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RELATIVE COST EFFECTIVENESS OF AGRICULTURAL AND URBAN NONPOINT POLLUTION CONTROL

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Abstract

The relative cost effectiveness of agricultural and urban BMPs in improving receiving water quality is investigated for a river basin within a designated 208 area. Implications of agricultural BMPs being more cost effective than urban BMPs for implementation for cost-efficient nonpoint pollution control strategies are discussed.

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Introduction

Pursuant to the Federal Water Pollution Control Act of 1972, Section 208 planning efforts have been focused on nonpoint pollution control in primarily metropolitan areas.[1] Though many of these areas have a significant proportion of land in agricultural uses, the 208 planning process has been focused upon urban best management practices (BMPs).[2] However, if a given improvement in water quality within a designated 208 area is to be obtained at minimum cost, a key issue is the relative cost effectiveness of agricultural and urban BMPs. The Occoquan River Basin in Northern Virginia which is included in the Washington, D.C., metropolitan 208 area illustrates the issue. The Occoquan Reservoir, which currently provides municipal water supply for over 600,000 persons and 40,000 recreational fishing visits annually, has been exhibiting symptoms of cultural eutrophication for several years (NVPDC, 1979). Recent 208 planning studies by the Northern Virginia Planning District Commission (NVPDC) have indicated that without implementation of nonpoint control there will be continued deterioration of the water quality of the Reservoir (NVPDC, 1979). As a result, the four counties (Fairfax, Fauquier, Loudoun and Prince William) and two cities (Manassas and Manassas Park) with land in the Basin have endorsed a goal of minimizing further deterioration in the water quality of the Reservoir (NVPDC, 1979a). Although more than one third of the 375,000 acres of land in the Basin is expected to remain in agricultural use through the end of the century, the planning emphasis has focused on the cost effectiveness of urban BMPs in achieving the 208 water quality goal.

However, a water quality simulation (WQS) model developed for the Occoquan Basin does offer an opportunity to analyze the relative cost effectiveness of agricultural and urban BMPs in the Occoquan Basin. Findings from this urbanizing watershed could have implications for other 208 areas. The structure of this paper is as follows. First, attention is given to the characteristics of the WQS model which allow for a valid comparison of the effectiveness of agricultural and urban BMPs in improving water quality in the Occoquan Basin. Second, a summary of the cost-effectiveness analysis is presented. Finally, implications for policy and research are outlined.

<u>Effectiveness of BMPs</u>

Most analyses of BMPs have focused on reducing sediment and nutrient loss from a given land area. However, a more relevant focus would be on the impact of reductions in sediment and nutrient loss on ambient water quality. In the case of the Occoquan Reservoir, chlorophyll <u>a</u> concentration in the April-October period served as an indicator of the eutrophic state of the reservoir (NVPDC, 1979). Phosphorus is the limiting nutrient in the Occoquan eutrophication process. However it is not simply the annual delivery of total phosphorus to the reservoir which controls the chlorophyll <u>a</u> concentration during the April-October period. Dissolved forms of phosphorus are more readily available to contribute to reservoir eutrophication than is phosphorus adsorbed to sediment; also, phosphorus delivered during the April-October period itself is relatively more important. These latter two points are important for the analysis of relative effectiveness of BMPs for two reasons. First, the form and timing of phosphorus loading differs across land-use types, e.g., phosphorous loads from urban land uses generally have a higher dissolved fraction of phosphorous than those from conventionally tilled corn (NVPDC, 1979b). Second, the form and timing of phosphorus loading reductions differ significantly across types of BMPs, e.g., sediment detention basins are relatively less effective in removing dissolved forms of phosphorus than is streetsweeping (NVPDC, 1979b). Therefore, an analysis of the relative cost effectiveness of agricultural and urban BMPs in improving water quality requires a model which accounts for the effect of the form and timing of pollutant loading on receiving water quality.

The WQS model of the Occoquan Basin does this in the following way. First, the WQS model projects storm runoff and associated phosphorous content from each land use within the basin on an hourly basis.[3] Second, the WQS model routes the flow of storm runoff and associated pollutant through the free-flowing streams to the headwaters of the Occoquan Reservoir. Third, the model predicts water quality changes in the Reservoir from the phosphorus delivery.

