Opportunities to Improve Salinity Management Practices Using Process-based Models

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1 INTRODUCTION

Water quality criteria, irrigation recommendations, and reclamation guidelines were all developed in an era of abundant high quality water and land resources, where the concept was to select resources that would avoid problems of salinity or reduced yield. Criteria were inevitably very cautious, as a result of this abundance, limited understanding of the processes and response by the ecosystem, as well as the need to simplify recommendations. More recently there has been a trend of limited water and land resources, due to competition from growing municipal and industrial needs. The agricultural sector no longer has the resources to select the optimal water for irrigation or over-irrigate or over- apply amendments to ensure high productivity. At the same time, knowledge that the resources deemed unsuitable can in fact often be used, results in a lack of confidence in the standards. Marginal water will increasingly be utilized for irrigation, in some instances successfully and in some unsuccessfully, with the outcome depending on factors that are not considered in the criteria. There is an urgent need to improve and refine these criteria and recommendations, incorporating more science and inevitably making the decision more complex. The needs are twofold: To improve out knowledge base to include all factors and interactions and to incorporate this knowledge into a decision tool. The complexity of the interactions suggests that computer modeling will be essential to predict system response.

2 FACTORS AFFECTING WATER SUITABILITY

2.1 *Chemical effects on hydraulic properties*

Existing criteria consider only electrical conductivity (EC) and sodium adsorption ratio (SAR), (e.g., Ayers and Westcot 1985). The processes of swelling, dispersion, slaking etc are known but the quantification, as related to soil properties, is not. More quantification is needed to separate those instances where marginal waters may be used successfully from those where it will not. The inadequacy of the criteria can be seen in the results of Figure 1 (after Pratt and Suarez, 1990) The data represent the SAR and EC at which various soils express a 50% reduction in saturated hydraulic conductivity. For any specific soil the relationship would follow a curve with a shape comparable to that shown for the guideline, however different soils have different curves, the aggregate of the data is shown. Soils with high organic matter and oxide contents are relatively stable, meaning they can tolerate high SAR and low EC without adverse effects. The composite of factors exceeds 20, only a few of which have been quantified, and none of the interactions have been considered.

Despite the limitations in our knowledge of all the factors and interactions, we can utilize the existing information to greatly improve our understanding. Kemper and Koch (1966), described the impact of organic matter and soil oxides on aggregate stability. Suarez et al., (1984) determined that pH had an adverse impact on saturated hydraulic conductivity,

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independent of the SAR, and determined the changes in hydraulic conductivity under variable conditions of EC, SAR and pH for 3 arid land soils.

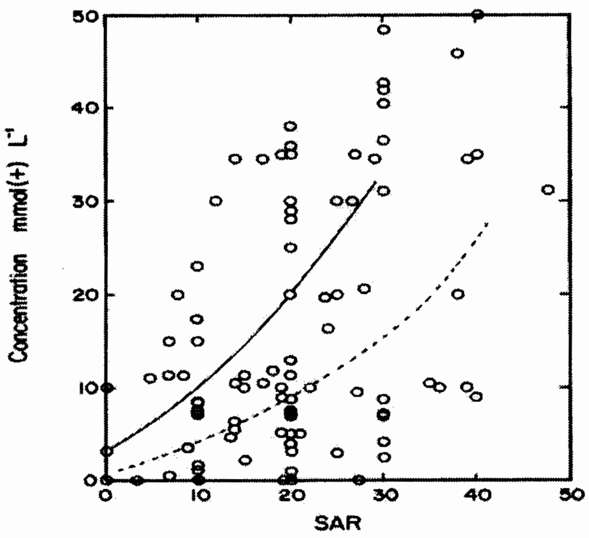

Figure 1 Concentrations and SAR at which soils exhibited a 25 % decrease in relative hydraulic conductivity. Compositions above two commonly used guidelines would be considered acceptable for use and those below unacceptable (after Pratt and Suarez, 1990).

