EVALUATING A WATER BUYBACK PROGRAM

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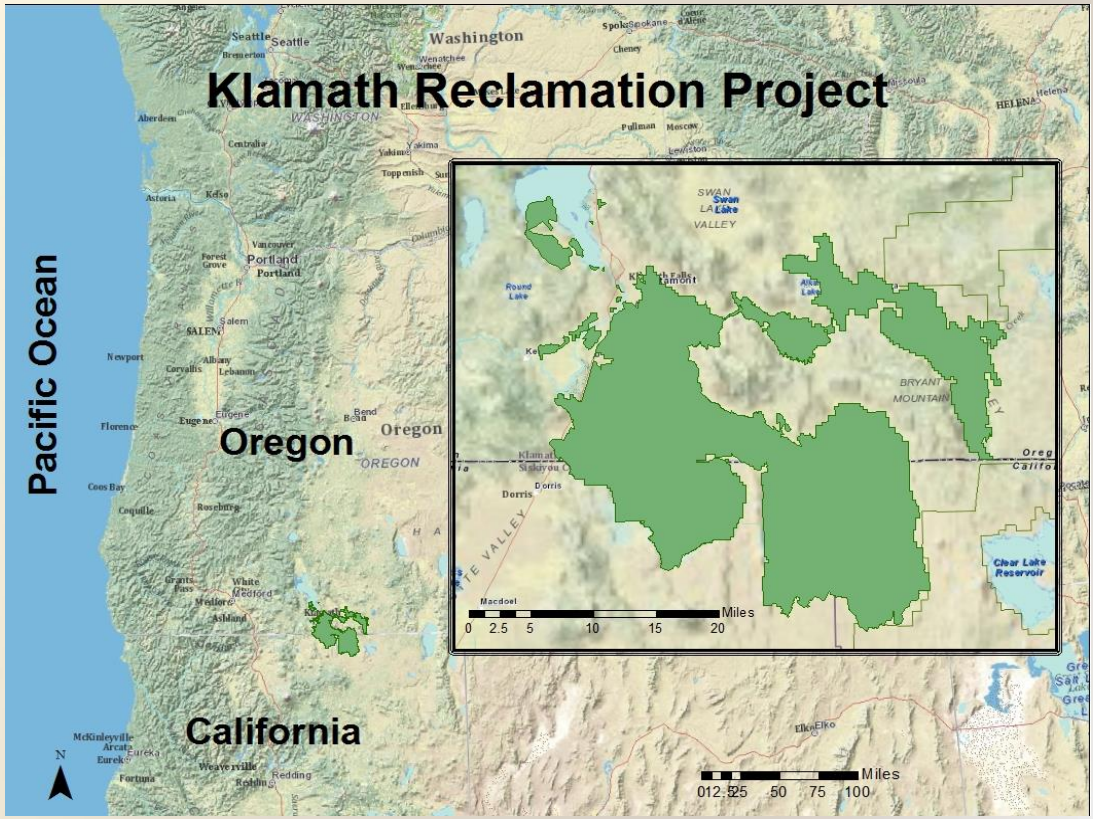
Outline

- Background and motivation
- Theoretical illustration
- Empirical model
  - Data
- Results

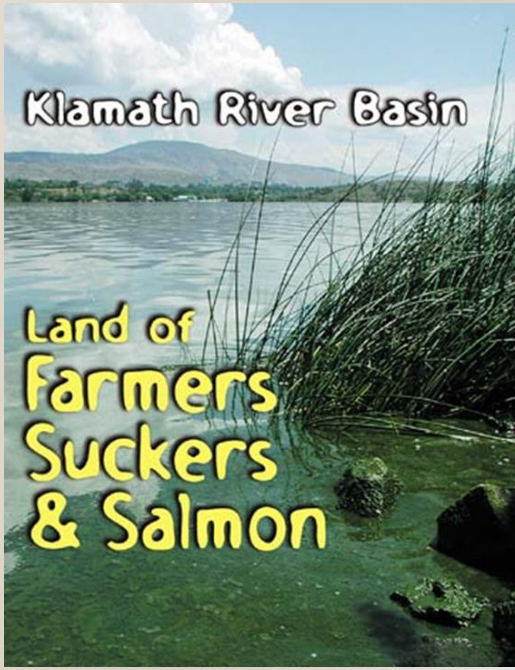
Background: Klamath Irrigation Project

- Created under the Reclamation Act (1902)to provide agricultural land for homesteading
- Managed by BOR
- Approx. 220,000 acres of farmland
- 9 major crops:
  - pasture,
  - alfalfa,
  - hay,
  - barley,
  - wheat,
  - oats,
  - potatoes,
  - peppermint,
  - onions
- 1,400 farms and ranches
- Produces $325 million in agricultural commodities (Lucero, 2011)



