When Should Irrigators Invest In More Water-Efficient Technology

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Climate Change Impacts Irrigated Agriculture

- Climate change $\rightarrow$ higher temperature, disturbed water cycle

- Climate Change is expected to bring more frequent and more severe droughts in many parts of the world
  - Reduction of snow packs $\rightarrow$ decrease in summer water availability
    - Less snowfall
    - Sooner flow
### Adaptation to Climate Change

**Adaptation strategy**

<table>
<thead>
<tr>
<th>1</th>
<th>Crop related adaptation strategies</th>
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<tbody>
<tr>
<td></td>
<td>i- cropping pattern</td>
</tr>
<tr>
<td></td>
<td>ii- Cropping acreage and location of cropping activities</td>
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<tr>
<td></td>
<td>iii- Timing of planting and harvesting date</td>
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<td>iv- using new variety of the same crop</td>
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</tbody>
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<table>
<thead>
<tr>
<th>2</th>
<th>Long term strategic water management adaptations</th>
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<tbody>
<tr>
<td></td>
<td>i- Switching to New Irrigation Systems</td>
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</table>

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<thead>
<tr>
<th>3</th>
<th>Seasonal adaptations to respond to temporal availability of water</th>
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<tbody>
<tr>
<td></td>
<td>i- Deficit irrigation magnitude</td>
</tr>
<tr>
<td></td>
<td>ii- Deficit irrigation timing in a season</td>
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</tbody>
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<thead>
<tr>
<th>4</th>
<th>Short term adaptations to minimize the impacts of heat stress</th>
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<tbody>
<tr>
<td></td>
<td>i- Supplementary/over irrigation</td>
</tr>
<tr>
<td></td>
<td>ii- Irrigation frequency</td>
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<td></td>
<td>iii- Irrigation intensity</td>
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</table>
Two Questions

1. When should irrigators invest in more water-efficient technologies as an adaptation to climate change?
   – Defining future irrigation patterns

2. What are the watershed level impacts of these farm level decisions?
   – Impacts of these new systems on downstream water availability and regional agricultural productivity
Why Irrigation System is Important?

Benefits:
- Less damages from drought
- Labor
- Irrigation system

Costs:
- Pumping
- Pumping Station

Higher water availability in the crops’ root zones
Objectives

• What climatic condition would provide economical justification for investment on more efficient systems?
• Would vs Should
  – Maximizing the profit

• Importance of
  – Crop type
  – Climatic condition
  – Initial irrigation system
Yakima River Basin (YRB)

Some facts about YRB:

- Area: 16000 square km (476*33 Km^2 gridcells)
- Average Precipitation: 686 mm / yr
- Has been ranked 1st county in many agricultural products in Washington State and US
- 10% of employments directly in agriculture (USBR, 2002)
- Income from irrigated crops: $1.3 B (USDA, 2007)
Climate Change Impacts on YRB Water and Agriculture

- Major curtailment has happened in 14% of years

- Significant decrease in snowpack which impacts water availability of YRB (Elsner et al 2010)

- Higher demand resulting to more frequent droughts. Rajagopalan et al (in preparation)

- The decrease in summer water supply increases frequency of curtailment (Vano et al 2010)
The irrigation efficiency can be improved.

Irrigation Efficiency in YRB
METHOD
Economic incentives of adaptation to climate change

- Impacts of climate on water resources
- Impacts of climate change on agriculture
- Uncertainty in climate
- Simulation tool
- Cost and benefits
- Water resource management
Modeling Platform: Agricultural Spatial Economic Analysis Model (ASEAM)

- 19 Climate Scenarios, 2 RCPs
- Yakima RiverWare (YAK-RW)
- Simulation of Curtailment
- Other Capital and Operational Costs and Benefits

