Linear Programming Analysis of Policy Influenced Factors Affecting Water Use Conservation in Established Irrigation Districts

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Water issues have aroused considerable interest in recent years in the United States. In the West an important dimension of that centers around water use and conservation in agricultural crop production because of increasing pressure from alternative demands for limited water supplies. That irrigated agriculture represents a dominant consumptive use of water is also a contributing factor. This study addresses a component of that issue by projecting water use and conservation impacts by growers associated with irrigation district policy influenced factors. An evaluation of the effectiveness of these factors and associated policies in improving water use efficiency also is made.

A case study approach using three established irrigation districts in Oregon was used. Districts chosen were Stanfield, Owyhee North Board and North Unit Irrigation District each being distinctly diverse and located east of the Cascade Mountain Range in Oregon.

A number of irrigation district policies and factors affecting water use were evaluated quantitatively. This paper confines its remarks to three policy influenced factors which had general impact across the three districts. These three are: annual water supply, water distribution system capacity, and water price.

Model Framework

A linear programming model was used to simulate water delivery requirements, water use and resulting crop production for each study district. A base model first was developed and subjected to validation then used repetitively to estimate the separate effects of the three policy influenced factors on each district. The model is a constrained, single valued expectations, maximization model. In the modeling process particular attention was given to water allocation activities of the district and crop enterprise choices of growers. Crop enterprise choices which maximized collective annual income to growers subject to district policy and resource constraints resulted from the model. Specific resource restraints include: irrigable acreage, canal capacity, stream and storage rights, water transportation efficiency, and pumping capacity. District activities include: stream diversions, storage release and diversion, transport of water, and water allocation (sales). Grower activities include a selected set of field crops which have been grown in the district, choice of flood or side-roll sprinkler irrigation methods with flood methods assumed in place with the option to convert to sprinkler irrigation, and a selected set of water application rates reflecting alternative seasonal and total water use and yield levels for each field crop.

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Results

Annual Water Supply

Projected impacts of a limited water supply in the Stanfield District are listed in table 1. This situation in Oregon is generally associated with small snowpacks in high altitude watersheds. In other areas it could be attributed to sparse rainfall, etc. Impacts are expressed as a change from full water supply conditions and are similar to those associated with limited water supplies in the other study districts. The effects of limited water supply are noted on district income, land irrigated, crop mix,

Table 1. Grower impacts attributed to a water supply which is about 75% of Stanfield's full supply situation, expressed as a change from the full supply situation

Item	Unit	Quantity
Grower income		
(return over variable cost)	dollars	-1,900,000
Land irrigated	acres	-200
Crops		
Barley	acres	+2,400
Potatoes	acres	-2,400
Irrigation		
Flood	acres	-100
Sprinklers	acres	+100
District Diversions	acre feet	-7,000
Water demand		
April	acre feet	+300
May	acre feet	+500
June	acre feet	+100
July	acre feet	-3,200
August	acre feet	-2,500
September	acre feet	-400

irrigation system choice, district water diversions, and water demands. Some flood irrigated land is converted to sprinklers, some land is left idle and barley replaces some intensive potato acreage. In this water supply situation, which was about 10,000 acre-feet less than the district's full supply situation of about 38,000 acre-feet, the projected MVP of water delivered to the farm headgate approached $350 per acre-foot.

Water Distribution System Capacity

Projected impacts associated with a 10% improvement in water transportation efficiency in the North Unit District are presented in table 2. They are expressed as a change from existing transportation efficiency in the district and depict impacts somewhat similar to those associated with improved transportation efficiency in the other study districts. Transportation efficiency improvements affect water distribution system capacity. The most important projected impact is for farmers to continue use of flood systems rather than convert to sprinkler methods which are technically more conserving in water use.

Water Price

Projected impacts associated with a variable water charge of $14.50 per acre-foot in the North Unit are shown in table 3. They are expressed as a change from the district's existing pricing policy which in 1970 included a base allotment of 2.0 acre-feet at a fixed O & M charge of $7.00 per year with water used in excess of the allotment at a cost of $3.30 for the first additional acre-foot and $3.85 for the second acre-foot or fraction thereof. The most important projected impacts are that all lands were irrigated by sprinkler methods which are technically more water conserving than flood methods, therefore, water demand was reduced, and aggregate average grower income was reduced about 11 percent initially.