Background: wildlife

- Endangered species:
  - Lost river and shortnose sucker
  - Coho salmon
- Reasons: water management, water quality, loss of habitat, overfishing, and other causes (Lewis et al., 2004).



Background: ESA (1973)

- BOR water release subject to Biological Opinions
  - *U.S. Fish and Wildlife Service Biological Opinion*
    - minimum elevation requirement for the Upper Klamath Lake to protect the endangered Lost River and Shortnose suckers
  - *National Marine Fisheries Service Biological Opinion*
    - minimum in-stream flows in the Klamath River to protect the endangered Coho salmon habitat

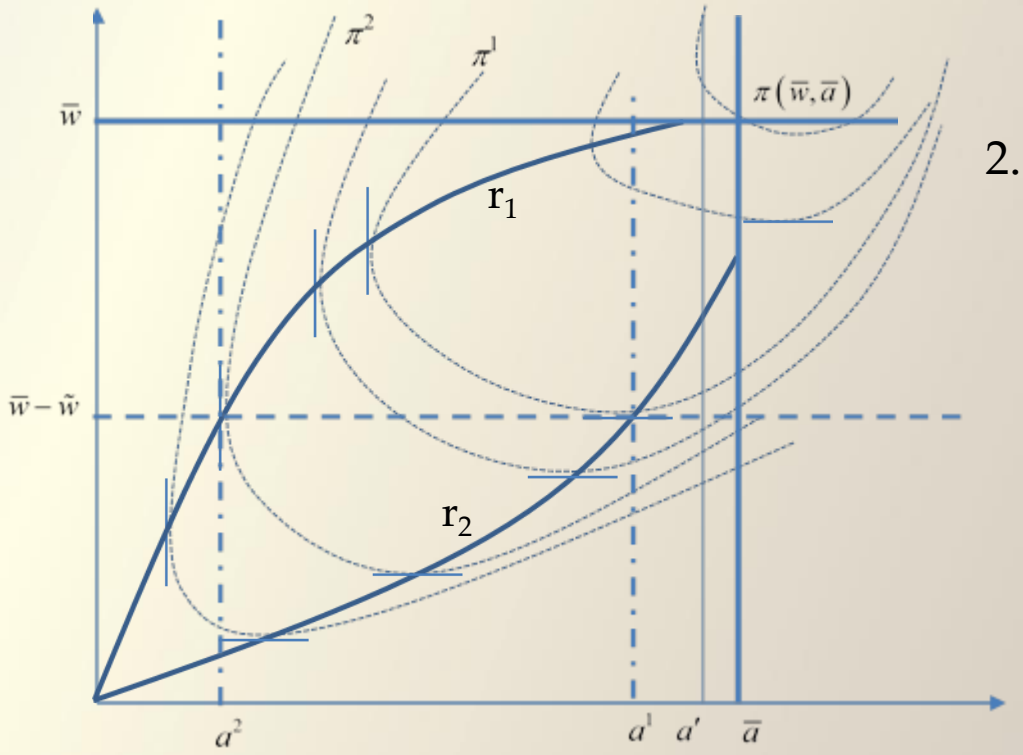
Background: 2001 shortage

- 2002 die-off 33,000 salmon (Guillen, 2003)
- Project water delivery was between 110,000 AF (OSU/UC, 2002) and 180,000 AF (Klamath Basin Coalition, 2003)
  - Agricultural losses - $27 to $46 million (Jaeger, 2002; 2004)
  - Recommendations:
    - simplifying and strengthening water property rights structure (Slaughter and Wiener, 2007),
    - allowing for off-Project water purchases and trades (Jaeger, 2004),
    - water banks (Burke et. al., 2004; Lewis et al., 2004),
    - tradable environmental rights (Tisdall, 2010).
    - deficit irrigation (Adams and Cho, 1998)

