR = .13,

stored water = 6 inches,

rainfall entering the soil = 4 inches after start of growth,

$$Aw = \frac{ET}{1-LR} - \text{stored water} - \text{effective rainfall}, \quad (6)$$

$$= \frac{30}{1-.13} - 6 - 4$$

$$= 34.5 - 10$$

$$= 24.5 \text{ inches}$$

This says a seasonal application of 24.5 inches of irrigation water can be expected to result in 13% leaching or 4.5 inches of drainage water. Rainfall that enters the soil during or after the growing season is equally effective in satisfying a leaching requirement and is part of the leaching fraction.

Water Management Evaluation By Determining An Apparent LF

An irrigation water analysis along with analyses of soil samples taken from each $\frac{1}{4}$ of the root zone can be used to evaluate the effectiveness of the on-farm irrigation water management to control salinity by determining the apparent leaching fraction (an estimate of the amount of leaching actually occurring in the field).

Step 1 - take soil samples for each $\frac{1}{4}$ of the root zone and take arithmetic average of soil EC_e as for salinity

evaluation.

Step 2 - take representative samples of the irrigation water and determine EC_w .

Step 3 - use equation (5) (same as for LR)

$$LF = \frac{EC_w}{5 EC_e - EC_w} \quad (5)$$

For example:

$EC_w = 1.4$ mmho/cm,

soil $EC_e = 4.2$ mmho/cm,

$$LF = \frac{1.4}{5(4.2)-1.4}$$
$$= .7 \text{ or } 7\%$$

This $LF = 7\%$ can then be compared with the LR for tomatoes previously calculated using $EC_w = 1.4$ mmho/cm irrigation water and a 100% yield.

$$LR = \frac{EC_w}{5EC_e - EC_w} \quad (5)$$
$$= \frac{1.4}{5(2.5)-1.4}$$
$$= .13 \text{ or } 13\%$$

This says the apparent LF was 7%, whereas a 13% LF would have been required to control the salts and allow 100% yield. Applied water (A_w) was not adequate to control salts. Using equation (6) and the data of the subsequent example, we would presume that only 12.26 inches had been applied resulting in 2.26 inches of drainage.

$$A_w = \frac{ET}{1-LR} - \text{stored water} - \text{effective rainfall}, \quad (6)$$

$$A_w = \frac{30}{1-.07} - 6-4$$

$$= 32.26 - 10 = 22.26$$

$$\text{and } 22.26 + 10 = 32.26$$

$$32.26 - ET = 2.26 \text{ for leaching}$$

What Is A Normal LF?

A 15% LF seems to be about "normal" for planning purposes. The effect of LF on soil salinity EC_e resulting from use of an irrigation water with salinity EC_w can be evaluated -- again by using Dr. Rhoades' equation

$$LF = \frac{EC_w}{5EC_e - EC_w} \quad (5)$$

This equation can be re-written

$$EC_e = \frac{EC_w(1+LF)}{5LF}$$

then

$$@ 10\% LF, EC_e = EC_w \times 2.2$$

$$@ 15\% LF, EC_e = EC_w \times 1.5$$

$$@ 20\% LF, EC_e = EC_w \times 1.2$$

$$@ 25\% LF, EC_w = EC_w \times 1.0$$

$$@ 30\% LF, EC_e = EC_w \times 0.87$$

$$@ 35\% LF, EC_e = EC_w \times 0.77$$

$$@ 40\% LF, EC_e = EC_w \times 0.70$$

This says that increasing the leaching fraction reduces the soil salinity accumulating from the salts applied in the water.

Or, it says that saltier water can be tolerated by the crop if the water

management is such that LF is increased.

If all else fails and salts cannot be controlled within tolerance of crop, change crop to one more tolerant of the conditions (refer to crop tolerance tables). The crop tolerance tables of FAO-29, and U.C. assume a 15% LF where water $EC_w \times 1.5 \approx EC_e$ of soil.

-- Robert S. Ayers

TAKING THE STICKY OUT OF CLAY

Is it feasible to add sand to a clay soil to create a soil that will work more easily and take water better? The question arises every now and then. The answer is yes, maybe, or no, depending on how well you can cope with the following problems:

1. The large amounts of sand required.
2. The texture of the resulting mix.
3. The particle size of the sand.
4. The difficulty of mixing.
5. Creation of an interface below the sand modified layer.

Amount of Sand Required

Table 1 gives the amounts of sand required to create sand/soil mixtures in proportions of 1:2, 1:1, and 2:1. The amounts of sand required are tremendous, particularly if a large area is involved. On a field scale, the only economically feasible way to change a soil texture is if the sandy soil can be brought from nearby with land leveling equipment, or can be brought up from the subsoil by deep plowing. If the sand has to be trucked in, the economics will kill

you in a hurry. What about a garden or landscaping project? You can afford to do some things here that would be out of the question for a field crop. Let's look at the other problems.

Texture of the Resulting Mix

Even if it is economically feasible to add sand to a soil, you may not necessarily end up with an ideal soil texture. Take a look at Figure 1 to see what happens to six soils when sand is added in the proportions given in Table 1. The soils shown are taken from analyses published in soil survey reports as shown in Table 2.

