

23rd California Fertilizer Conference

March 20-21, 1975

MANAGING SALINE AND ALKALI SOILS

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Broad areas of California, Particularly the low rainfall portion, are occupied by both saline soils and alkali soils. In order for these soils to become intensively farmed they must be reclaimed.

Saline soils and alkali soils are two different problems, although they may be found together.

A saline soil is one which has a soluble salt content great enough to prevent or seriously reduce plant growth. These salts may be native to the soil or they may come from fertilizers or more commonly, from irrigation water. The reduction in growth is roughly proportional to the amount of soluble salt present.

The pH of the soil is not excessively high -- usually less than 8.2.

The physical properties of saline soils are about the same as non-saline soils of the same texture. Soils which are extremely saline may actually be very soft and fluffy.

Alkali soils, on the other hand, are more complex. Alkali soils are soils which contain sufficient exchangeable sodium to interfere with the growth of most crops. Exchangeable sodium is chemically attached to the clay in the soil and can only be removed by being replaced by or exchanged for calcium or some other cation.

There is some exchangeable sodium in most soils--but when sodium makes up 15 percent or more of the exchangeable cations it is considered to be an alkali soil.

The saturated paste of an alkali soil usually has a pH greater than 8.5. As the percent of exchangeable sodium increases, the soils become dispersed and less permeable to both water and air. The soils develop hard clods when tilled so that a good seedbed is difficult to prepare.

Since the term "alkali" is often used for both saline and alkali soils I prefer to use the term sodic for these high sodium soils.

Where a sodic soil also has excessive soluble salts, it is called a saline-alkali soil. Many virgin salt-affected soils are saline-alkali soils.

Reclaiming Saline and Alkali Soils

It is theoretically possible to reclaim any saline or alkali soil but it may not be economically feasible to do so. Soils with very high clay content or

those with compacted or cemented subsoils may best be left to minimum uses such as pastures and wildlife refuges. However, before it is practical to reclaim any salt-affected soil a grower must have:

1. An ample supply of good quality water.
2. Good surface and subsurface drainage.
3. Adequate financing to complete the job.
4. Patience.

Water

Not all well water is suitable for irrigation over a long period of time. Some wells yield water high in total salts, some contain excessive sodium, carbonates, and bicarbonates which may create alkali (sodic) soils. Waters relatively high in calcium and magnesium salts will on the other hand, be desirable if the soil contains excessive exchangeable sodium.

Other waters may contain toxic amounts of boron, lithium, or other ions.

Before any reclamation is contemplated the irrigation water should be analyzed by a reliable laboratory and the results interpreted by some competent person. With careful management even some marginal waters may be used.

There must be enough water available so that the excess salts can be removed from the root zone.

Drainage

Both surface and internal drainage must be adequate. This requires well graded land and perhaps deep ripping to break up cemented or compacted layers. Salts are washed through the soil, not off the soil.

Financing

If you don't have financing to complete the job, don't start. We've seen too many people get half way through a well planned job only to go broke and let someone else finish the job with little further expense.

Patience

Don't try to plant permanent crops which require a high investment until you've been able to produce good yields of grain, alfalfa, pasture, or other less intensively farmed crops.

For the first year at least you should be content to take your profit as better land rather than as cash return from a crop.

Reclamation

What about reclaiming these soils? If your soil is saline only, all you need to do after you have met the four conditions outlined earlier, is to grade the land and irrigate.

It takes roughly one foot of water per foot of soil to remove 80 percent of the salts from the top foot of soil. It takes about twice that amount to remove 90 percent of the salt. Experience has shown that frequent light irrigations or sprinkling is more efficient than continuous flooding.

Whether a soil is sandy or fine textured has little to do with the amount of water needed but it will have a bearing on the time it takes to complete the job.

Barley or some other relatively salt tolerant crop which is not furrow irrigated usually can be grown after the initial leaching.

Alkali and Saline-Alkali Soils

Nearly all virgin alkali soils are really saline-alkali. For this reason they will be discussed together.

After the land has been prepared, sprinkle irrigate or throw up some temporary borders and irrigate once or twice until the soil seals up and refuses to take water. This will remove much of the excess salt and reduce the amount of soil amendment needed.

The soil amendment chosen is then applied and worked into the top few inches of soil. Again the land should be irrigated at least once. Now a crop relatively tolerant to salt and alkali such as barley, should be planted and farmed in the usual manner. After harvest more of the soil amendment should be applied only to the bare and weak spots in the field, worked into the soil, irrigated, and another tolerant crop planted as soon as possible. This spot treating should be continued until the field is sufficiently productive to warrant more intensive farming.

Excess sodium attached to the alkali soil particles must be replaced by calcium. This may be supplied directly by adding gypsum, a soluble calcium salt. Calcium also may be supplied by dissolving the lime (calcium carbonate) in the soil with acid or some acid forming material. Amendments commonly used are sulfuric acid, sulfur, or lime sulfur.

