SOIL SALINITY PROBLEMS IN SHORELINE AREAS OF HAWAII

Cooperative Extension Service
University of Hawaii
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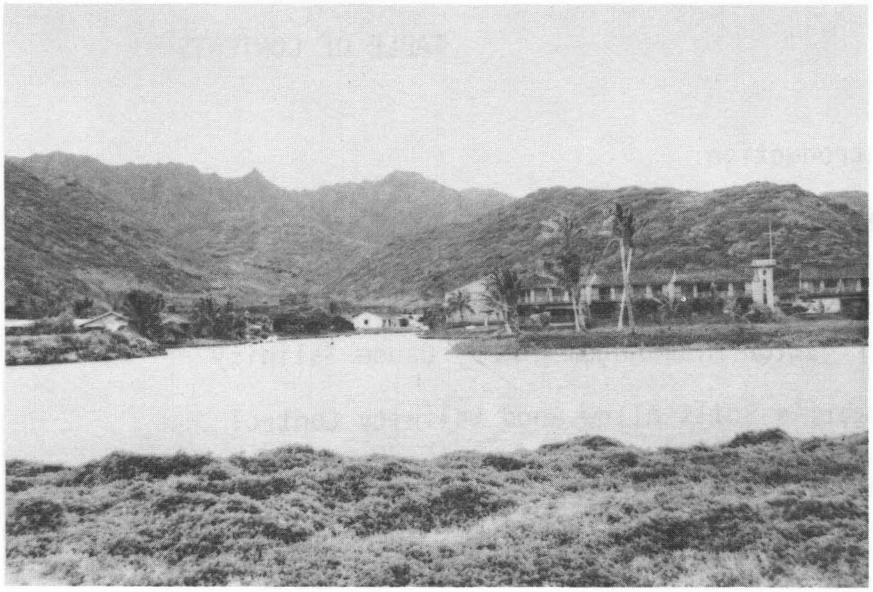

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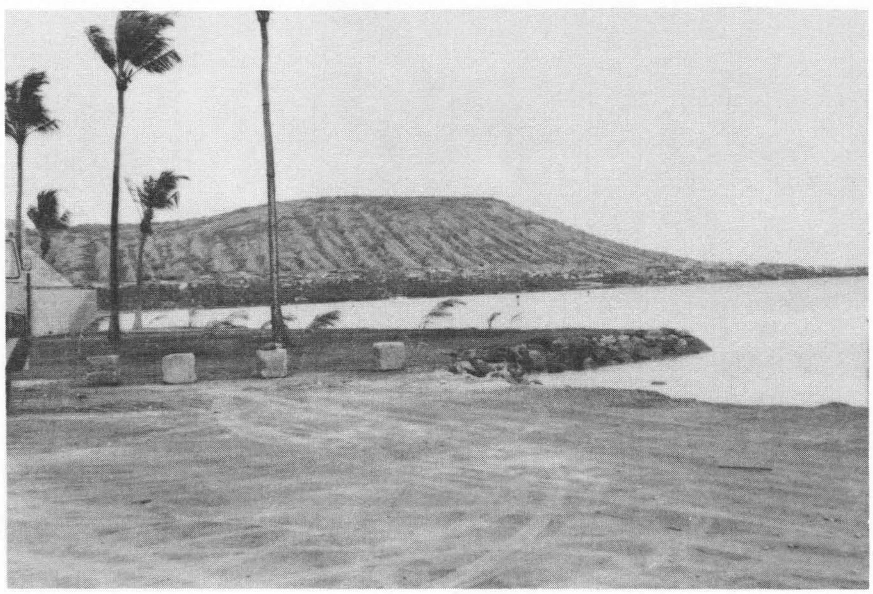

Figure 1. Shoreline residential areas (a) or recreational developments (b) are most subject to soil salinity hazard in Hawaii.

Introduction

Soil salinity is detrimental to plant growth in certain shoreline areas of the Hawaiian Islands and, consequently, a threat to the beauty of residential, recreational, and commercial developments. There are, however, methods of preventing or minimizing the danger of salt accumulation. Soils may become saline from natural causes such as floods, impaired drainage, wind-sprayed ocean water, and evaporation of salty ground waters. In recent centuries vast areas of saline soils have developed from man-made causes such as mismanagement of irrigation waters. In Hawaii, salt problems occur in soils of some shoreline areas due to man-made causes. For example, the soil may be part of a salt-laden deposit that was dredged from the ocean bottom during construction near the shore.

What Is Soil Salinity?

Soil may be affected by any salt present in a soluble or "free" form. For instance, inorganic fertilizers are salts. The soil to which they are added may be regarded as salt-affected until the fertilizers are used by the growing plants or are lost by leaching. Unless fertilizers are misused, however, we seldom consider them hazardous salts, because salt buildup in soils must exceed certain levels before plants are adversely affected. The following soil-salinity scale is based on the response by various types of plants to salt in the soil solution.

