Impacts of Climate Change on Irrigated Agriculture in Northwest Kansas

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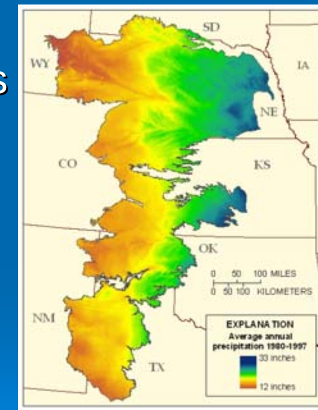
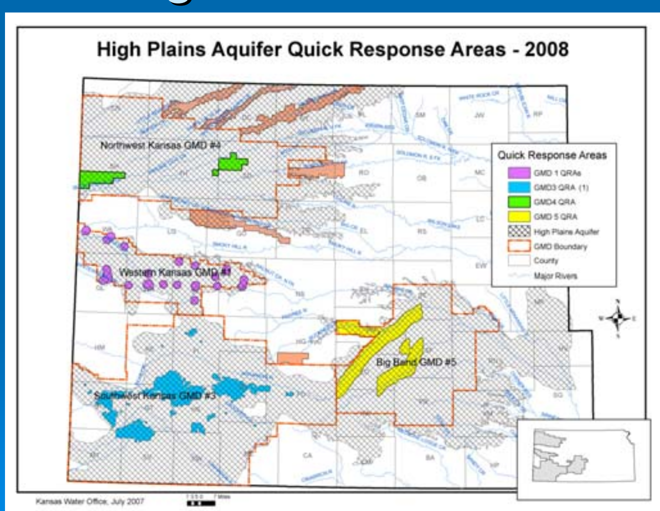
Kansas Water Office

The Ogallala Aquifer

- Water levels are declining
- 10% - 70% depletion rates
- Rural economies are vertically linked with irrigated agriculture



Voluntary & Incentive Based Programs in Kansas



Policy Development

- Multidisciplinary analysis
  - Economists
  - Engineers/Agronomists
  - Hydrologist
  - State water planners
  - Local stakeholders

Policy Development

- Compare a status-quo scenario to various policy options
  - Water rights buyout
  - Conservation Reserve Enhancement Program
  - Technology adoption
  - Water-use restrictions

Policy Development

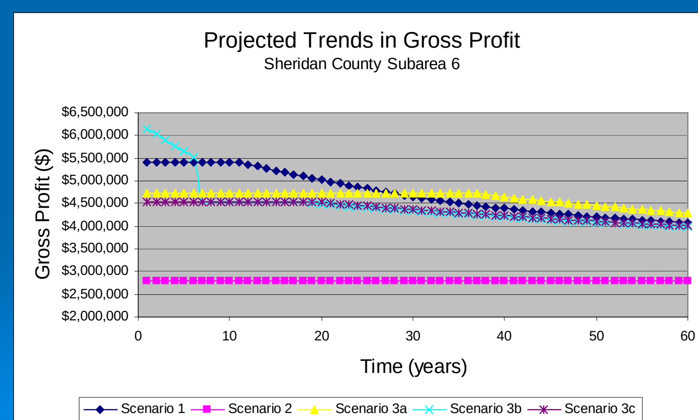
- Compare a status-quo scenario to various policy options
  - Impacts on producer profits
  - Impacts on community value-added
  - Impacts on the aquifer
  - Impacts on the taxpayer

Policy Development

- Economic Tools
  - Dynamic simulation models
    - Calibrated to observed crop mix
    - Calibrated to observed water-use
    - Calibrated to observed drawdown
  - IMPLAN

Policy Development

- Dynamic simulation models

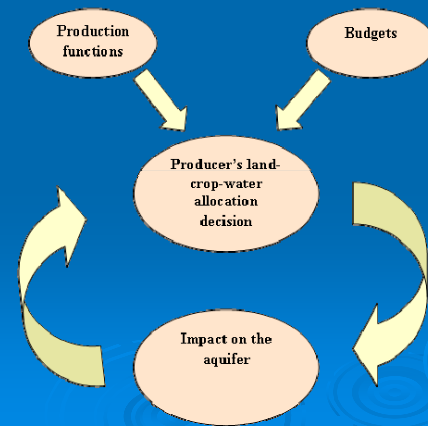


Policy Development

- Concern !
- The current dynamic simulation models do not incorporate possible impacts of climate change.
- The literature suggests that - in general - agriculture can adapt to climate change without significant financial impacts

