Linking economic and integrated hydrologic models to investigate the effects of reduced surface water deliveries on the aquifers of California’s Central Valley

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Outline

- The role of the Central Valley in California’s water system
- Climate Vulnerability of Central Valley watersheds
- Methods and Tools
  - Climate scenarios
  - C2VSIM Integrated hydrologic model using IWFM
  - CVPM Economic model
  - Linking economic and hydrologic models
- Results
  - Groundwater pumping for fixed and variable crop simulations
  - Simulated changes in crop acreages
- Future work
California’s Central Valley

Supply in North and East
Demand in South and West

25 MAF/yr surface water inflow

Moderately-sized reservoirs
Store winter precipitation as Sierra snowpack (~15 MAF)

~9 MAF pumped in 2002
or 13% if US pumping

Pumping is not measured
or regulated
Climate Variability

Statewide Average Annual Temperature

- Historical
- Projections

Year

Temperature (°C)


Decreasing California Snowpack

Lower Warming Range Drier Climate

Medium Warming Range Drier Climate

April-July Sacramento River Runoff

Percent of Water Year Runoff


Water Year (October 1 - September 30)

Methods

- Construct 10-year monthly valley-rim inflows for base case, slight, moderate and severe droughts from historical 1972-2003 data
- Develop diversion scenarios using CALSIM-II
- Determine economic parameters using CVPM
- Integrated hydrologic simulations with C2VSIM
  - 10-year spin-up at ‘average’ conditions
  - 10-, 20-, 30- or 60-year drought
  - 30-year recovery period
  - Calculate groundwater pumping to meet demands
- Incorporate economic factors using Logit functions
  - Fixed agricultural water demand
  - Variable agricultural water demand
CA Groundwater-Surface Water Simulation Model (C2VSIM)

IWFM Application

Groundwater Flow System
- Finite Element grid
- 3 layers
- 1393 nodes
- 1392 elements

Surface Water System
- 72 stream reaches
- 97 surface water diversion points
- 2 lakes
- 8 bypass canals

Land Use Process
- 5 Regions
- 21 Subregions
- 4 Land Use Types
  - Agriculture
  - Urban
  - Native
  - Riparian
Incorporating Variable Demand

- Crop mix is a function of water cost
  - Surface water availability
  - Depth to groundwater
  - Crop water demand
  - Crop production costs and returns
- Incorporate Logit equation in IWFM application

\[
\alpha_{ir} = \frac{e^{x_r\beta_{ir}}}{1 + \sum_j e^{x_r\beta_{jr}}}
\]

- Determine Logit equation parameters from a series of simulations conducted with the Central Valley Production Model
Water Use
Severe drought for 60 years, fixed crops
Groundwater Pumping
Severe drought for 60 years, fixed vs variable crops

![Graph showing groundwater pumping and drought recovery over time. The graph compares fixed and variable crops during drought and recovery periods.](graph.png)
Difference in Groundwater Pumping

Severe drought for 60 years, fixed minus variable crops
Crop Changes
Severe drought for 60 years, variable crops

[Graph showing crop acreage changes over time with specific data points and categories such as Fallow, Trees & Vines, Subtropical, Rice, Truck Crops, Pasture & Alfalfa, Field Crops, and their percentage changes.]
Water Table at End of Drought

Fixed Crops

Variable vs Fixed Crops

Relative WT Change (Feet)

Difference in Water Table Altitude (ft)
Depth to Groundwater
Severe drought for 60 years, fixed crops
Depth to Groundwater
Severe drought for 60 years, variable crops
Water Table vs Surface Water Deliveries

Slight, Moderate and Severe Drought after 60 years
Findings

- Regional impacts of extreme drought
  - Moderate in north (Sacramento River Basin)
  - Locally severe in middle (San Joaquin River Basin)
  - Severe in south (Tulare Basin)

- Economic behavior may significantly reduce drought impacts below levels projected using a fixed level of future development

- The C2VSIM integrated model with CVPM emulation
  - performs as expected
  - can provide valuable insights into the impacts of climate change on Central Valley aquifers and on Central Valley agriculture
Future Work

- Develop more realistic drought scenarios
  - Downscale GCM precipitation and use VIC to simulate rim inflows
  - Monte Carlo simulations
  - Changes in amount and timing of crop water demands
  - Changes in amount and timing of reservoir releases
  - More elaborate economic model

- More complex variable-crop drought simulations
  - Economic parameters from SWAP
  - More detailed model subregions
For more information

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