Salinity effects mostly negligible	Very sensitive plants affected	Many plants affected	Only tolerant plants grow or yield satis-factorily	Only a few very tolerant plants grow or yield satis-factorily

0   2   4   8   16

Increasing Salt Concentration (millimhos/centimeter at 25 C)

SALINITY IN SATURATED SOIL EXTRACT,
BASED ON SCALE OF ELECTRICAL CONDUCTIVITY

This scale provides a basis for defining a given soil as "saline." Special laboratory techniques are used to obtain an aqueous extract from a saturated soil. The electrical conductivity of the extract is measured by conductivity (Wheatstone) bridges. The University of Hawaii Department of Agronomy and Soil Science analyzes each sample sent in for a soil test. The results are recorded on Cooperative Extension Service Form 313, "Soil Test Report," and returned to the person making the request. An electrical conductivity of 1 millimho/cm corresponds to approximately 700 parts per million (ppm), 10 milliequivalents per liter (meq/1), or 40 grains per gallon (gpg) of salt in soil solution. Because the growth and yielding capacities of most plants are restricted when the salinity level, in the saturated soil extract, attains an electrical conductivity of 4 millimhos/cm, this value defines the lower limit of a "saline soil."

Visual Soil and Plant Symptoms

In addition to chemical analysis of the soil, there are other means of identifying salt-affected soil. Distinct white crusts may appear on the soil surface, particularly on the slightly higher elevations of land that is not level. An irregular pattern of plant growth, sometimes referred to as "spottiness," is usually associated with an unequal distribution of salt. The presence of barren spots may be more indicative of a soil salinity condition during germination than of a long-term condition of salinity in the soil, as most plants are more sensitive to salt during germination than at later stages of growth. The plants may be stunted and may vary considerably in size. Sometimes the foliage becomes a deep blue-green in color. Some plants develop characteristic necrotic spots, tip burn, and "firing" of the leaf margins. Others may develop cupped or rolled leaves, even when the water supply is adequate. Although uneven crop distribution and growth are indications of salinity, they also may indicate problems of excessive irrigation, soil fertility, or diseases. Soil and plant tests are needed for reliable diagnosis of salinity.

The so-called "indicator plants" provide another means of identifying salt-affected soils. These native plants are relatively salt-tolerant, and their presence in certain soils can indicate salinity. Such plants include mesquite (a relative of the keawe), sagebush, desert saltbush, arrowweed, and saltgrass.

a

b

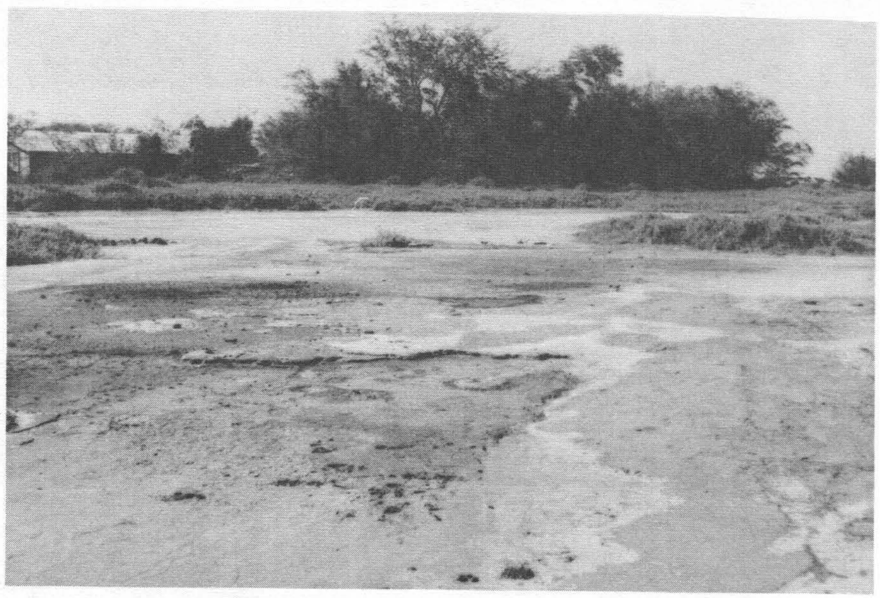

Figure 2. Small variations in land elevation can result from improper levelling. Spottiness in salt-affected soils is associated with differences in elevation because salts tend to move to higher localities through capillary activity.

a

b

Figure 3.