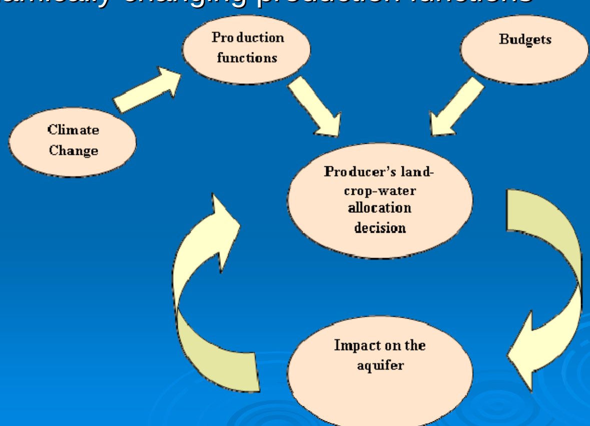
Dynamic Simulation Models

- Simulates a producers decision on an annual basis



Dynamic Simulation Models

- Incorporate the impacts of climate change via dynamically changing production functions



Dynamic Simulation Model

$$\max_{A,w} \sum_{i=1}^{n} P_i Y_{i,t}(w_{i,t}) A_{i,t} - C_{i,t}(w_{i,t}) A_{i,t}$$

$$s.t. \quad \sum_{i=1}^{n} A_{i,t} \leq TA$$

$$\sum_{i=1}^{n} w_{i,t} A_{i,t} \leq TW_t$$

Dynamic Production Function

- Requirements
  - As temperatures increases the function must respond to increasing crop ET requirements
  - As precipitation decreases the function must respond to increasing irrigation requirements necessary to achieve the fully watered yield.
  - The function should exhibit diminishing marginal returns to irrigation water
  - The function should be parameterized with readily available information based on physically defined parameters
  - The function should be consistent with engineering and agronomic principles

Dynamic Production Function

$$Y_{i,t} = DY_{i,t} + [FWY_i - DY_{i,t}) * (1 - (1 - \frac{GI_{i,t}}{GIR_{i,t}})^{1/WUE}]$$

Martin D.L., D.G. Watts, J.R. Gilley. “Model and Production Function for Irrigation Management.” Journal of Irrigation and Drainage Engineering. Vol. 110, No. 2, June 1984, pp. 149-164.

Dynamic Production Function

$$NIR = ET_{FWY} - GSP * EP - \Delta SM \; .$$

$$NIR_{i,t} = (ET_{FWY_i} + \lambda_i * \Delta Temp * \frac{t}{T}) - (GSP_{t=0} + \Delta GSP * \frac{t}{T}) * EP - \Delta SM$$

and

$$GIR_{i,t} = \frac{NIR_{i,t}}{WUE}$$

Dynamic Production Function

$$DY_{i,t} = b_0 + b_1 * ET_{DY_{i,t}}$$

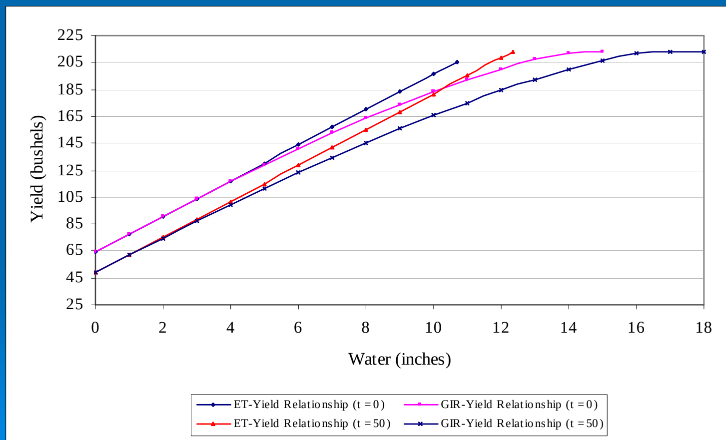
$$FWY_i = b_0 + b_1 * ET_{FWY_i}$$

$$DY_{i,t} = FWY_i - b_1 * (ET_{FWY_i} - ET_{DY_{i,t}})$$

$$NIR_t = ET_{FWY_i} - ET_{DY_{i,t}}$$

$$DY_{i,t} = FWY_i - b_1 * NIR_{i,t}$$

Dynamic Production Function



Data

- Kansas Geological Survey
- Kansas Division of Water Resources
- NASS
- Stone et al. (2006)
- Kansas Weather Library

