Moving forward with Prior Appropriations Doctrine in Coping with Irrigation Water Shortages

Levan Elbakidze[1], Xiaozhe Shen[1], Garth Taylor[1], Siân Mooney[2]

1. **Department of Agricultural Economics and Rural Sociology , University of Idaho**
2. **Department of Economics, Boise State University**

Address correspondence to:

LEVAN ELBAKIDZE

Department of Agricultural Economics and Rural Sociology
University of Idaho ,Moscow, Idaho 83844 USA
Telephone: 208-885-7382
Fax: 208-885-5759
Email: lelbakidze@uidaho.edu

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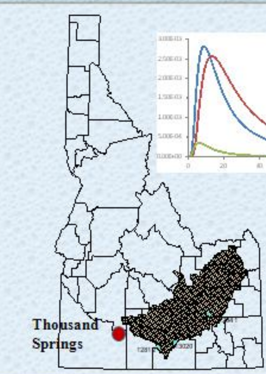
Introduction

Prior Appropriation (PA) doctrine is the predominant system for establishing initial water endowments within the Western US and for water allocation during shortages. In a water shortage, PA doctrine allows senior water rights holders to place water calls to meet their water rights, if they believe that their water rights are impaired by water use of junior right holders.

The highly transmissive Eastern Snake River Plain Aquifer (ESRPA) (Figure 1) underlies 26,000 km² of southeastern Idaho, a productive agricultural area dependent on irrigation (Cosgrove and Johnson, 2005; Cosgrove, Johnson, and Tuthill, 2008). Irrigated agriculture accounts for more than 90% of water use in the region. The area is also home to trout farms, located in the Thousands Springs area (Figure 1), which depend upon the cold and highly oxygenated waters that spring from the walls of the Snake River Canyon to produce over 70% of U.S. trout supplies (USTFA, 2010). Some aquaculture producers in this area hold water rights that are senior, relative to some of the ground water pumping rights.

In 2005, consistent with the Prior Appropriations doctrine, senior spring-water users filed water delivery calls with the Idaho Department of Water Resources (IDWR), claiming that extraction by ground water pumpers in the ESRPA was causing spring flows to decline in the Snake River Canyon at Thousand Springs (Wilkins, 2009). In response to the water call from senior water users, in March 2009, IDWR issued curtailment notices affecting 865 ground water rights with priority dates later than January 16, 1972. This notice had the potential to affect irrigated production on 41,000 acres of agricultural land.



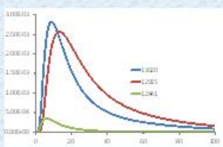
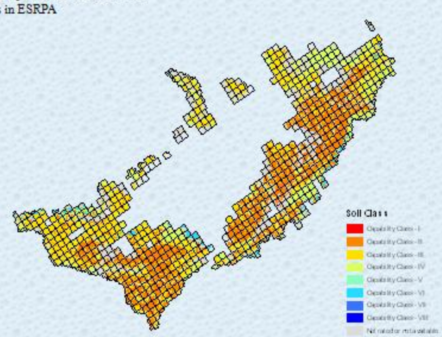


Figure 1. ESRPA and the dynamic response functions that express the effects of 1 acre-foot reduction in consumptive use in three different zones (A, B, C) on discharge at Thousand Springs. Integration of a response function from t=0 to t=t' provides total volume of additional relief at the target area (Thousand Springs) produced by reducing consumptive use of groundwater in that zone by 1 AF.

Figure 2 Spatial distribution of soil classes in ESRPA



Problem statement

Distribution of water right seniority may, in some cases, coincide with the distribution of soil productivity if most productive soils were settled first and hold more senior water rights. In that case, curtailment without water reallocation inadvertently may achieve some efficiency by curtailing least-productive producers first. However, PA-based curtailment does not necessarily and cannot explicitly consider productivity and does not account for hydrologic connectivity between curtailed water users and the target area. Supplementing PA based administrative curtailment with appropriate policies for water right reallocation could incorporate both soil productivity and hydrologic connectivity, in determining optimal spatio-temporal distribution of curtailment necessary to meet a senior water users' call. .

Objective

- Objective in this study is to measure the magnitude of welfare gains (change in the discounted present value of combined regional profits from crop production,),if costless water reallocation policies are in place when water call is placed by senior water users.
- We compare outcomes from two policy scenarios
  - PA – Prior appropriations based administrative curtailment of water users junior to 1973
  - PAR – PA supplemented with reallocation water use based on economic efficiency

Empirical Model

Maximize combined discounted regional crop production profits in ESRPA over the 100 year horizon.

