

Surface and Groundwater Management for Irrigated Agriculture under Alternative Water Supply Conditions/Climate Change Scenarios

Kurt Schwabe Associate Professor of Environmental and Natural Resource Policy Department of Environmental Sciences University of California, Riverside

January 26, 2009

Outline

- I. General Approach to Analyzing the Economics of Irrigated Agriculture
- II. Identification of Three Models of Irrigated Agriculture in CV, California*
 - Account for salinity and drainage issues
 - Use soil & crop science-based crop-water production functions
 - *Adjusted for salinity*
 - Unadjusted for climate-related changes in et
- III. Illustration of Impacts of Climate Change on Regional Irrigated Agriculture in WWD
 - Climate Change => Decrease in Surface Water Supplies / Increase in Variability

* Knapp, Schwabe, and Baerenklau 2007; Schwabe, Baerenklau, and Knapp 2008

Question...

Is irrigated agricultural sustainable in a closed basin with possibly lower and more variable surface water supplies?

...Answer

It depends...

biophysical characteristics of system
behavior of growers in basin
Economic factors
Technology available
Policy

I. What is the economic/**physical** nature of the problem?

- Water Applied in Excess of plant requirements
- Deep Percolation flows accumulate/perch above clay layer
- No natural drainage outlet for Westland Water District
- Region slopes downward from west to east
- Possible Climate Change Effects
 - Indirect Effects: changes in quantity and variability of surface water supplies
 - Direct Effects: changes in temperature and Co2 on et and yield

<u>Yield-Evaportranspiration (ET)-Water Relationships</u></u>

- Mass and Hoffman (1977); Van Genuchten (1987);
- Letey and Dinar (1985); Kan, Schwabe, &Knapp(2002)



2. What is the feasible set of biophysical management options to solve this problem?

Adjusting Factors Related to Surface Water Use

 Crops, land allocation, irrigation systems, water application rates

Adjusting Factors Related to Groundwater Use/Reuse

 Crops, land allocation, irrigation systems, water application rates and salt concentrations (a) Strategy mix at the farm-level.

Marginal Cost (\$/a-f)



If overlook full array => naïve farmer label (AER 1993; 1999; 2001)

Integrated Management in San Joaquin Valley: Three Models For Evaluation

1.) Integrated Baseline Model

- Static
- Homogenous regional characteristics

2.) Upslope-Downslope Model

- Dynamic
- Heterogeneous Cells w/ differing watertable heights

3.) Endogenous Groundwater Model

- Dynamic
- Endogenous groundwater salinty and watertable height

Model I. Baseline Model for San Joaquin Valley

- Homogenous region overlying shallow, saline water table
- Surface water imports + groundwater/reuse extractions
- No external drainage facilities
- Static model
- Objective:

Maximizing regional agricultural profits while maintaining regional hydrologic balance.



Computer Model

Objective: Maximize Regional Net Benefits

Crop production + reuse – evaporation pond and CH costs

<u>Crop Production Using Surface water</u>:

Crops: Cotton, Tomatoes, Lettuce, Alfalfa, Wheat *Irrigation Systems*: Furrow ¹/₄, Furrow ¹/₂, Sprinkler, Linear, LEPA, Drip

Reuse Production:

Crops: same as freshwater + Bermuda grass Irrigation systems: same as above

Land and Water allocation: Endogenous for both types of production Crop-water production function: based on soil and crop science literature – gives yield and deep percolation flows

Computer Model (continued)

Disposal: Evaporation ponds Compensating habitat and/or netting

Regional Constraints:

Land area Land use \leq Land Available

 $Hydrologic \ balance$ $Deep \ percolation \ flows \leq reuse \ + \ pond \ disposal$

Salt balance—not imposed

Decisions (GAMS/NLP)

Choose crop areas, irrigation systems, water rates to maximize social net benefits subject to land and hydrologic constraints Model II. Upslope/Downslope Model (Dynamic / Upslope Emissions / Lateral Flows) There can be upslope areas which generate drainage flows impacting downslope areas.

 Previous analysis did not consider consequences of lateral flows from upslope nor benefits of managing these flows

Now address dynamic watertable management...consider

- how water tables evolve in closed-basins,
- efficient management strategies that prevent or delay watertable problems,
- extent to which upslope source control is economically efficient.

Figure 1. Side view of the agricultural production/groundwater aquifer system on the westside of the San Joaquin valley, California. (Vertical scale is exaggerated.)



Model III: Endogenous Groundwater Quantity & Quality Model

- Homogenous region overlying saline water table
- Surface water imports + groundwater/reuse extractions
- No external drainage facilities
- Dynamic groundwater Model
 - Endogenous groundwater salinity
 - Endogenous water table height
 - Additions to aquifer volume (elevation) and salinity
 - Surface water and groundwater applications
 - Natural recharge
 - Canal losses
 - Extractions from aquifer volume and salinity
 - Reuse/groundwater applications (recirculates salts)
 - Disposal into evaporation basin/pond

Agricultural production in saline aquifer system



Model III: Endogenous Watertable Height and Salinity

- Maximize Regional Agricultural Profits
 - Period-by-period (and PV Solutions)
 - 30-year time horizon / 5% discount rate
- Groundwater=>unconfined aquifer (reuse)
 - Height Initial: 83 meters (msl)
 - Salinity Concentration Initial: 10 dS/m
 - Surface water salinity: 0.7 dS/m
- Simple Climate Change Represented by:
 - Reductions in surface water supplies
 - Baseline: 100%
 - 80% allocation and 60% allocation
 - Increases in surface supply variability
 - For 80% allocation

Evolution of State Variables: Unconfined Aquifer Height and Unconfined Aquifer Salinity



Evolution of Control Variables: Applied Surface Water and Applied Groundwater/reuse



Evolution of Control Variables: % Land Area Applied w/ Freshwater and % w/ Groundwater



Time Profile for Annual Net Benefits



Conclusions

- Modest reductions (20%) in surface water supplies have modest impacts (8% reduction in profits over 30 years). More significant reductions can have significant impacts (25% reduction over 30 years).
- Benefits of efficient management due to common property aspects of aquifer are small and dissipate with lower surface water supplies

Results will depend upon

- Availability and quality of a substitute
- Ability of crops to use substitute water source
- Initial Aquifer Characteristics
- Prices and Policy Options (e.g., water markets; carry-over water, etc.)

Unsure of the impacts from changes in et due to climate change