2.2 *Changes in chemical properties*

The chemical properties affecting the hydraulic properties are usually dynamic, and thus need to be predicted. Among the simplest assumptions is that the water will achieve a steady state condition and only concentration of the water by evaporation is considered. This is not satisfactory as will be demonstrated below. Processes of mineral precipitation and dissolution, cation exchange and ion adsorption all affect solution composition. The simple assumption regarding chemical processes is to assume thermodynamic equilibrium. This is generally not a good assumption for predicting the water composition of the dynamic soil or vadose zone, but is a large improvement over simple guidelines. Often use of saline waters for irrigation can be successful if there is a winter rainy season and leaching of the surface soil, reducing salinity during the germination and seedling establishment, when many plants are most sensitive to salinity. Modeling the dynamics of water and chemical changes allows for prediction of these important temporal changes in salinity and water composition, critical to success when irrigating with saline waters.

3 MODELING CHEMICAL AND PHYSICAL PROCESSES

3.1 *Model criteria and development*

There are numerous models describing chemical processes and water movement. For example WATSUIT (Rhoades et al., 1992) can be used to predict the major ion composition at steady state. It does not consider ion exchange or adsorption thus its prediction reflects the long-term chemical consequences of using a specific water for irrigation with a constant leaching fraction. Other models consider detailed water flow routines but do not consider chemical processes. Coupled unsaturated water and chemical models such as LEACHM, Hutson and Wagenet, 1992, and UNSATCHEM (Suarez and Simunek, 1996) have been used successfully in various applications.

UNSATCHEM (Suarez and Simunek, 1996) was specifically designed for arid land irrigated agriculture and has additional features which increase its capability to predict soil water composition under field conditions. Among these is the prediction of the dynamics of soil pH as related to CO_2 production and transport, effect of water chemistry on soil hydraulic conductivity, a generalized model for B adsorption and inclusion of kinetic rates for mineral dissolution.

3.2 *Example 1. Management of high boron waters*

As shown by this model prediction, high B waters, such as 0.8 mmol/L, considered unsuitable for long-term use, can be utilized under certain transient conditions such as under Mediteranean climate with adequate winter rains. In the case of sandy soils it appears best to utilize low leaching only if B sensitivity is greatest in the early stages of growth while for clay soils the B concentration is lower and it appears best to utilize low leaching (Suarez, 2002). These results emphasize the site-specific nature of optimal management practices.

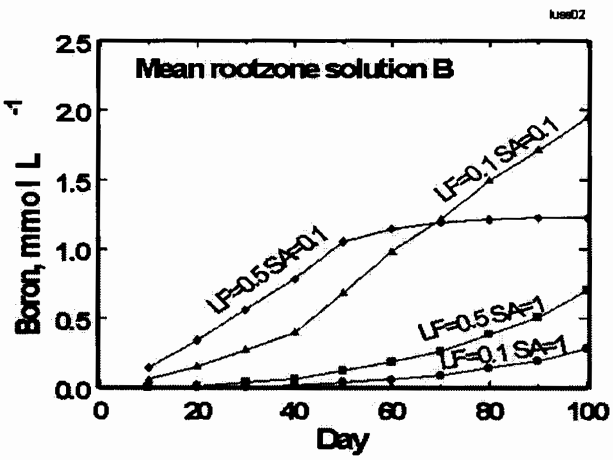

Figure 2 Changes in soil solution B concentrations upon application of high B water as related to leaching fraction and soil texture, Suarez, 2002). SA=1 (10^3 m^2/g) corresponds to a clay soil and SA=0.1($10^3 m^2/g$) corresponds to a clay soil

3.3 *Example 2. Application of gypsum*

Gypsum is commonly applied as a soil amendment in combination with leaching for reclamation of sodic soils and as a yearly winter amendment to maintain adequate infiltration when irrigating with sodic waters. The following simulations indicate how placement depth affects the SAR distribution in the soil after 70 cm of leaching (Suarez, 2001). Mixing to 8-10 cm appears optimal for reclamation of a sodic soil where the objective is to remove sodium from the profile, while surface application is best when irrigating with sodic waters where the objective is to keep the SAR low in the surface and maintain the existing SAR at depth. In Figure 3B we see that green manuring (thereby enhancing CO_2 concentrations in the soil) can effectively reclaim a sodic soil using existing calcite in the soil, although with an increased water requirement relative to gypsum.