Spottiness of soil salinity is usually associated with a spotty pattern of plant growth, as in

a. Soybeans on Molokai

b. Corn on Molokai

Irrigation Mismanagement May Cause Salinity

All irrigation waters contain dissolved salts. A high-salinity water may damage plant leaves if allowed to come in contact with them, as during sprinkler irrigation. This hazard is small, however, compared with that of salt accumulation in the soil if water is used improperly for irrigation. Water applied for irrigation is usually lost by evaporation and plant use, but almost all of the salts in the water remain to increase the salt concentration in the soil. The drier the soil is allowed to become before irrigation, the higher will be the average concentration of salts in the soil solution and the greater its effect on crop growth.

More frequent irrigation is essential to reduce the harmful effects of salt. If only enough water is added to meet the crop requirement, there may be an increase in the salinity of the root zone regardless of the salt content of the irrigation water. Proper irrigation management also requires that extra water be applied to guarantee the downward movement of salt and to reduce salt accumulation in the root zone. The fraction of irrigation water that must be applied to keep the salt level below a specified value is called the "leaching requirement." This fraction increases with increasing salinity of irrigation water, increasing consumptive use by plants, and decreasing salt tolerance of the plants under consideration.

Hawaii's Soils Allow Good Salinity Control

Most of Hawaii's soils have excellent drainage, making it easy to apply extra water to prevent salt accumulation in the root zone. In areas having poor drainage in the root zone, it may be necessary to install drainage facilities, improve soil permeability, and change the irrigation method. University of Hawaii Extension or Experiment Station research personnel can help you with these problems. Salt removal from the root zone depends not only on the amount of water applied to the soil but also on how it is applied. For instance, ponding is usually less efficient* than rainfall for moving salts downward in a soil. Therefore, an irrigation method which simulates rainfall, such as sprinklers, would be the better choice when salinity hazard is high. Such a method has two obvious advantages. First, the larger soil pores never become saturated, and therefore do not conduct the large volumes of water that usually contribute to water waste. Second, the soil surface is maintained in a more favorable condition for gaseous exchange and water penetration, both of which contribute to healthy plant growth. Where ponding is the only available method for irrigation, intermittent water applications should prove more efficient for salinity control. This method provides for better mixing of the applied water and the soil solution, and reduces water losses through the large pores. It is important to remember that with an efficient leaching process you waste less water and have fewer drainage problems.

*"Efficiency" refers to the amount of salt removed from the root zone by the leaching action of a unit volume of water.

Selection of Plants

Plants differ widely in their ability to tolerate salts in the soil. Proper selection of plants is an essential part of successful management of salt-affected areas. Many investigators have evaluated the salt tolerance of a wide variety of plants in both field and greenhouse research. In vegetable, field, forage, and fruit crops of high economic significance, the main index for tolerance was the extent of reduction in yield. Published salt-tolerance values are based upon the conductivity* of the soil-saturation extract at which a certain percent yield decrement may be expected, based on yields when the plant is grown on a nonsaline soil under

Figure 4. Plant establishment is usually the critical stage which may determine the success or failure of a new planting in salt-affected areas, whether the salt originates in the soil or the water. These coconut seedlings show signs of need for special irrigation management for modifying salt effects.

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*EC in millimhos/cm

comparable growing conditions. (50% yield decrement was used by the U.S. Salinity Laboratory, Riverside, California.) Unfortunately, only a few plants of importance in Hawaii or the tropics have been studied.

Table 1 shows the relative tolerances to salt of certain plants, some of which are grown in Hawaii. Included are grasses, some of which are used as turfgrasses. Limited work has been done on the salt tolerance of shade and roadside trees, or plants grown as windbreaks. Such information would be valuable for shoreline areas subject to ocean spray. When information is unavailable on the salt tolerance of a given plant, its resistance to drought may be used as an approximate indication. For instance, casuarina (ironwood), coconut, croton, false kamani, hala, hibiscus, keawe, kukui, monkeypod, Norfolk Island pine, oleander, paperbark, plumeria, rubia, and wiliwili are low water-requirement trees or shrubs that may be presumed to have varying degrees of salt tolerance. However, since there are some exceptions to this rule, care must be exercised in making this judgment. Also, the effect of saline substrates on trees may be cumulative. Over a period of years, even low concentrations of salt may result in a slow but progressive decline of tree growth and vigor.

Precise judgments of plant tolerance to salinity are not simple to obtain because some plants are more affected by salinity at one stage of development than at another. Even highly tolerant plants may be acutely affected at some particular stage. For instance, rice is more affected by salinity during early seedling growth, flowering, and seed set than during germination or intermediate growth stages. In general, well-established plants are more tolerant to salt than new transplants. This fact is of considerable importance for plants propagated by transplanting.