When you add sand to each one of these soils, the resulting mix (Fig. 1) will fall somewhere along the line between the original texture and the 100% sand corner. As you move down each line from the letter, the first dot represents a 1:2 sand:soil mix; the second dot a 1:1 mix; the third dot a 2:1 mix.

Notice that with soils A, B, and C, adding sand will never make a loam soil. A 1:1 sand soil mix will be a sandy clay loam, still a sticky soil with less than ideal properties of friability and water penetration. A 2:1 mix will finally yield a sandy loam, but only at a considerable cost and effort in adding a great deal of sand.

Soils D, E, and F will make loams with a 1:2 sand:soil mix and sandy loams with 1:1 or richer sand:soil mixes. So it appears that silt is good for something, after all, since you need a certain amount of it to make a loam soil.

Particle Size of Sand

You do not want to use a coarse or

TABLE 1

Weight of sand required per 6" depth of new soil mix

<u>Soil mix</u>	<u>per 1000 sq. ft.</u>	<u>per acre</u>
1 part sand, 2 parts soil	15300 lbs	333 tons
1 part sand, 1 part soil	23000 "	500 "
2 parts sand, 1 part soil	30600 "	667 "

TABLE 2

<u>Ident.</u>	<u>Soil</u>	<u>County</u>	<u>Clay</u>	<u>Silt</u>	<u>Sand</u>
A	Porterville clay	Fresno	54	26	20
B	Merced clay	"	48	40	12
C	Capay silty clay	Yolo	46	46	8
D	Sunnyvale silty clay loam	Santa Clara	35	55	10
E	Wyo silt loam	Glenn	24	52	24
F	Tehama silt loam	"	18	70	12

washed sand. These clean sands have a limited range of particle size and probably no silt. It would be better to use a "dirty" sand, which would have a mixture of medium, fine, and very fine sand, and also it wouldn't hurt if it contained considerable silt, particularly if you were going to mix it with soils A, B, or C.

Difficulty of Mixing

Just spading or rototilling the sand in with the clay will not form a uniform texture immediately. In fact, it may take several years of annual tilling before the sand grains are intimately and uniformly mixed with the clay. It may still be a better medium than the original soil as far as water penetration and workability

are concerned, but there will be small interfaces within the soil fabric that may affect root growth.

Creation of an Interface Below the Mixed Soil

The clay below the mixed layer will still have a low rate of water infiltration. If the modified surface soil takes water rapidly, there may be a tendency to apply more water than can readily be absorbed by the subsoil, leading to a perched water condition above the clay below. Therefore, careful management of water applied to the modified surface soil is imperative. If care is not taken, roots at the interface may suffocate from lack of oxygen, or may be attacked by water molds and die.

