Salinity Management in Agriculture

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As modern agricultural research developed in the late nineteenth century, soil salination and reclamation were among the first topics examined. Some southwestern soils were naturally saline due to soil weathering processes and limited rainfall even before irrigation was introduced. Early studies showed that plants take up only a small amount of the salts in water, leaving the bulk of the salts to accumulate in the remaining soil water. Therefore leaching these accumulated salts—applying extra water to move them out of the root zone—is necessary for salinity control and maintaining agricultural productivity.

Guidelines and standards for reclamation of saline soils and management to control salinity evolved from this basic information, contributing to the successful development of large irrigation projects in the Southwest. Saline soils were reclaimed with amendments, tillage, land leveling, and high-quality irrigation water. By the mid-20th century, the total number of irrigated acres stabilized and soil salinity was perceived as a problem that had been successfully managed.

Modern Challenges

Recently, however, a looming water scarcity has called in question the long-term future of many of these large irrigation projects. Irrigated acreage is declining due to competition for water, with mandated, reduced water deliveries being imposed to address environmental issues or drought, and urban water agencies buying up irrigation water. Irrigated agriculture cannot compete economically with the urban sector in a competitively priced water market. Use of desalinated water is not likely a viable option for agriculture due to its high costs. Regulations on the discharge of drainage water to surface waters are increasing, and have in many instances resulted in rising water tables, reduced leaching capability, and subsequent soil salination.

Restrictions on surface discharge of agricultural drainage water threaten the sustainability of irrigated lands.

Development along coastal California has resulted in salination of coastal aquifers through sea water intrusion; further degradation has occurred from high groundwater utilization by the urban and agricultural sectors. This region produces high-value crops, such as vegetables, citrus, berries, and avocados, almost all of which are sensitive to salinity.

Alternative Water Sources

Looking beyond high-quality fresh water resources, numerous water supplies can be utilized to sustain irrigated agriculture, primarily treated municipal wastewater, brackish groundwater, and agricultural drainage water. These water supplies can be productively managed but require application of improved salinity management technologies, development of new crop varieties, and treatment processes that consider the needs of users. Using brackish waters for irrigation is not without drawbacks and added costs, but these appear minor compared to the alternatives. Clearly, this requires the soil salinity to be continuously monitored, as well as concentrations of various other constituents often associated with these waters. Brackish waters and drainage waters may contain trace elements such as boron, selenium, and molybdenum that can impair crop production or adversely impact wildlife. Equally important, these waters may have an imbalance of various elements that affect crop production or suitability as forage.

Monitoring and Mapping

Recent advances in salinity sensing have made detailed monitoring rapid and affordable. Remote-sensing technologies permit development of maps of salinity and associated variables such as soil texture and exchangeable sodium (Corwin and Lesch, 2005). The most-utilized sensing technology uses electrical conductivity (EC) measurements of the soil obtained through remote sensing using electromagnetic induction equipment or by inserting probes directly into the soil to measure electrical resistivity. Equipment is commercially available for both technologies. When coordinated with global positioning system measurements and collected with a data logger or computer, these measurements can be used to produce detailed, 3-D salinity distribution maps.

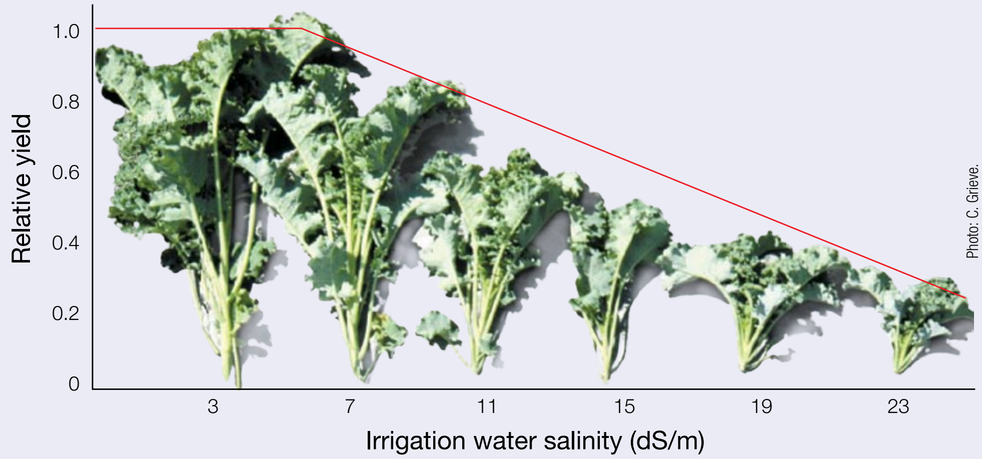
Detailed information on bulk soil EC can be converted into the traditional EC of a water extract by collecting a limited number of soil samples for calibration. Software is available to download the data, select optimum sample locations, and generate georeferenced salinity maps (Lesch, 2006). Additional sensing technology relevant to salinity control includes multiband satellite imagery, hyperspectral imaging, and field infrared measurements.