The choice of amendment depends upon relative cost, the temperature of the soil and the speed of reclamation you are willing to pay for.

Gypsum can be used on any alkali soil, at any soil temperature. It only needs to be worked into the top few inches of soil and irrigated. It works almost immediately after wetting.

Sulfur or lime sulfur is slower to react. It must be worked into the soil where it is converted into sulfuric acid by microbial activity. This requires that the soil be moist and the temperature be above 60° Fahrenheit. The acid thus formed dissolves the lime present in practically all alkali soils to form calcium sulfate (gypsum).

Sulfuric acid will react immediately with the lime in the soil to form calcium sulfate which brings about the reclamation and may be used at any temperature.

The following table shows the relative values of the common soil amendments used in alkali reclamation.

<u>Amendment</u>	<u>Pounds Required to Equal 1 Ton Gypsum</u>	<u>Relative Value Applied to the Soil</u>
Gypsum (100%)	2,000	1.00
Sulfur (100%)	372	5.38
Sulfuric Acid (93.2%) 66° Baume'	1,223	1.64
Lime Sulfur (24° sulfur) 32° Baume'	1,550	1.29

All we do when we reclaim either a saline or an alkali soil is to reverse the process by which it was formed. These salt-affected soils were not this way when they were deposited in their present location by streams. They were nearly neutral soils and became saline or alkali by having been subjected to waters of poor quality either from a water table below or by deposition on the surface. The salts in these waters were concentrated by transpiration and evaporation resulting in the development of salt affected soils.

Are we now developing saline and alkali soils by our irrigation practices? It could be that we are. Mankind does not have a very good track record when it comes to maintaining irrigated agriculture over a long period of time.

It is not likely that we are developing saline soils in areas with adequate surface and internal drainage. We are more than likely using more water than is necessary to prevent excessive salt buildup.

Bernstein and Francois (Ref. 1) have done some excellent work to show that we can use much less water for salinity control than we used to think was needed.

If we used only the water required to prevent excessive salinity in the root zone, we could reduce the amount of water and salts which passes below the root zone to enter streams and drainage basins. This excess leaching also may cause rising water tables at the lower ends of the alluvial fans bringing with it severe salinity and water logged soils. We need only to look at the Salton Sea and parts of the San Joaquin Valley for striking examples.

I think most people understand and appreciate the dangers of encroaching salinity. The Bureau of Reclamation and various irrigation districts are doing a good job of encouraging growers to reduce excessive leaching, hopefully without causing any excessive salt buildup.

I'm more concerned with the accumulation of exchangeable sodium or the development of alkali soils than I am about salinity.

This discussion on the possibility of creating sodic soils is based upon the excellent research work published by the U. S. Salinity Laboratory at Riverside, California over the past several years.

Using these findings and the chemical analyses of some of the waters commonly used in the San Joaquin Valley, we come up with figures which may give us some real concern for the long run.

Let's take an actual analysis of a water which is representative of a large number of wells being used in the San Joaquin Valley for irrigation.

The Electrical Conductivity of this irrigation water (EC_{iw}) is 0.60 mmhos/cm. We don't consider that we have a salinity problem if the EC_{iw} is below 0.75. It has an Adjusted Sodium Adsorption Ratio (Adj-SAR) of 5.8. Anything below 6.0 is not considered likely to create problems. Suppose we decide to irrigate beans, a crop which is very salt sensitive. This means that we would need to provide greater leaching than would be required for cotton, barley, sugar beets, or some more salt tolerant plant.

According to the best data available the EC of the drainage water (EC_{dw}) could be ~~12~~ mmhos/cm. The Leaching Fraction (LF) would be:

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$$LF = \frac{EC_{iw}}{EC_{dw}} = \frac{0.60}{12.0} = 0.05 \quad \text{or we}$$

would only need to use 5.0 percent excess water to maintain a safe salinity level as far as growing beans. This would assure us that salts would never be a problem.

If we now use the formula developed by J. D. Rhoades (Ref. 2) for estimating the exchangeable sodium at the bottom of the root zone (ESP_b)* we arrive at an exchangeable sodium percentage of 17.5. This water, remember, is considered water of good quality. This may not be toxic to plants but it would damage the soil structure and probably reduce the infiltration rate.

Let's take another water which is actually being used for drip irrigation on citrus. One of the strong points of drip irrigation systems is the water savings -- you only need put on enough water to satisfy the plants' needs and enough leaching to prevent the buildup of excessive salts. This water has an EC_{iw} of 0.75 mmhos/cm. an Adj.SAR of 12.0. Citrus can tolerate an EC_{dw} of 16 mmhos/cm. Hence, to irrigate without creating a salinity problem we need to apply:

$$LF = \frac{EC_{iw}}{EC_{dw}} = \frac{0.75}{16.0} = 0.047$$

*

$$ESP_b \approx \left[\frac{y^{1+2LF}}{\sqrt{LF}} \right] \text{ Adj-SAR}$$

or about 5 percent over the evapotranspiration needs. Using this we arrive at an ESP_b of 36 percent! Even if we apply 10 percent extra water, the ESP_b would be 25 percent. (See fig. 1). If the research findings are as accurate as I believe they are, we could eventually be in real trouble.