Table 2. Grower impacts attributed to a 10% improvement in water transportation efficiency in the north unit, expressed as a change from existing conditions

Item	Unit	Quantity
Grower income		
(return over variable costs)	dollars	+108,000
Land irrigated	acres	——
Crops		
Wheat	acre	——
Potatoes	acre	——
Irrigation		
Flood	acres	+9,000
Sprinklers	acres	-9,000
District diversions	acre feet	+15,000
Water demand		
April	acre feet	——
May	acre feet	——
June	acre feet	+1,300
July	acre feet	+4,200
August	acre feet	+4,111
September	acre feet	——

Table 3. Grower impacts attributed to increasing water price to $14.50 per acre foot, expressed as a change from the north unit irrigation district's existing pricing policy

Item	Unit	Quantity
Grower income		
(return over variable costs)	dollars	-425,000
Land irrigated	acres	——
Crops		
Wheat	acres	——
Potatoes	acres	——
Irrigation		
Flood	acres	-31,000
Sprinklers	acres	+31,000
District diversions	acre feet	-40,000
Water demand		
April	acre feet	-3,500
May	acre feet	-5,400
June	acre feet	-8,400
July	acre feet	-5,200
August	acre feet	-6,000
September	acre feet	——

General Implications

Several measures for improving water use efficiency are suggested from this study. Technological advances, general economic conditions and public demands for water may promote some water conservation in irrigated western agriculture over time. These forces generally are indirect in nature and may or may not be effective at a moment in time depending upon economic and political conditions. Water supply, distribution system capacity, and water price can directly affect water conservation at district and grower level.

Restrictive water supply conditions tend to make water "dear" for both the district and grower. At the grower level direct substitutes tend to replace water input and water use tends to be more technically efficient. For example, more capital intensive and lower water using irrigation systems may profitably replace higher use systems. At the district level, when water supply is limiting it becomes expedient for the district to explore ways of reducing transportation losses and water waste by canal lining or piping, improved management, etc., or of increasing water supply and/or reducing supply variability by negotiating for more storage right or holdover storage. Herein lies a major weakness in relying on limited water supply conditions to promote water conservation at the farm level. Stated simply, in the absence of other policies or factors promoting conservation, any district policy and/or action which simply increase total water supply at the farm gate does not automatically encourage water conservation by the grower. In fact, model results suggest a deterioration in water conservation by growers might be expected. In any case, the result is a district-irrigator conservation paradox where a vigorous water conservation program at the district level, including canal lining, waste water reclamation, etc., may have minimal or no water conservation incentive at the grower level.

District distribution system restrictions, like limited water supply, also tend to make water "dear" for the grower and tend to make it expedient for the district to consider system modifications which elimiante water flow bottlenecks and improve the district's ability to meet demands. Like limited water supply conditions, the major weakness in relying on distribution system restrictions to promote water conservation is that district policies or actions which increase the net flow of total water to growers without reflecting this as a higher unit price do not encourage more technically efficient water use at the grower level.

Unit water pricing is a means for making water more "dear" to users which can encourage a desired blend of conservation at district and grower levels. It is a flexible policy tool, active rather than passive, for use by districts and can be used to account for changing supply conditions and distribution system restrictions. This approach to conservation has its problems too, including acceptance, because of relatively large increases in the price of water which may be required in some cases to achieve resource substitution between lower water using irrigation technology and water inputs. Also initially there are problems of lower farm income associated with this approach to water conservation.

The above implications have practical application to at least two audiences—people directly and indirectly involved with the operation of irrigation districts, such as direct farmers, district managers, consultants, etc., and finally researchers. With respect to the first group, awareness of water use impacts of district policies and factors should prove useful to districts responsible for serving farms while also concerned with greater efficiency of water use. For researchers these impacts and relationships, often unique to individual districts, must be considered when modeling operating irrigation districts for purposes of evaluating water use and policies and/or factors which affect water use.

Limitations

Inherent in a study of this type are limitations which restrict the interpretation of results. Two important enough to note here are methodology and data availability. The programming routine was a single-valued expectations, maximizing model; as such it did not adequately consider risk and uncertainty and the use of crop rotations to account for it, which in turn affect water use and conservation. The data base precluded analysis of grower conservation activities at the farm level other than irrigation systems. Changes in water scheduling technique, for example, could not be evaluated; yet many of these activities have conservation impacts. Also data on monthly irrigation system input coefficients and their relationships to crop yield and water use had limitations.