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Solute Transport in Heterogeneous Unsaturated Field Soil: Measurements, Prediction and Application to Crop Production

E. Bresler, G. Dagan, R.J. Hanks

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SOLUTE TRANSPORT IN HETEROGENEOUS UNSATURATED FIELD SOIL:
MEASUREMENTS, PREDICTION AND APPLICATION TO CROP PRODUCTION

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* Scientific papers

1. ABSTRACT

The research activity has been focussed on two major subjects:

(i) analysis and modeling of water flow and salt transport processes in soil of spatially variable fields and (ii) field experiments and analysis of statistical properties of crop yield in relationship to water application.

The results of the research on the first topic are reported in Sects. 2(a), 2(c) and 2(f). The main idea is that agricultural fields of large extent display spatial variability of their hydraulic properties and this affects profoundly the water and solute transport at field scale. In contrast with the traditional approach which regards the field as an homogeneous unit of effective equivalent soil properties, it is demonstrated that such properties do not exist generally for variable fields. Statistical models for analysis and prediction of the average and of variances of soil moisture content, salt concentration and water fluxes as functions of soil properties and water rate of application are developed. In Sect. 2(f) it is shown by numerical simulation for two fields (Bet Dagan, Panoche) that quite accurate results can be obtained by simplified models of flow in the profile, but accounting for variability. The major implication is that knowledge of the latter is more important than refinements in modeling flow and transport in homogeneous columns.

The results on subject (ii) are reported in Sects. 2(b), 2(d) and 2(e). The crop yield in a few fields (Bet Dagan in Israel and Logan, Utah) have been analyzed statistically in order to determine their probability density function (in particular mean and variance) and spatial correlation structure. In 2(b) and 2(c) it was found that the yield fluctuations

around the average have a completely random component accounting for up to 60% of its variance and a spatially correlated component accounting for the rest. The latter is attributed to variability of moisture content and implicitly to that of soil properties. In 2(d) the effect of nonuniform water application by sprinklers upon yield on small plots of relatively uniform soil is examined. A major conclusion is that water application variability may have an appreciable effect upon average yield for low levels of average water application. Therefore, the study of impact of soil and water application variability upon yield is bound to be particularly significant under conditions of water stress.

2. RESEARCH RESULTS

- (a) Effect of field variability in soil hydraulic properties on solutions of unsaturated water and salt flows.

3. EVALUATION OF THE RESEARCH ACHIEVEMENTS WITH RESPECT TO THE ORIGINAL RESEARCH PROPOSAL

Generally speaking the work carried out during the 3 years of the project have followed our original program. Thus, we have carried out most of the work concerning development of models of water and salt flows in heterogeneous (spatially variable) fields. We have developed models, to various degrees of sophistication, of simultaneous water and solute flow in spatially variable fields for conditions of infiltration and redistribution in the absence of plant roots. Some of the models are very much simplified to "take advantage" of the spatial variability in the field. We have developed the model of crop yield estimate in response to soil water content in a spatially variable field. We still have to develop the models of the simultaneous flows in heterogeneous field under the same conditions in the presence of plant roots and also of crop yield estimate to both water and salt contents. These model developments are scheduled in the next year if the proposal will be supported.

A considerable amount of work has been carried out in field experiments related to crop yield, its variability and its dependence upon soil and water application heterogeneity both in Israel and in the U.S.A. In this respect we have exceeded our original program. In contrast, our progress in implementing salinity measurements in field conditions has been slower than anticipated.

4. DESCRIPTION AND RESULTS OF COOPERATION

Hanks' first part of the project was concentrated on computations using the following data (collected in the field at Bet Dagan, Israel):

1. Data on K- θ and H- θ (30 data sets).
2. Data on initial water and salt contents with depth (30 sets).
3. Data on boundary conditions of potential evaporation, rainfall and irrigation with time.
4. Data on salinity of the irrigation water.
5. Data on the crop being grown, root distribution, above-ground cover, etc.

The first set of computations used the 30 sets of data on K- θ and h- θ to compute relative transpiration, ET, infiltrated water, drainage and salinity for a given irrigation season assuming one irrigation, rainfall and potential evapotranspiration sequence. Also, being computed are the average salinity in the root zone for the season, and appropriate statistical parameters. Effects of spatial variability of ET, and relative water quantities on the spatial variability of the crop yield of sweet corn in Bet Dagan field have been analyzed.

Data of wheat yield from Greenville Farm and of corn yield from Evans Farm were collected in Utah under line source irrigation conditions. The results were jointly analyzed and summarized jointly by the Israelis and American investigators. The outcome manuscript has been published by a leading soil science journal as a joint contribution supported by BARD.

A field experiment similar to that of Bet Dagan was carried out at Huntington, Utah / About 400 samples for spatial variability studies were collected. Soil water contents were measured by neutron probe at 18-24 inches. Four probe conductivity measurements were also made. Samples to measure EC and chloride contents have been collected. The material will serve for future analysis in the framework of a proposed BARD project.

Eshel Bresler and R.J. Hanks have met three times during the three years of the project to summarize past results and to plan and coordinate future activities.

G. Dagan and E. Bresler have met a few of the leading U.S. spatial variability scientists and discussed the problem of spatial variability in soil-water-salt modeling.

5. THESES

The present BARD project has supported one M.Sc. and one Ph.D. study program. Mr. J. Stern has conducted his M.Sc. work on the subject entitled: "Nonuniform sprinkle irrigation and crop yield".

His thesis had been submitted to BARD as a part of the Comprehensive BARD Report on October 22nd, 1981. Mr. A. Naor has already completed a year of his Ph.D. program, working on relationships between spatial field variability and distribution of interactive salts.

6. LIST OF PUBLISHED REPRINTS

1. Bresler, E., S. Dasberg, D. Russo, and G. Dagan. (1981) Spatial variability of crop yield as a stochastic soil process. Soil Sci. Soc. Amer. J. 45(3): 600-605.
2. Russo, D., and E. Bresler. (1981) Effect of field variability of soil hydraulic properties on solutions of unsaturated water and salt flows. Soil Sci. Soc. Amer. J. 45(4): 675-681.
3. Bresler, E., and G. Dagan. (1981) Convection and pore-scale dispersive solute transport in unsaturated heterogeneous fields. Water Resour. Res. 17(6): 1683-1693.
4. Bresler, E., G. Dagan, and R. J. Hanks (1981) Statistical analysis of crop yield under controlled line-source irrigation. Soil Sci. Soc. Amer. J. 46(4): 841-847.
5. Stern, J. and E. Bresler (1982) Nonuniform sprinkler irrigation and crop yield. Irrig. Sci. (In press).
6. Bresler, E. and G. Dagan (1982) Modeling of water flow and solute transport in unsaturated heterogeneous fields. Proc. Symp. Unsaturated Flow and Transport Modeling. (Arnold, E. M., G.W. Gee and R.W. Nelson, Eds.) Seattle, Washington, NUREG/CP-0030 PNL-SA-10325, pp.159-177.
7. Dagan, G and E. Bresler (1982) Unsaturated flow in spatially variable fields. I. Derivation of models of infiltration and redistribution. Water Resour. Res. (accepted for publication).
8. Bresler, E. and G. Dagan (1982) Unsaturated flow in spatially variable fields. II. Application of water flow models to various fields. Water Resour. Res. (accepted for publication).
9. Bresler, E. and G. Dagan (1982) Unsaturated flow in spatially variable fields. III. Solute transport models and their application to two fields. Water Resour. Res. (accepted for publication).