Salinity maps can be used to diagnose the cause of a salinity problem. For example, the depth distribution of salinity provides information about adequacy of irrigation and drainage. Buildup at the surface with decreasing salinity with depth indicates upward water movement likely caused by a perched water table or a drainage problem, while excessive and increasing salinity with depth suggests insufficient water application. The spatial distribution of salts in the field may relate to soil texture, nonuniform irrigation application, or localized drainage problems.

Once a problem is diagnosed, sensor technology also allows for site-specific management at the field scale, especially when combined with management-oriented modeling tools (Suarez, 2001). Rather than leaching a field with a uniform application of water, it may be possible to leach different regions with variable quantities of water, thereby reducing total water requirements or amendments. Such practices will likely require modification of the irrigation systems.

Drainage Issues

Regulatory restrictions on surface discharge of agricultural drainage water threaten the sustainability of irrigated lands unless current practices are changed. Drains are used primarily for water table control, as irrigation practices typically result in leaching volumes of 20 to 40 percent of the applied irrigation water. As water tables rise to within a few feet of the surface, crop yields are reduced and direct evaporation from the soil causes rapid surface salination. On-farm drainage evaporation ponds provide a short-term solution but create environmental concerns in addition to loss of cultivated acres. Reuse of agricultural drainage water for irrigation of salt-tolerant crops is a viable alternative, as is reduction of the drainage volume via improved irrigation practices.



Growth of kale plants in response to irrigation water salinity. Plants were grown outdoors in individual sand tanks at electrical conductivity levels of 3 to 23 deciSiemens per meter (dS/m).

While these are likely the most cost-effective societal solutions, they impose additional costs on the producers.

Traditionally, crops were selected for the greatest yield based on water and soil salinity levels. Unfortunately, most high-value crops are salt-sensitive and most salt-tolerant crops have lower value and/or produce less biomass. Thus, considering both crop value and total yield, growing high-value crops with some yield loss makes economic sense. These salt-sensitive crops are grown predominantly where low-salinity water is available using existing recommendations regarding the drainage discharge needed to control salinity through leaching. However, research has found that the guidelines commonly used may overestimate leaching requirements (Letey and Feng, 2007), thus it may be possible to reduce drainage volumes without causing yield losses.

Research Offers Promise

Development of crop varieties with improved salt tolerance is possible but currently limited, partly due to the lack of a large commercial market. However, recent research suggests that damage to and reduction in yield of salt-sensitive plants is related to uptake of sodium or chloride into the plant or displacement of these ions to the leaves and fruit, rather than due to osmotic effects in the root zone, as previously thought. This finding offers promise for the development of salt-tolerant, economically useful plants.

New molecular techniques are being used to insert salt-tolerance-related genes of one species into another. Zhang and Blumwald (2001) have reported the development of a transgenic salt-tolerant tomato plant. Other transgenic plants are in development. This research is rapidly developing with the awareness that constraints on freshwater sources will force changes in irrigated agriculture in arid regions and a dramatic rise in use of more saline water for irrigation. Conventional breeding programs appear more promising in the short term, as they can be used to develop plants that more efficiently exclude sodium or chloride. These conventional approaches can readily utilize existing differences in salt tolerance of species to develop new commercial varieties.

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