$$OBJ = \sum e^{-rt}[p\,Y(w)\,x - C\,x - CW\,w\,x]$$

Subject to:

$$Y = Ym - (Ym - Yd)\left(1 - \frac{w}{wm}\right)^{\frac{XTm - XTd}{wm}} \quad \forall z,s,c,ws,jr,t$$

$$\sum x \le LAND \quad \forall z,s,ws,jr,t$$

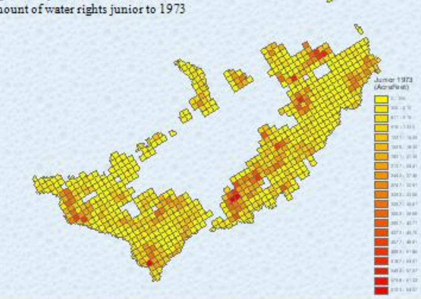
$$\sum x \le \sum_h \lambda \, cmix \cdot \sum LAND \quad \forall c,t,cnt$$

$$\sum_h \lambda = 1 \quad \forall t,cnt$$

$$\sum w \cdot x \le \bar{W} \quad \forall z,t,ws = ground\ water$$

$$\sum\sum\left(\bar{w} - \sum w \cdot x \cdot ie\right)\Psi \ge \sum\sum \bar{W}\,\Psi \quad \forall t,ws = ground\ water$$

Figure 3. Spatial distribution of the amount of water rights junior to 1973



For more detail see :

Elbakidze, L., X Shen, G. Taylor, S. Mooney, "Spatio-temporal Analysis of Prior Appropriations Water Calls", *Water Resources Research* (2012), VOL. 48, W00L07, 13 PP., doi:10.1029/2011WR010609

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Results

Not accounting for potential transaction costs associated with water use reallocation process, under a water call requiring curtailment of water rights junior to 1973:

- For a one-year administrative curtailment, optimized reallocation of water use can increase discounted returns over one-hundred years by 0.3 percent,
- For a ten-year curtailment scenario, discounted returns increase by 2.5 percent.
- For a one-hundred year curtailment scenario, discounted returns increase by close to 7 percent
- A 40 percent increase in pumping produces only 7 percent increase in discounted net present value of profits over a hundred year period

	Ratio of discounted returns under PAR vs. PA scenarios (percentage)	Ratio of total amount of extracted water under PAR vs. PA scenarios (percentage)
r=0.05		
1 year	100.31	100.30
10 years	102.56	102.98
100 years	106.85	140.36

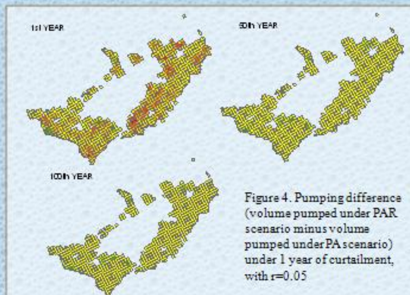
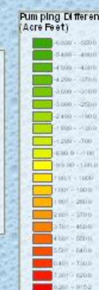


Figure 4. Pumping difference (volume pumped under PAR scenario minus volume pumped under PA scenario) under 1 year of curtailment, with r=0.05

Legend

Green shading indicates areas in which pumping decreased under PAR scenario, compared to pumping under PA scenario. Red shading indicates areas in which pumping increased under PAR scenario



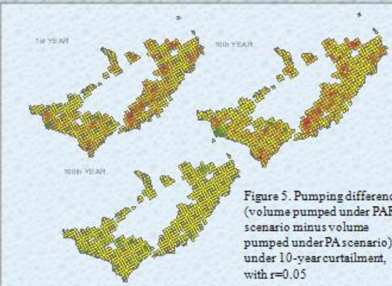


Figure 5. Pumping difference (volume pumped under PAR scenario minus volume pumped under PA scenario) under 10-year curtailment, with r=0.05

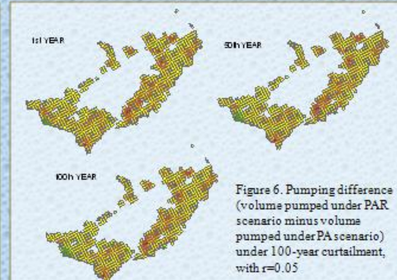


Figure 6. Pumping difference (volume pumped under PAR scenario minus volume pumped under PA scenario) under 100-year curtailment, with r=0.05

Contributions and conclusions

- Under PAR, pumping reductions take place closer to the Thousand Springs area, providing greater relief at the Thousand Springs area per acre-foot of reduced pumping. Therefore, under PAR, pumping reduction that produces the required relief at Thousand Springs, is less than under PA.
- While the distribution of pumping reductions in the PAR scenario are more economically efficient for fulfilling senior water users' water call in terms of overall profit maximization, they may not be effective at stabilizing aquifer water levels in the long run.
- Incorporated spatial as well as temporal considerations of the hydrologic system in concert with economic decisions
- Incorporated soil productivity as well as hydrologic connectivity in designing a management strategy
- Quantified potential benefits of enhancing the PA-based water allocation with a policy that would facilitate optimized water use (the estimated benefits can be used as an upper bound of potential transaction costs for feasibility of implementing such policy)