Fortunately most growers, except those with drip irrigation systems, are using more than 10 percent excess water and are thus avoiding most of these problems. However, some irrigation districts are encouraging and may some day require growers to use less water. If they are successful in getting growers to use only enough water for salinity control, we may develop high sodium in the subsoil.

Figure 2 shows what the leaching requirement would be if you wish to maintain an ESP_b of 10, 15, or 20 with various waters.

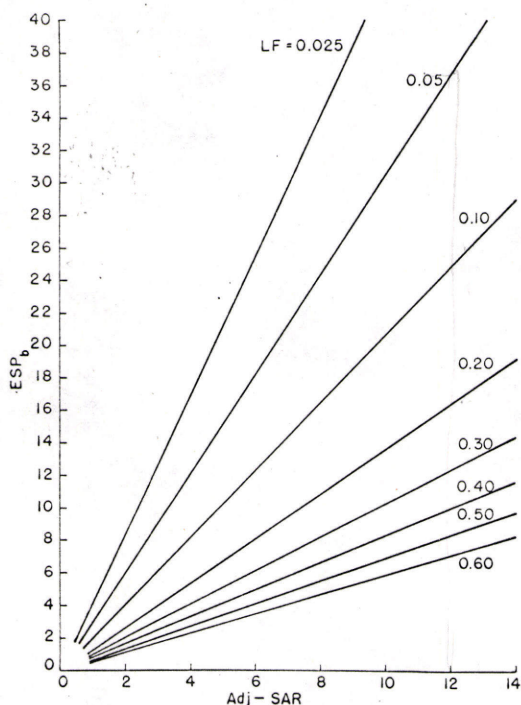


Figure 1. The Exchangeable Sodium Percentage at the bottom of the root zone (ESP_b) as affected by the Adjusted Sodium Adsorption Ratio (Adj-SAR) and selected Leaching Fractions (LF).

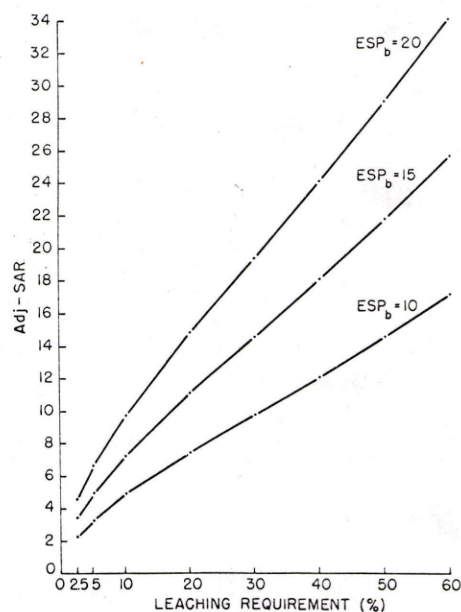


Figure 2. Leaching requirement to maintain Exchangeable Sodium Percentage at the base of the root zone (ESP_b) of 10, 15, and 20.

Minimum leaching for salinity control could lead to increasing the exchangeable sodium in another way. Many of the irrigation waters we are obliged to use have more carbonate plus bicarbonate than they have calcium plus magnesium. In other words, they have a Residual Sodium Carbonate (RSC). This concept of RSC is now out of fashion and the role of carbonates is presumed to be accounted for in the adjusted SAR. I wonder if we have not abandoned the RSC concept without completely evaluating all its facets? With common irrigation methods, the top several inches of the soil are allowed to become almost air dry before the next irrigation. When the irrigation water has an RSC, lime (calcium carbonate) is precipitated from the soil solution. When all the calcium in the irrigation water is precipitated the remaining carbonate and bicarbonate removes the exchangeable calcium from the soil and precipitates it as lime. This may happen in waters with high RSC when the soils are still moist and above the wilting point.

In some areas of the San Joaquin Valley this problem is so severe that the only growers who are successful are those who apply annual applications of gypsum to the soil. They are, in effect, reclaiming the top few inches of the soil each year.

Where the excess carbonate and bicarbonates are being applied, we do not reach a "steady state" such as we get with salinity control but instead the removal of exchangeable calcium from the soil is cumulative until the soil becomes unmanageable. This situation is not theoretical but has been observed many times.

I'm not saying that we should not reduce the proportion of water we are using for leaching below the root zone. I'm sure we have wasted some in the past and have brought about areas of saline soils and high water tables. What I am saying is, let's be very careful about jumping on the bandwagon of greatly reducing the leaching until we've had an opportunity to fully evaluate all of the side effects. Most people understand the need for saving water and reducing the salt load of our streams and drainage ways -- but I'm afraid they don't fully consider the problem of exchangeable sodium.

References -

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