Background: 2010 shortage

- 18,000 acres of bids accepted at a cost of $3.2 million
- Water use decreased by approx. 36,000 - 45,000 AF
- Accepted land idling bids
  - Ranged from $0 to $225 per idled acre
  - The weighted average bid $176 per idled acre
  - Per acre foot cost between $70 and $90

Theoretical illustration



1. Buy water directly

π^1

2. Idle enough land

π^2

$\pi^1 > \pi^2$

Empirical model

- Math programming: Demand for water as a Marginal Value of Product (MVP)
  - Tsur (2005), Shumway (1973), Scheierling, Young and Cardon (2004), Yaron and Dinar (1982)
- No Deficit Irrigation
  - Shumway, 1973; Briand, Schuck, and Holland, 2008; Heady et al, 1973

Empirical model

Max:
w.r.t. a, w

$$\pi = \sum_{cr,st,\ it,ws,state} a_{cr,st,it,ws,state} * \left[\begin{array}{l} f_{cr,st,\ it,ws,state}\left(w_{cr,st,\ it,ws,state}\right) * P_{cr,state} - \\ IrrCo_{cr,\ it,ws,state} * w_{cr,st,\ it,ws,state} - Co_{cr} \end{array} \right] \quad (1)$$

Subject to:

$$f_{cr,st,it,ws,state}\left(w_{cr,st,it,ws,state}\right) = Yd_{cr,st,state} + \left(Ym_{cr,st,state} - Yd_{cr,st,state}\right)\left[1 - \left(1 - \frac{w_{cr,st,it,ws,state}}{Im_{cr,st,it,state}}\right)^{\left(\frac{Im_{cr,st,state}}{ETm_{cr} - ETd_{cr}}\right)}\right] \quad (2)$$

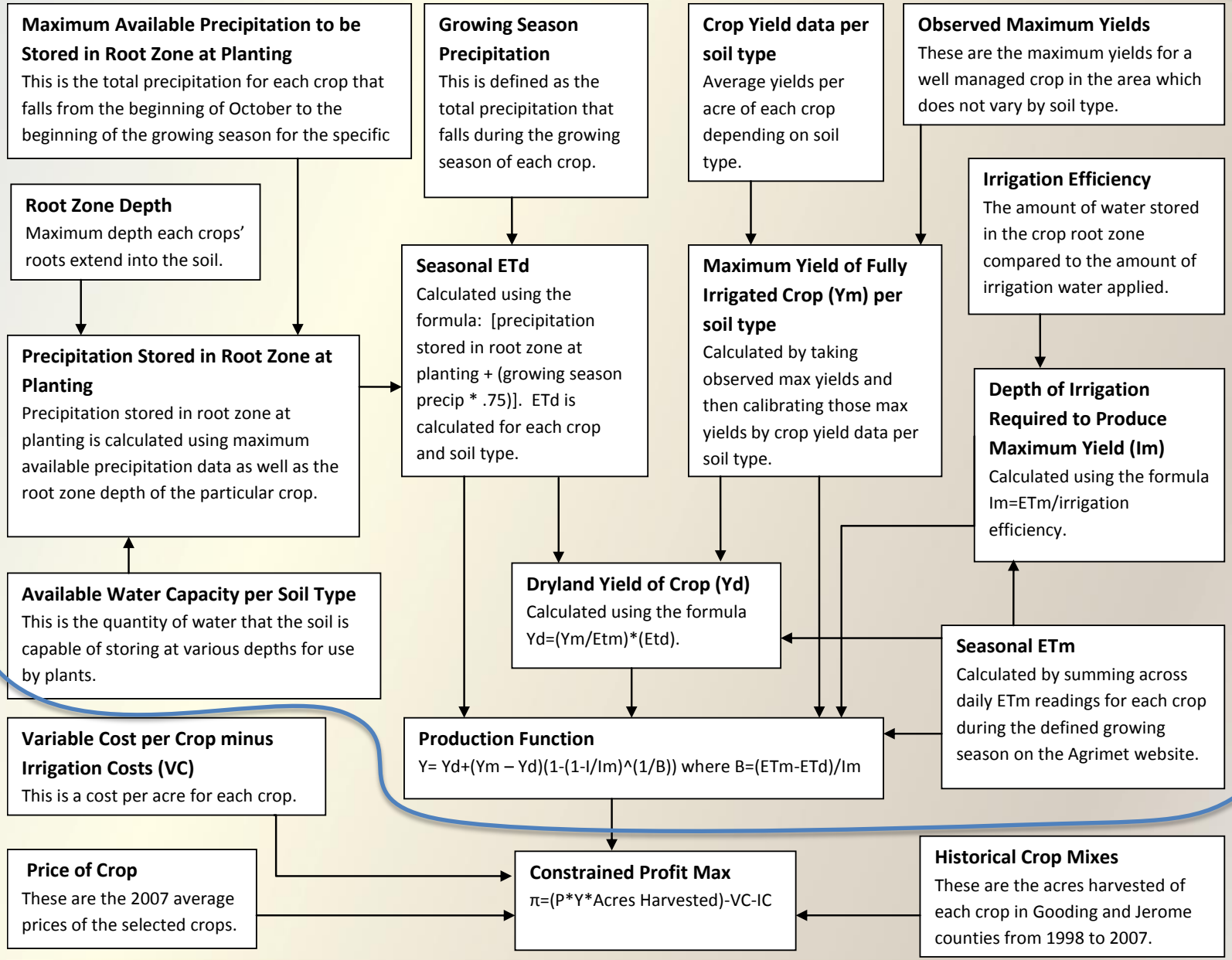
$$\sum_{cr} a_{cr,st,it,ws,state} \le Land_{st,it,ws,state} \ \forall\, st,it,ws,state \quad (3)$$