Two Scenarios

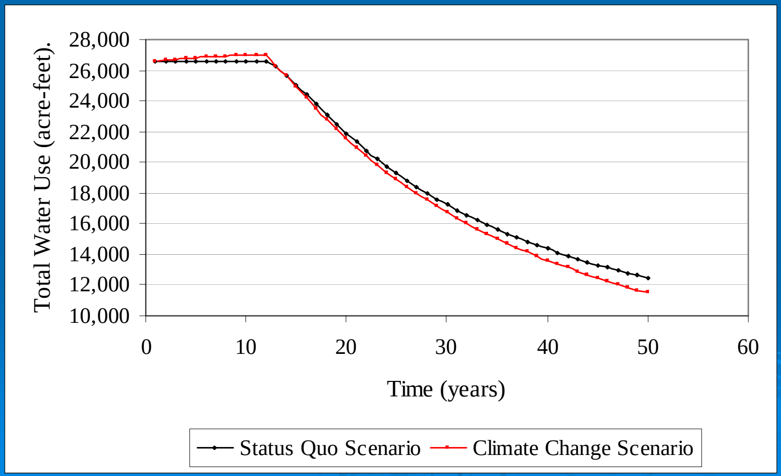
- Status-Quo (no climate change)
- Climate Change (status-quo w/ climate change)
  - 2.5 F° increase in mean temperature (North, 2008)
  - 2.5 % decrease in mean growing season precipitation (North, 2008)
  - No CO_2 fertilization effects
  - 20% decrease in aquifer recharge (Noah, Stuntz, and Abrams, 2008)
  - T = 50

Study Area

- Sub-basin in Sheridan county
  - 24,850 irrigated acres
  - 26,600 acre-feet of water annually
  - 75% corn
  - 98% center pivot technology
  - 90 feet of saturated thickness remaining

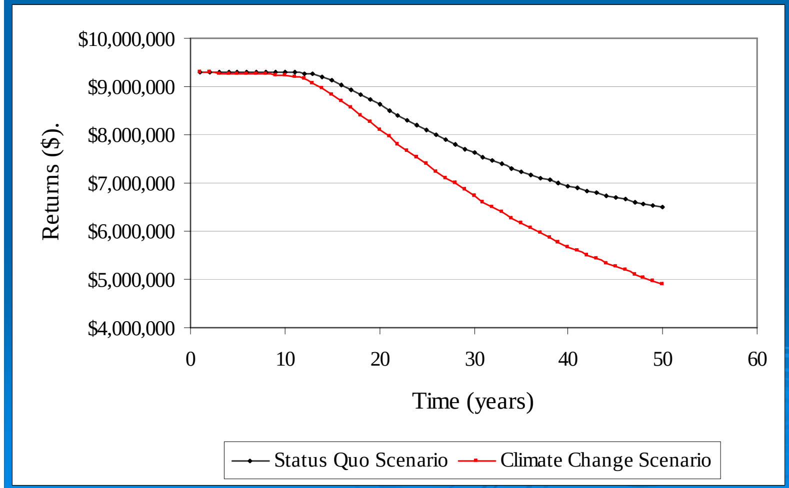
Results

Figure 2. Time Path for Total Water-Use



Results

Figure 3. Time Path for Returns to Land, Management, and Equipment



Conclusions

- The literature suggests that - in general - agriculture can adapt to climate change without significant financial impacts
- This may not be true for areas with limited groundwater supplies
- Climate impacts may need to be included in our dynamic models

Future Direction

- Add CO_2 fertilization
- Add technology impact on yield
- Add technology impact on water use efficiency
- Add random climate change