Economics of Water Quality Improvement in an Irrigated River Basin

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It has been traditionally assumed that the social benefits of irrigated agriculture far outweigh the social cost imposed by its contribution to environmental degradation. This assumption is now being questioned on many fronts, however. The purposes of this study were to estimate the agricultural contribution to water quality problems in the Yakima Basin of eastern Washington, to evaluate the efficiency and the impact on agriculture of alternative water quality improvement policies in the area, and to recommend policies which could improve water quality in this and similar irrigated river basins.

The Study Area

The Yakima River Basin is an intensively cultivated area of some 450,000 irrigated acres located in eastern Washington. Most of the irrigation water for the Basin is diverted from the Yakima River. Hence, the river flow is influenced by irrigation water demands and partially regulated by releases of water from upstream storage reservoirs. Most of the land in the Basin is irrigated by traditional surface or rill irrigation methods because of the relative abundance of water, resulting in low irrigation efficiency and high levels of runoff and deep percolation loss.

Irrigation return flows acquire suspended particulate matter, agricultural chemicals and dissolved solids which cause water quality degradation. Because 80 percent to 90 percent of the water in the lower reaches of the Yakima River is irrigation return flow water during the late summer, the quality of the river water is a direct consequence of the quality of the return flow. Furthermore, the low summer flow volume in the river permits the water to warm substantially, diminishing its usefulness for recreation, fisheries, and promoting the growth of water-borne organisms. Nitrate nitrogen concentration, August water temperature, and sediment lost from the farm were the primary environmental concerns of the study.

Economic Theory

Economic efficiency is maximized when pollution is directly controlled through taxation, restrictions, or bribes for abatement. However, agricultural effluents are not subject to the same types of constraints that are applicable to smokestack and sewage discharges because it is difficult, if not impossible, to identify the source of the discharges. Consequently, agricultural pollution abatement must be controlled through policies affecting the use of inputs causing the externality rather than policies directly affecting the externality.

Langham has shown that when externality output is a function of the use of one input, taxation or restriction on the use of that input is equivalent to controlling the externality itself from an efficiency standpoint. It can be shown that when externality output is a function of more than one input, the efficiency criterion can still be satisfied by appropriately taxing or restricting the use of all those inputs [Pfeiffer, pp. 81-86]. Income or cost distribution between the public and private sectors, however, depends on whether input use is controlled by taxation, restriction, or bribery.

The Analytical Model

The analytical model used was composed of two submodels. A linear programming submodel of the agricultural sector of the Basin and the hydro-

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logy of the Yakima River was used to determine the profit maximizing combination of crop activities and resource use subject to economic technological and hydrological constraints. Resource use, effluent output, and water flows determined in the linear programming submodel were used as inputs for an environmental quality simulation submodel. The simulation submodel used these and exogenously supplied data concerning physical and biological relationships governing environmental quality to estimate river nitrogen concentration, water temperature, and farm loss of sediment in each of seven river reaches and producing regions. The effectiveness, cost, and income distribution of alternative policies designed to improve water quality were then evaluated and compared from the results of these submodels. Each policy was imposed with increasing intensity until pollution abatement goals were reached or approximated. The desired environmental standards were a maximum river water temperature of 70°F, and maximum average soil loss in the river basin of one ton per acre. Economic efficiency of achieving these goals was measured by net social cost.[1] Agricultural impact and income transfer was measured by reduction in farm income, acreage and crop sales reductions, and taxes and charges collected.

Policy Options

The policies evaluated are represented by Solutions 1 through 6 below:

Solution 1 represents existing agricultural production and environmental quality in the Yakima Basin for use as a comparison with other policies.

Solution 2 imposed a tax on nitrogen fertilizer to control the level of its use for pollution abatement.

Solution 3 imposed a per-acre-foot charge for irrigation water delivered to the farm to reduce water use.

Solution 4 reduced water rights by a uniform percentage in all regions of the Basin.

Solution 5 combined a nitrogen fertilizer tax with a charge for irrigation water.

Solution 6 combined a nitrogen fertilizer tax with a uniform reduction of water rights.

[1] Net social cost is defined as the reduction of producer income minus taxes and charges collected for abatement purposes (when applicable).

Results

Table 1 shows the results of policies which met the proposed maximum nitrogen concentration and water temperature goals. All policies except the nitrogen tax, Solution 2, satisfied the sediment loss goal.

The means by which the policies met environmental goals depended on which inputs were affected. The nitrogen tax of $.60 per pound (Solution 2) reduced fertilizer use by 46 percent and irrigated acreage by 9 percent. Fertilizer use was reduced on all crops, but most noticeably on forage crops. The increase of water flow in the lower river caused by reduced water diversions was sufficient to reduce water temperature below 70°F. Sediment loss was also improved, but remained above one ton per acre. Crop income in the Basin was reduced 41 percent by the nitrogen tax. The income reduction was caused by a major reduction in forage crop output, small reductions in row and field crops, and the collection of approximately $30.8 million in nitrogen taxes from agriculture. The redistribution of income would clearly reduce land values and the limited forage output would reduce livestock dependent on harvested feed during the winter.