VIC-CropSyst

- 476 Gridcells
- 37 Crop Type

Bias Correction of Flow Output

- Yield Simulation
- Yield Response Table for Each Combination
- Crop Price

Cost-Benefit Analysis

- If NPV > 0

Irrigation System Modified

476 Gridcells

37 Crop Type

Crop Price

If NPV > 0

Irrigation System Modified
Hydrology and Crop System Models: VIC-CropSyst

**VIC**
Hydrology
Liang et al, 1994 and Elsner et al, 2010

**CropSyst**
Cropping Systems
Stockle and Nelson 1994
Simulation of Irrigation System Losses

Ec is calculated from intercepted water which depends on canopy coverage.

\[ E_d = ET_0 \times A_p \times \frac{1^a}{D} \times t^b \]

Es changes by canopy coverage.

\[ T: \text{transpiration} \]
\[ Ec: \text{evaporation from canopy intercepted water} \]
\[ Es: \text{evaporation from soil} \]
\[ Ed: \text{evaporation from irrigation droplets} \]
\[ Dp: \text{deep percolation loss} \]
\[ R: \text{Runoff loss} \]
\[ ** \text{processes that were developed in the current modeling effort} \]

Efficiency = 1 - \( \frac{E_d + E_s + E_c + R + D_p}{\text{total applied water}} \)

R = I_r - K_s \times T_i

Dp increases soil moisture which increases base flow generation.
Yakima-RiverWare

YAKRW

- 5 Dams
- Ground water
- Diversion
- Irrigation
- Municipal
- instream
- Demands and water rights info
- Rules and functions
- Return flow
- Water Supply
- YBIP options
- Increase Instream Flow
- Modify dams and facilities
- New storage facilities
- Conservation
- proration
- VIC-CropSyst

Water availability gets calculated through iteration of this process
Agricultural Spatial Economic Analysis Model (ASEAM)

- Model is Written in R
- It can be implemented for other adaptation decisions

**Costs**

- Capital Costs
  - Irrigation system
  - Pumping station

**Operational Costs**

- Labor
  - Electricity
  - Maintenance

(Depending on the system type)

**Benefits**

- Increase in Productivity
- Reduction of losses in drought periods
Percentage of Farmers in Each Gridcell Switching to New Irrigation Systems

<table>
<thead>
<tr>
<th>Year</th>
<th>%</th>
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<tbody>
<tr>
<td>1980</td>
<td>25</td>
</tr>
<tr>
<td>1990</td>
<td>42</td>
</tr>
<tr>
<td>2000</td>
<td>37</td>
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<tr>
<td>2030</td>
<td>43</td>
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<tr>
<td>2040</td>
<td>50</td>
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<td>2050</td>
<td>48</td>
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<td>2060</td>
<td>50</td>
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<tr>
<td>2070</td>
<td>48</td>
</tr>
<tr>
<td>2080</td>
<td>51</td>
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Different Crop Groups

High Value Crops:
Cherry, Nectarine, Peach, Grape Juice, Grapes, Pear, Walnuts, Other Tree Nuts and Orchards

Average Value Crops:
Barley, Corn, Oats, Rye, Spring Wheat, Winer Wheat, Asparagus, Dry Beans, Green Bean, Broccoli, Cabbage, Carrots, Cauliflower, Chickpea, Sweet Corn, Cucumber, Garlic, Lentils, Onions, Peas, Peppers, Potatoes, Squash, Sugar beets, Radish, Dill, Canola

Low Value Crops:
Pasture, Clover, Alfalfa, Hay, Sorghum, Herbs, Hops, Grass
Different Climatic Conditions

- **Low precipitation**
  - P < 250 mm

- **Moderate precipitation**
  - 250 < P < 500 mm

- **High precipitation**
  - P > 500 mm
Initial Irrigation Type

- **Surface irrigation**
- **Sprinkler irrigation**
Conclusion

• Climate change increases the frequency and magnitude of droughts

• Climate impacts provides economical justification for switching to new irrigation technologies

• Regional impacts and crop type has to be considered towards a sustainable agriculture
THANKS!
Acknowledgements