$$\sum_{st,\ ws,it} a_{cr,st,it,ws,state} = \sum_{y} \lambda_{state,y} * CropMix_{cr,state,y} \ \forall\, cr,state \quad (4)$$

$$\sum_{y} \lambda_{state,y} = 1 \forall\ state \quad (5)$$

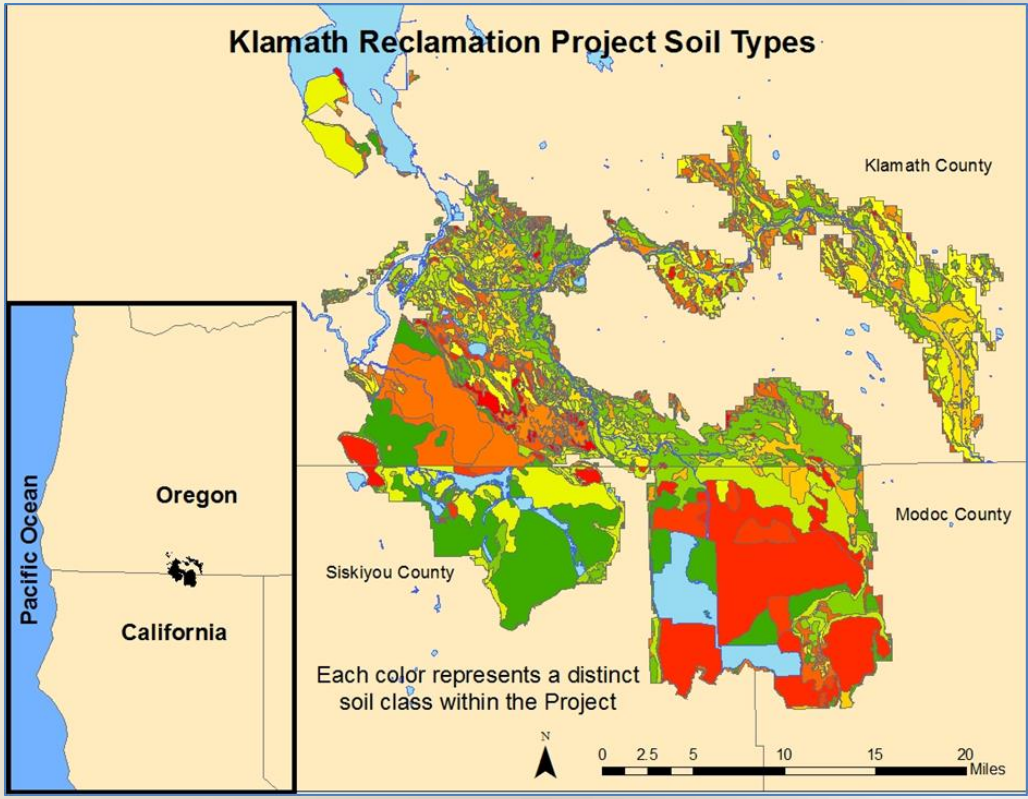
$$\sum_{cr,state,st,it} w_{cr,st,it,\text{'surface'},state} * a_{cr,st,it,\text{'surface'},state'} \le Water_{'surface'} \quad (6)$$