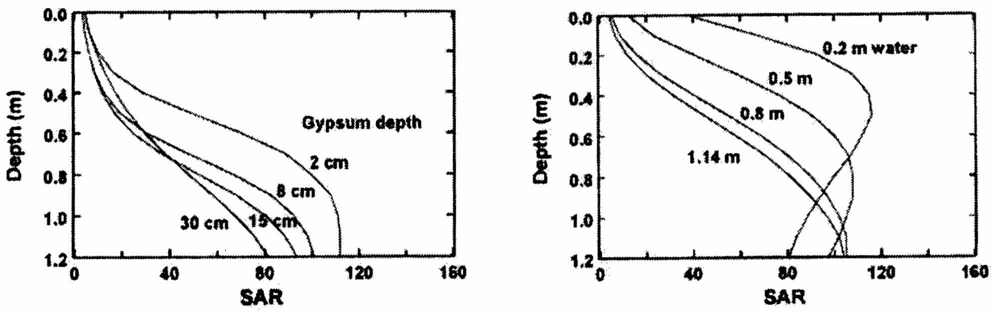

Figure 3 A, The relationship between SAR and depth after application of 85 cm of water and 10 t ha of gypsum applied at the indicated depths, and B, the SAR after leaching with indicated amounts of water and addition of organic matter to enhance carbon dioxide production and dissolution of calcite (Suarez, 2001).

4 CONCLUSIONS

Existing models are useful to analyze management options when using saline or marginal waters for irrigation, especially if they are able to consider transient conditions. Low quality waters can be safely used with appropriate site specific management practices, predicted from computer simulations. However much additional experimental research is needed before the models can be used without field confirmation of predictions. Quantitative knowledge of the interaction of many physical and chemical processes is necessary for predicting short and long term consequences of varied management practices.

5 REFERENCES

Ayers, R.S., and D.W. Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev.1. FAO. Rome.

Hutson, J.L., and R.J. Wagenet. 1992. LEACHM: Leaching estimation and chemistry model ver.3 Dept. of Crop and Atmospheric Sci. Res. Ser. No. 92-3. Cornell Univ. Ithaca. N.Y.

Kemper, W.D. and E.J. Koch. 1966. Aggregate stability of soils from western United States and Canada. U.S. Dept. of Agric. Tech Bulletin 1335. U.S. Gov. Printing Office. Washington D.C.

Pratt, P.F. and D.L. Suarez. 1990. Chapt 11, Irrigation water quality assessments. In K.K.Tanji (ed.) Agricultural Salinity Assessment and Management. ASCE, Manuals and Reports on Engineering Practices No.71.. ASCE. NY, pp. 220-236.

Rhoades, J.D., A. Kandiah, and A.M. Mashali. 1992. The Use of Saline Waters for Crop Production. FAO Irrigation and Drainage Paper 48. FAO. Rome.

Suarez, D.L. 2001. Sodic soil reclamation: Model and field study. Aust. J. Soil Res. 39:1225-1246.

Suarez, D.L. 2002. Evaluation of management practices for use of low quality waters for irrigation: Model simulations. In, Proc. Meeting of Internat. Union of Soil Sci. Aug 14-21, 2002. Bangkok, Thailand. Symposium No. 34, 1096:1-8

Suarez, D.L., J.D. Rhoades, R. Lavado, and C.M. Grieve. 1984. Effect of pH on saturated hydraulic conductivity and soil dispersion. Soil Sci. Soc. Am. J. 48:50-55.

Suarez, D.L., and J. Simunek. 1997. UNSATCHEM: Unsaturated water and solute transport model with equilibrium and kinetic chemistry. Soil Sci. Soc. Am. J. 61:1633-1646.