Irrigation with Saline Water

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ABSTRACT: The potential of the saline water for irrigation against the background of the world's food shortage is reviewed. It is shown that irrigation has improved food situation wherever it has been used. However, irrigation is always associated with salinity problems. Leaching techniques and drip irrigation suggest a partial solution for the problem. The objective of this paper is to review and examine additional solutions in order to increase the use of saline water for irrigation. A quantitative approach to further research on the use of saline water for irrigation is suggested. An analytical solution to the mass-balance equation of nutrients and salt in the soil, which includes a sink term for absorption by a plant, revealed some valuable derivatives, both for planning further research in irrigation with saline water and making decisions about fertilization and soil leaching throughout the growth period of a crop. Preliminary attempts to meaningfully increase the fertilization level of crops irrigated with saline water support the approach that was developed from one of the model's derivatives.

Introduction

With the present growth rate of the world's population it is expected that six billion people will inhabit this planet by the year 2000, an increase of two billion from 1980. Global food production will need to be nearly doubled by the end of this century. This increase is not uniformly distributed, with developing countries accounting for about 90% of this anticipated growth. The most seriously affected area is Asia which has only 17% of the world's arable land, but will have 57% of the world's population by the year 2000.

According to the 1977 Annual Report of the Food and Agriculture Organization of the United Nations (FAO 1977), the growth of agricultural production in 53 developing countries has not kept pace with the population growth rate. Furthermore, the index of food production per capita shows that in many of these countries the prevailing level of nutrition is already below what is considered adequate. Thus, every means must be sought to increase the world's agricultural production.

Irrigation

The ultimate reason behind these threatening facts is that most developing countries are located in arid or semiarid zones. Using simple technical terms this means that for these countries the water requirement for crops is larger than the total annual precipitation. This deficiency of water should be alleviated by use of various irrigation methods. In many deserts only a water source is required for converting arid or semi arid lands into prime agricultural producing land. This has been demonstrated in Israel (and to a lesser extent in other Mediterranean areas), Australia, Mexico, in the SW parts of the United States, and elsewhere.

In order to demonstrate the global importance of irrigation we modified data published by Finkel (1982) and defined the irrigation index (II) as:

\[
II = \frac{(IL/CL)}{(ALD/TA)}
\]

(1)

Where

- \(IL\) = irrigated land,
- \(CL\) = cultivated land,
- \(ALD\) = areas limited by drought,
- \(TA\) = total area of a given region

(all units are length squared and II is dimensionless).

The above expression gives the extent to which population in arid and semiarid regions use irrigation to close the gap between the amount of
rainfall and the crop water consumption. The food production in these regions (the FAO food index) is a function of the irrigation index shown in Fig 1.

Fig 1 suggests a quantitative measure of the relationship between irrigation and the availability of food. In addition, Fig 1 shows that the larger the irrigated area, the better the food index for that region. Note that a food index of less than 110 is considered inadequate. The slope of the linear relationship between the two indices can be interpreted as a quantitative measure for irrigation efficiency. The lower line is also characterized by a moderate slope that suggests that a large increase in the irrigated area is associated with a small increase in food production; while in the upper line a small increase in irrigated area is associated with a large increase in food production. Furthermore, the so-called western civilization is characterized by large food production per capita, more than 110, and high irrigation efficiency, while the developing world is characterized by a low production of food and low irrigation efficiency. Israel was chosen to demonstrate a unique situation where limiting water resources under arid conditions forced the nation to increase irrigated areas and water use efficiency simultaneously, thus achieving high food production.

On the other hand, Europe demonstrates no need for efficient uses of water. However, it should be mentioned that the low irrigation index in Israel was caused by the fact that 95% of the water potential is already being utilized for industry and agriculture and any further development along this line requires the use of inferior-quality water, namely saline water.

Irrigation and Salinity

As all natural water resources contain a certain amount of soluble salts, a frequent problem with developing irrigated areas is the accumulation of salts, which imposes stress on the crop growth. This stress is often associated with a decreased yield, and in severe cases a complete crop failure. These salts are dissolved during the process of infiltration of rain water into the ground. Naturally, the highly soluble salts will be most frequently found in irrigation water. Thus, chloride (Cl) is the dominant anion and sodium (Na) the dominant cation (together with Ca, K and Mg). Wherever irrigation water is added the soil salinity problem is unpreventable. Approximately one third of the irrigated land in arid and semiarid regions show symptoms of salinity problems caused by insufficient annual rainfall to flush the accumulated salts.

For many years farmers have used extra irrigation water to reclaim saline soils. The so-called "leaching requirement technique" enables the grower to control the salinity of the soil and to use saline water for irrigation without significant damage to the soil thus achieving feasible crop yield under saline water irrigation. The second stage involves the introduction of trickle irrigation and is associated with an increase in the upper salinity limit as well as yield. In Israel this method was introduced some twenty years ago (Goldberg et al. 1967) and since then it has been widely excepted the world over. To demonstrate the potential impact of trickle irrigation on the use of saline water we summarized some results (Goldberg et al. 1971) in which the effect of the irrigation method on crop yield was studied under various water qualities.

Tab 1 shows general increases in yield using trickle irrigation with no apparent effect of salinity on the tomatoes. However, when using sprinkler irrigation the yield was drastically reduced while increasing the salinity of the irrigation water. This effect is less pronounced in pepper and cucumber plants, presumably because they are salt-sensitive species. The question now is whether we have reached a "dead end" in using saline water for irrigation; and if not, where to go from here in terms of research and application.

In Israel there are two rather new accepted approaches. Both introduce mixing high and low quality water. One suggests reducing total salinity by mixing saline and fresh water sources at a mixing junction (Sinai 1984). The optimal application of this approach is based on system-operation theories and it requires at least two water sources, which are not always available. Furthermore, it does not provide additional understanding of salinity effects and therefore cannot help to increase the upper limit of salinity for irrigation water in agriculture.

The second approach (Pasternak 1982) suggests alternative use of high and low quality water according to plant growth periods. It distinguishes between salt-sensitive growing stages and salt-tolerant growing stages. Saline water is used only during the salt-tolerant growing stage. This