Model


Maximum Available Precipitation to be Stored in Root Zone at Planting
This is the total precipitation for each crop that falls from the beginning of October to the beginning of the growing season for the specific
Growing Season Precipitation
This is defined as the total precipitation that falls during the growing season of each crop.
Crop Yield data per soil type
Average yields per acre of each crop depending on soil type.
Observed Maximum Yields
These are the maximum yields for a well managed crop in the area which does not vary by soil type.
Root Zone Depth
Maximum depth each crops' roots extend into the soil.
Irrigation Efficiency
The amount of water stored in the crop root zone compared to the amount of irrigation water applied.
Seasonal ETd
Calculated using the formula: [precipitation stored in root zone at planting + (growing season precip * .75)]. ETd is calculated for each crop and soil type.
Maximum Yield of Fully Irrigated Crop (Ym) per soil type
Calculated by taking observed max yields and then calibrating those max yields by crop yield data per soil type.
Precipitation Stored in Root Zone at Planting
Precipitation stored in root zone at planting is calculated using maximum available precipitation data as well as the root zone depth of the particular crop.
Depth of Irrigation Required to Produce Maximum Yield (Im)
Calculated using the formula Im=ETm/irrigation efficiency.
Dryland Yield of Crop (Yd)
Calculated using the formula Yd=(Ym/Etm)*(Etd).
Available Water Capacity per Soil Type
This is the quantity of water that the soil is capable of storing at various depths for use by plants.
Seasonal ETm
Calculated by summing across daily ETm readings for each crop during the defined growing season on the Agrimet website.
Variable Cost per Crop minus Irrigation Costs (VC)
This is a cost per acre for each crop.
Production Function
Y= Yd+(Ym – Yd)(1-(1-I/Im)^(1/B)) where B=(ETm-ETd)/Im
Price of Crop
These are the 2007 average prices of the selected crops.
Constrained Profit Max
π=(P*Y*Acres Harvested)-VC-IC
Historical Crop Mixes
These are the acres harvested of each crop in Gooding and Jerome counties from 1998 to 2007.

Data

- NRCS
  - Soil types and characteristics
  - Yields
  - Water capacity per soil type
  - Root zone depth
- Oregon State extension publications
  - Variable costs of production
  - Irrigation costs
  - Maximum yields
- Bureau of Reclamation
  - Agrimet Website
    - Seasonal ETm
    - Growing Season precipitation
  - Klmath project historical crop mix



Results

- MVP values are calculated under two scenarios
  - Deficit irrigation:
    - Choice variables: acreage and per acre applied water
  - No Deficit Irrigation:
    - Choice variables: Acreage