A water charge of $20.00 per acre-foot, Solution 3, satisfied the nitrogen concentration goal by simultaneously reducing nitrogen leaching and increasing river flow which had a diluting effect on remaining effluents. The 42 percent reduction of irrigated land was largely forage crops, leaving the output of high value crops relatively unaffected. The water temperature goal was met as a result of the increased water flow. This policy of charging for water reduced farm income by $28 million, $16 million less than the nitrogen tax in meeting desired water quality standards. In addition, the water charge fostered the use of more efficient irrigation systems and would clearly induce better irrigation management. Also, the adoption of improved irrigation systems substantially diminished sediment loss. However, the expected adoption of sprinkler and tailwater reuse irrigation systems would require substantial capital investment by farmers.

Proportionally, reducing water rights, Solution 4, had effects similar to those of the water charge except that income was not redistributed by input charges. Consequently, producer income was re-

Table 1. Summary of policies meeting proposed nitrate-nitrogen concentration, water temperature, and soil loss standards in the Yakima River Basin

Item	Unit	Solution					
		1[a]	2	3	4	5	6
Policy Constraint							
N tax	$/lb.	–	.60	–	–	.20	.20
Water charge	$/ac. ft.	–	–	20	–	10	–
Water rights reduction	Percent	–	–	–	50	–	40
Agricultural Impact							
Crop acreage	1,000 acres	453	420	261	288	296	322
Net crop income	$1,000	106,910	62,972	78,959	90,317	75,233	81,757
Net producer cost	$1,000	–	43,938	27,951	16,593	31,676	25,153
Taxes and charges collected	$1,000	–	30,774	16,057	–	22,012	12,772
Net social cost	$1,000	–	13,164	11,894	16,593	9,664	12,431
N applied per acre	lbs.	209	122	269	237	203	198
Water diverted	1,000 ac. ft.	2,393	1,916	1,069	1,219	1,344	1,464
Environmental Impact							
River flow, August[b]	1,000 ac. ft.	100	176	251	228	219	170
N concentration, August	mg/1	0.87	0.28	0.28	0.30	0.27	0.30
Sediment lost per irrigated acre	tons	1.74	1.30	0.35	0.37	0.77	0.40
Maximum temperature	°F	75.5	69.8	67.6	67.8	68.5	68.6

[a]Benchmark solution
[b]Flow at river mile 30

duced by only $17 million, 16 percent, by a 50 percent reduction of water rights which was necessary to meet environmental goals. However, social cost was almost $5 million higher than when using a water charge because an inefficient distribution of water among regions resulted from uniformly reducing water rights in all regions. From a policy standpoint, these inefficiencies might well be outweighed by the more acceptable reduction of producer income caused by this policy. Required capital investment for improved irrigation systems induced by this policy might be ameliorated through subsidized loans if that were a political restraint.

Solution 5 combined a nitrogen tax of $.20 per pound with a $10.00 per acre-foot charge for water, while Solution 6 combined the same nitrogen tax with a 40 percent reduction of water rights. Solution 5 resulted in the lowest net social cost of all policies considered because it affected both of those inputs primarily related to environmental degradation. However, the taxes and charges collected caused farm income to decline more than any other policy except a nitrogen tax, Solution 2. This income redistribution would adversely affect the farm sector as would the capital expenditure caused by the water charge.

Solution 6, a combination $.20 per pound tax on nitrogen and 40 percent reduction of water rights, had 29 percent higher social costs than Solution 5, but was less costly to producers. Farm income fell by 23 percent in Solution 6, while it fell by 30 percent under Solution 5. For this reason this policy, though less efficient, would probably be more politically acceptable than the use of a water charge.

Conclusions

This research has shown that it is possible to improve water quality in the Yakima River to high-quality river standards by controlling agricultural inputs or activities. The environmental improvement was accomplished with a reduction of farm income ranging from 16 percent to 41 percent, depending on the policy employed. In addition to reducing farm income, these policies would also impose a burden on the agricultural input supply and agricultural processing firms. In all cases, the primary crops affected were low value forage crops. Consequently, the livestock sector would be affected most.

Net social cost ranged from $9.7 to $16.6 million depending on the policy used. A trade-off existed between economic efficiency and producer cost. For example, a combination nitrogen tax and water charge had the lowest net social cost but was relatively expensive to farmers. Reducing water rights uniformly had the highest social cost of policies evaluated but the least cost to farmers. This policy would minimize adverse agricultural impacts.

These results show that considerable improvement in water quality, approximately 50 percent of the distance to desired water quality standards, can be achieved without significant costs to agriculture or the public [Pfeiffer, pp. 153-217]. However, additional improvement becomes very expensive as indicated by the above discussion.

The ultimate choice of policies to control water pollution depends upon many factors. Efficiency will be of primary concern, but the distribution of costs between the public and private sectors will probably carry greater importance in the political arena. In any case, state and federal agencies are proceeding to develop policies to meet the desired standards of water quality, often with less than perfect information regarding the effectiveness or cost of such policies. It is expected that this research will be a valuable input in designing these policies.

This research has estimated the costs to society and agriculture that might be imposed by policies to improve water quality. However, society desperately needs a better measure of the benefits to be derived from higher water quality. In some cases, the Yakima River Basin for example, it is doubtful that societal benefits from having a river meeting the environmental standards evaluated here would be as high as the costs of achieving that standard. Hopefully, someone can address this important problem with well-designed research in the near future.

References

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