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BARD Project Number: IS-3397-03R

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Project Title: Dynamic intraseasonal irrigation management under water scarcity, water quality, irrigation technology and environmental constraints

Investigators          Institutions
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Co-Principal Investigator (Co-PI):
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  Amos Zemel                        Ben Gurion University of the Negev
  David Sunding                     University of California, Berkeley

Collaborating Investigators:

Keywords: Irrigation Scheduling, Dynamic Optimization, Bio-physical Models, Water and Soil Contamination, Technology Adoption

Budget: IS: $ 105,000          US: $ 95,000          Total: $ 200,000

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Signature                      Signature
Principal Investigator          Authorizing Official, Principal Institution
Final Scientific Report

Publication Summary (numbers)

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Postdoctoral Training: List the names and social security/identity numbers of all postdocs who received more than 50% of their funding by the grant.

Cooperation Summary (numbers)

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Description of Cooperation:

This project is the result of joint interdisciplinary work combining soil science and economics, and the publications that came out of this collaboration provide insights derived from both scientific fields. During the 2005-2006 academic year, Tsur spent a sabbatical year at UC Berkeley and collaborated with Zilberman on extending the work on optimal dynamic irrigation models developed earlier in Rehovot and Sde Boker. The research benefited from three additional short visits of Israeli team members to UC Berkeley. The cooperation between the Israeli team members was carried out via frequent travels between Rehovot and Sde Boker.
ABSTRACT

In this project we studied optimal use and adoption of sophisticated irrigation technologies. The stated objectives in the original proposal were to develop a conceptual framework for analyzing intra-season timing of water application rates with implications for crop and irrigation technology selection. We proposed to base the analysis on an intra-seasonal, dynamic, agro-economic model of plants' water demand, paying special attention to contamination of groundwater and soil in intensively cultivated areas that increasingly rely on water of lesser quality. The framework developed in the project integrates (i) a bio-physical model of water flow in the vadose zone and water uptake by plants and yield response with (ii) a dynamic management model to determine the optimal intra-season irrigation policy. It consists of a dynamic optimization model to determine irrigation rates at each point of time during the growing season and aggregation relating harvested yield with accumulated water input. The detailed dynamic approach provides a description of yield production processes at the plant’s level, and serves to determine intra-season irrigation decisions. Data derived from extensive field experiments were used to calibrate the model's parameters.

We use the framework to establish the substitution between irrigation technology (capital) and water inputs; this is an important property of irrigation water productivity that has been overlooked in the literature. Another important feature investigated is the possibility to substitute fresh and saline water with a minimal productivity loss. The effects of soil properties and crop characteristics on optimal technology adoption have also been studied. We find that sandy soil, with low water holding capacity, is more conducive to adoption of sophisticated drip irrigation, as compared to heavier soils in which drainage losses are significantly smaller.
Summary of Achievements

We developed a conceptual framework for analyzing intra-season timing of water application rates with different irrigation water salinity levels. The analysis is based on an intra-seasonal, dynamic, agro-economic model of plants' water demand when irrigation water is derived from water sources of different salinity. Our framework consists of a dynamic optimization model to determine irrigation rates at each point of time during the growing season and aggregation relating harvested yield with accumulated water input. The detailed dynamic approach provides a description of yield production processes at the plant level, and serves to determine intra-season irrigation decisions. In Shani, Tsur and Zemel (2004) we analyzed a situation in which irrigation is tuned to the plant's needs at each point of time during the growing period and characterized the optimal irrigation policy. The follow-up work in Shani, Tsur and Zemel (2005) extends the analysis by incorporating effects of irrigation water salinity. We find that significant saving of freshwater can be achieved with minor productivity loss.

Parallel agro-biological work is summarized in Shani et al. (2007a). A mechanism-based analytical model, the first of its kind, that considers multiple environmental variables and their combined effects on plant response was developed and found to successfully predict water use and yield of crops with variable soils, climate conditions, input water levels and water salinity. Water uptake by plants, water and salt leakage below the roots and yield are calculated by solving for transpiration in a single mathematical expression where response to combined water and salt stress is determined according to effective root zone salinity and water status. Input variables include the quantity and salinity of applied water, terms accounting for plant sensitivity to salinity and water stress, potential evapotranspiration, and soil hydraulic parameters. The results of this study provide essential input for the combined bio-economic models described above.
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Shani et al (2007b) considers irrigation production functions with water-capital substitution. Advanced irrigation technologies relax constraints on irrigation rates and timing, allowing to better adjust irrigation scheduling to the varying needs of the plants along the growing period. Irrigation production functions, then, should include capital (or expenditures on irrigation equipment) in addition to aggregate water. We derive such functions and study their water-capital substitution properties. Implications for water demand and adoption of irrigation technologies are investigated. The effects of soil properties and crop characteristics on optimal technology adoption have also been studied. We find that sandy soil, with low water holding capacity, is more conducive to adoption of sophisticated drip irrigation, as compared to heavier soils in which drainage losses are significantly smaller.

Social aspects of water policies are considered in Hellegers, Schoengold and Zilberman (2006) that explains how water resource allocation has to adjust for income distribution. Concern about poverty may lead to schemes like tiered pricing where a minimal amount of water for essential uses is subsidized. Energy may also be subsidized to allow poor farmers to have access for water, but we argue that while tiered pricing can be sustained within limits, subsidization of water prices or related water prices across the board will lead to significant inefficiencies and are not sustainable. Instead, we recommend a system where users pay full prices and governments develop subsidy schemes based on income. Governments with good welfare systems that address the poor can manage environmental problems better than governments that do not have a welfare system and subsidize the poor by allowing free access to natural resources. We find that the current system of subsidized energy and water is threatened by higher energy prices.

Hellegers and Zilberman (2006) show how the specification of production functions matters when it comes to adoption of new technologies and land use. If differences across locations affect only water use efficiency, then lands with low water productivity are most likely to adopt new technologies. But if differences among locations affect productivities of both land and water, then high quality lands are more likely to be adopters of new technology. Understanding the sources of
productivity variation over space is essential to understanding adoption patterns and water use and the impacts of new irrigation technologies.

References