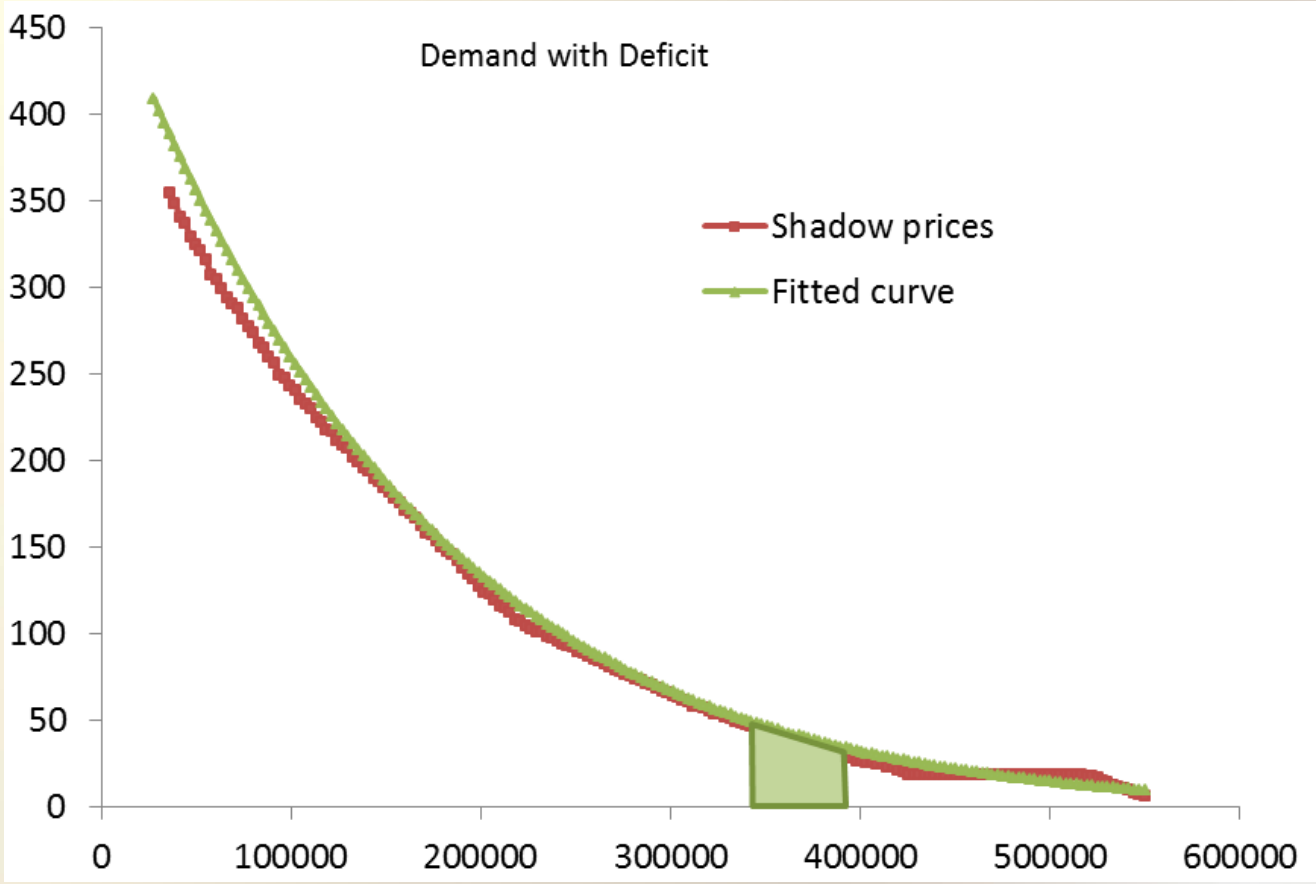
- Historic Klamath Project Operation Plans : average irrigation water use 390,000 acre feet. Max 500,000.

- Reducing irrigation by 45,000 AF
  - From 200,000 AF
  - From 390,000 AF
  - From 500,000 AF

Results

	With Deficit Irrigation
θ	0.082
St. Err.	*(0.0173)*
Z-value	*4.74*
P-value	*0*
β_1	-9.84E-06
$\chi^2(1)$	*830.492*
P-value	*0*
β_0	7.904