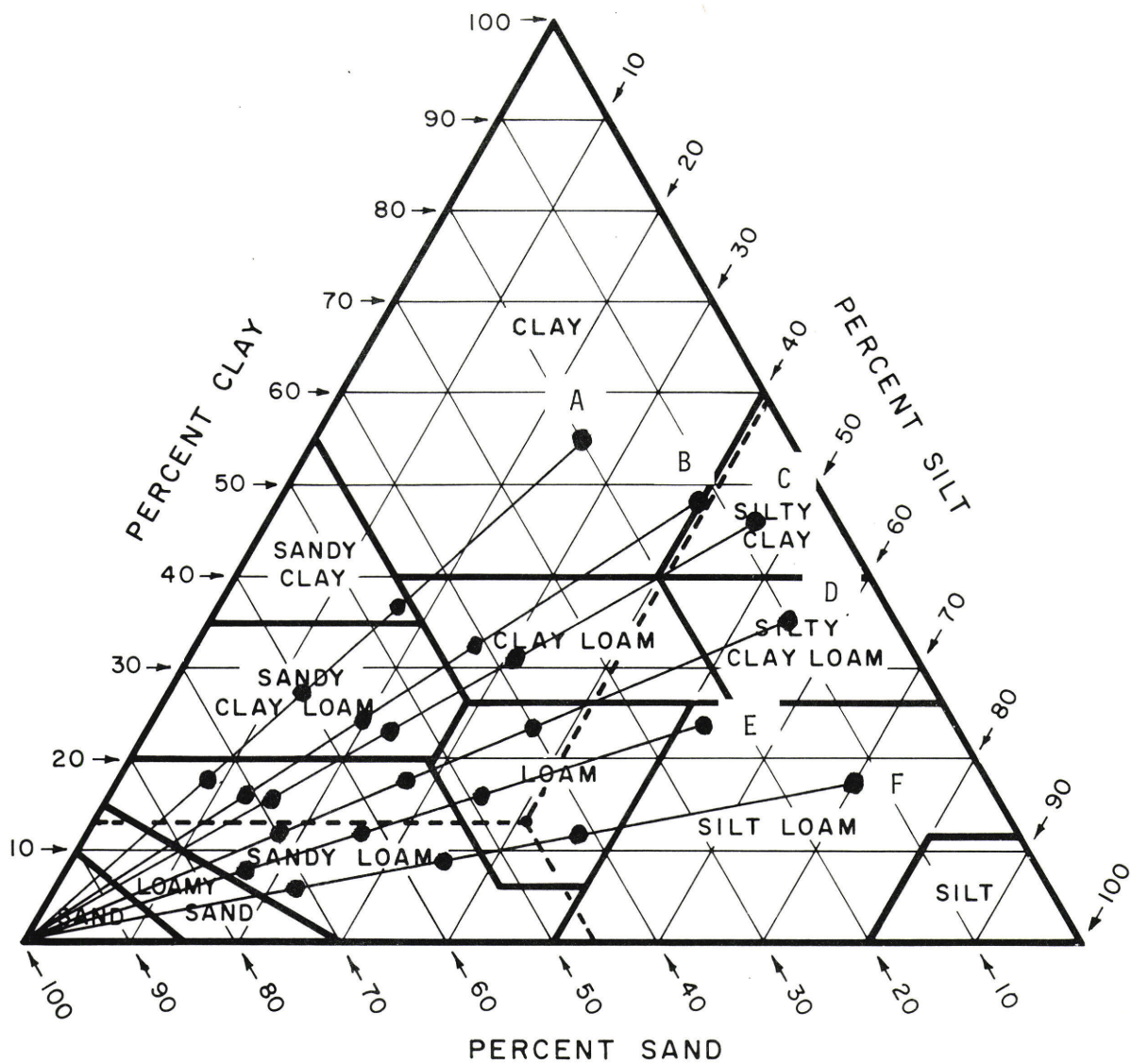


Figure 1. Soil textural triangle.

Putting Some Gumption into Sand

Occasionally the reverse question is asked: can you add clay to a sandy soil to increase its waterholding capacity and improve its nutritional potential? Most of the problems already discussed also apply to this situation. However, it may not require as much clay to improve a sandy soil as it does sand to improve the clay soil. Refer again to Figure 1 and work backwards up the lines from the 100% sand corner. If you were to add one part of any of the soils shown to two parts of your 100% sand, the resulting mix would be a sandy loam with a significant improvement in water and nutrient holding capacity. But most sandy soils are not 100% sand to begin with; they already contain small amounts of silt and clay. So your 1:2 soil:sand addition will take you further up the line, perhaps approaching a loam or sandy clay loam, depending on which fine textured soil you mix with your sand. Again, the siltier soils, D, E, and F look preferable to mix with sand.

To summarize then, for modifying the properties of either clays or sands:

1. A large quantity of added materials is required. These amounts may be feasible for a garden or landscape project, but not on a large acreage unless the sand or clay can be hauled by carryall from nearby or brought up from the lower soil profile by deep plowing.
2. Find out the particle size distribution of your original soil so you can arrive at a loam or sandy loam in your final mix. You may need to enrich the proportion of silt in order to stay away from the sandy clay loam box.
3. Use an unwashed sand with some fines in it to modify a clay. Use a

silt loam or silty clay loam to modify a sand.

4. Mix as thoroughly as possible without destroying soil structure. Subsequent annual tillage will improve the uniformity of the mix.

5. Irrigate frequently and with light applications to avoid perching water above the clay (or sand) interface below the new soil mix.

-- Bill Wildman

RESERVOIR AERIAL PHOTOS

Most of California's reservoirs are now filling nicely, after having reached historically low levels during the fall of 1977. We caught those low levels in aerial photographs in both color and black and white. Copies of color slides or black and white 8 x 10 prints may be ordered from Visual Aids, University of California, Davis, CA 95616.

A complete index and order form of all reservoir aerial photos taken in fall 76 (19 reservoirs), spring 77 (146 reservoirs) and fall 77 (120 reservoirs) may be obtained by writing or phoning:

Bill Wildman
LAWR: 169 Hoagland Hall
University of California
Davis, CA 95616

(916 752-2532)

-- Bill Wildman
-- Jack Clark

WELL AND PUMP REFERENCES

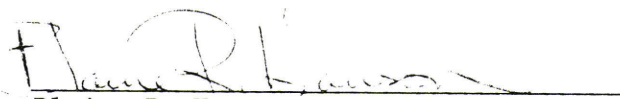
During the recent Soil and Water Unit training sessions, a request for references on wells and pumps was made. A good reference book on this subject is Ground Water and Wells, written and published by Johnson Division, UOP, Inc. This book contains practical information on the design, construction and maintenance of well and pump selection along with some basic theory on groundwater flow. It can be obtained from the UCD Bookstore for \$13.90 (including tax and shipping. The address is:

UCD Bookstore
University of California
Davis CA 95616

Attention: Book Dept.

A second good reference is the soon-to-be-published Experiment Station publication titled Water Wells and Pumps: Design, Construction, Operation, and Maintenance by Verne H. Scott and Joseph C. Scalmanini. Estimated date of publication is April 1, 1978.

-- Blaine R. Hanson



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