TABLE 1. RELATIVE TOLERANCE OF SOME PLANTS TO SALT[1]

High salt tolerance[2]	Medium salt tolerance[3]	Low salt tolerance[4]
Asparagus	Alfalfa	Avocado
Barley	Bell pepper	Beans, green
Beets, garden	Broccoli	Celery
Bermudagrass	Cabbage	Grapefruit
Cotton	Carrots	Lemon
Rescuegrass	Castorbeans	Orange
Rhodesgrass	Cauliflower	Radish
Saltgrass	Corn, field	Strawberry
Spinach	Corn, sweet	
	Cucumber	
	Lettuce	
	Onions	
	Peas	
	Rice	
	Sorghum	
	Squash	
	Strawberry clover	
	Sudangrass	
	Sugarcane	
	Tomato	

[1]Plants are listed alphabetically.

[2]Electrical conductivity values of the saturation extract which are tolerated by this group range from 10-18 mmhos/cm.

[3]Electrical conductivity values of the saturation extract which are tolerated by this group range from 4-12 mmhos/cm.

[4]Electrical conductivity values of the saturation extract which are tolerated by this group range from 2-4 mmhos/cm.

Salinity in Irrigation Water

Salinity may become a hazard if dissolved constituents in irrigation water are allowed to accumulate in the soil. This hazard becomes greater with increasing salinity of the irrigation water; therefore, salinity diagnosis of irrigation water is of utmost importance when selecting appropriate irrigation management for salinity control.

Irrigation water quality is usually decided after chemical analysis has provided certain parameters. For routine diagnosis, the parameters listed in Table 2 are usually determined. In some waters it may be necessary to determine other constituents such as toxic metals or pesticide residues.

TABLE 2. PARAMETERS USUALLY DETERMINED IN IRRIGATION WATER

Determination	Abbreviation	Unit
Electrical conductivity	EC X 10^3 at 25 C or EC X 10^6 at 25 C	millimhos/cm micromhos/cm
Boron	B	parts per million
Acidity or alkalinity	pH	pH units
Cations		
Calcium	Ca	milliequivalents per liter (meq/l)
Magnesium	Mg	"
Sodium	Na	"
Potassium	K	"
Anions		
Carbonate	CO_3	"
Bicarbonate	HCO_3	"
Sulfate	SO_4	"
Chloride	Cl	"
Nitrate	NO_3	"

Water quality classifications are rather complex because they depend on many factors related to soils, climate, crops, and intended type of irrigation management. In general, however, the most important indices used for classification are related to the total concentration of dissolved constituents and the proportions of sodium relative to divalent cations. If water contains more dissolved salts than the electrical conductivity equivalent of EC = 5 millimhos/cm, it is usually considered unsuitable for irrigation purposes. Waters containing less dissolved salt than that amount are usually suitable for irrigation. Water is normally placed in several classes, depending on the salt content. For instance, the U.S. Salinity Laboratory classifies waters with EC values of 0.10-0.25 mmhos/cm, 0.25-0.75 mmhos/cm, 0.75-2.25 mmhos/cm, and 2.25-5.00 mmhos/cm as low, medium, high, and very high salinity waters, respectively. To give an idea of the magnitudes involved, drinking water in Honolulu usually falls within the low or medium classes. Seawater, on the other hand, has an electrical conductivity of approximately 44 mmhos/cm.

As stated earlier, many of Hawaii's soils lend themselves to successful salinity control when high-salinity waters are used for irrigation. This is fortunate because water pumped from artesian wells may contain relatively high salt concentrations during certain times of the year, particularly those located near the shoreline. The source of salt in those waters is direct seawater intrusion into the basal freshwater lenses from which water is drawn. This intrusion process becomes significant at the outer edges of these lenses.

It is necessary to classify irrigation waters as to sodium content because sodium ions may have a detrimental effect on soil physical properties such as permeability to water and air. Where soils may be drastically affected, the use of high-sodium water requires special management and the addition of certain corrective amendments such as gypsum or organic matter. Fortunately, most of Hawaii's soils are less susceptible to sodium damage than are soils of other arid regions. Nevertheless, caution must be exercised in using high-sodium water for irrigating certain soils, especially those characterized by a high degree of swelling. Swelling, a process enhanced by the presence of sodium ions, can lead to the destruction of soil aggregates and a subsequent problem in soil permeability to water.

Water samples will be tested if submitted to the Department of Agronomy and Soil Science, University of Hawaii, or to your local County Agent. The results are recorded on Cooperative Extension Service Form 315, "Water Test Report," and returned to the person making the request. An irrigation management program, taking into account specific soil and plant types, may be developed with the help of your County Agricultural Agent or other appropriate University of Hawaii personnel.

Conclusions

Whether the salts are native to the soil or added through irrigation water, you should be able to cope with salinity effects and achieve good control.

STEPS TO CONTROL SALINITY

1. Irrigate often.
2. Apply extra water.
3. Don't use a ponding method.
4. Select salt-tolerant plants.
5. Have soil and water tested.
6. Obtain help from the University of Hawaii in planning your irrigation program.

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