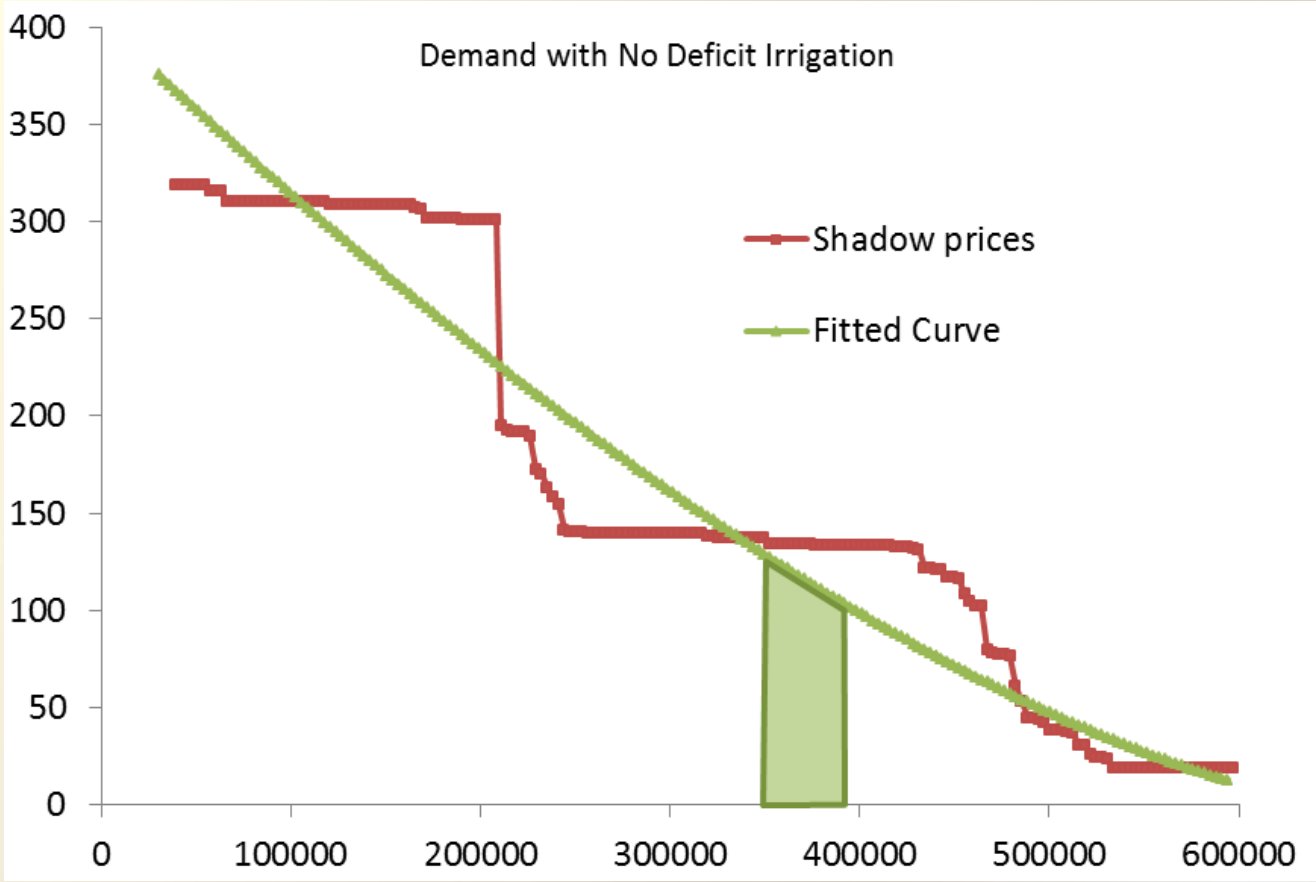
$$y = (\theta\beta_0 + \theta\beta_1 x + 1)^{1/\theta}$$



Results

	With No Deficit Irrigation
θ	0.663
St. Err.	*(0.0455)*
Z-value	*14.57*
P-value	*0*
β_1	-0.00012
$\chi^2(1)$	*474.753*
P-value	*0*
β_0	77.92

$$y = (\theta\beta_0 + \theta\beta_1 x + 1)^{1/\theta}$$



Results

	With Deficit Irrigation	With No Deficit Irrigation
	Value of idled irrigation water	
$MVP_{x^*}^{low=200K}$	6,601,133	11,300,000
Std. Err	*(1246787)*	*(3139579)*
P-value	*0.013*	*0.037*
$MVP_{x^*}^{med=390K}$	1,782,845	5,512,179
Std. Err	*(189715)*	*(1272237)*
P-value	*0.003*	*0.023*
$MVP_{x^*}^{high=500K}$	779,404	2,866,820
Std. Err	*(51003)*	*(540234)*
P-value	*0.01*	*0.013*

Buy back program

$3,2 million.

18,312 acres of idled land

45,000 acre feet

$$MVP_{x^*} = \int_{x'}^{x'+x^*} (\theta\beta_0 + \theta\beta_1 x + 1)^{\frac{1}{\theta}}\, dx$$

Conclusions

- Average per AF values - $17, $40, and $64
  - $22 to $79 per acre foot (Adams and Cho, 1998)
  - $9 to $105 per acre foot (Boehlert and Jaeger, 2010)
  - $75 (Burke et al., 2004)
- Difference between estimated and actual
  - Discontinuity of buy-back program
  - "Participation factor" (Burke, Adams, and Wallender (2004)
  - Multi-year contracts

Thank you!

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