Simulation of the effectivenes of various BMPs in improving water quality is accomplished by adjusting model parameters to reflect changes in land-use practices which affect the quantity and quality of storm runoff, e.g., the rate of dry weather pollutant accumulation for streetsweeping or the percentage of vegetative cover for a shift from continous corn to continuous hay. Comparison of reservoir water quality with and without application of a particular BMP indicates the BMP's effectiveness in improving water quality.

Cost-Effectiveness of BMPs

Urban land was separated into two classes--that which is already developed and that which is expected to be developed in the future. The only urban BMP considered for existing development was vacuum streetsweeping.[4] Effectiveness estimates for streetsweeping were made assuming one pass per week for residential and institutional land uses and three passes per week for commercial land uses across all urban land in the Basin.

Several of the jurisdictions in the Basin currently (or soon are expected to) require stormwater detention basins for flood control on new development. In its evaluation of sediment detention basins for water quality control the NVPDC considered a modified structural design for detention basins which would provide a level of flood control equivalent to what is now required in the Basin, while achieving significantly higher rates of sediment and phosphorus removal. In such case the relevant cost and effectiveness are the incremental amounts associated with modification of the flood control structure.[5] Effectiveness estimates for this urban BMP were based on its application to all land projected by the NVPDC to be developed for urban uses over the 1979-2005 planning period.

Estimates of annual cost (1979 dollars) per acre for the urban BMPs were based on engineering cost data developed by the NVPDC. Useful lives were assumed to be 6.7 years and 40 years for streetsweepers and sediment detention basins, respectively. Capital costs were annualized assuming interest rates of 7% and 10% for streetsweeping and sediment detention basins, respectively, to reflect the differential between public and private costs of borrowing. Annual operation and maintenance costs were also estimated. Per acre costs were obtained by dividing the total annual costs for streetsweeping and modification of detention basins by the number of acres each was applied to.

For consideration of agricultural BMPs, a representation of current land use and practices was needed. The NVPDC, with the help of local planning agencies as well as SCS and ASCS offices, estimated total cropland acreage for each of the four counties in the Basin for inclusion in the WQS model. Discussions with SCS and extension personnel in the Basin indicated that a rapid shift from conventional tillage to minimum tillage has been occurring (such that two of the counties have little or no conventional tillage) and can be expected to continue.[6] Thus, the base case from which agricultural BMP's effectiveness and costs were analyzed was one of minimum tillage exclusively.

The three major groups of crops in each county in the Basin are corn (both for grain and silage), small grains (primarily wheat, barley, and rye), and hay (primarily orchard grass-red clover). Some land in the Basin is planted in corn and hay continuously, while some is planted in a rotation. This is important from the standpoint of suggesting potential BMPs involving shifts to less intensive rotations. The predominant rotation in the area involves two years of corn, a small grain (usually wheat) planted in the fall after the second-year corn harvest, overseeding of hay the following spring, and two more years of hay alone--a five-year rotation abbreviated by CC(WH)HH.

Based on discussion with SCS and extension personnel in the Basin and research-extension personnel in the College of Agriculture at VPI & SU, a set of alternative agricultural BMPs was chosen for analysis with the WQS model.[7] For acreage currently in continuous corn alternative BMPs considered included a shift to the five-year rotation described previously, CC(WH)HH; a shift to a three-year rotation with no corn, (WH)HH; and a shift to continuous hay. For acreage currently in CsC(WH)HH rotation (where Cs indicates corn for silage), alternative BMPs considered included a shift to (WH)HH and a shift to continuous hay. The changed crop patterns were entered into the WQS Model and the resulting impact on water quality was simulated.

Costs for the agricultural BMPs were calculated as reductions in net returns from changes in cropping patterns. Enterprise budgets, 1974-78 average yields, and 1974-78 average prices plus 10% (to reflect the effect of inflation on expected prices in 1979 dollars) were used to estimate expected net returns for each of these alternatives. No adjustment was made to reflect on-site benefits in terms of long-term soil productivity maintenance due to relatively small level of such benefits found in studies at the University of Illinois (see Lee, et al. (1974) for example), and the expectation that given the large amount of projected urban development in the Basin, most farmers would discount such benefits significantly.

The results of the analysis are presented in Table 1 in terms of reductions in chlorophyll a concentration per thousand dollars of annual BMP application.[8] As is evident, shifts from continuous corn to less intensive rotations appear to be the most cost effective, followed by the multipurpose modification to sediment detention basins, elimination of corn from land already in rotation, and streetsweeping. It should be noted that no complementary benefits were assumed for streetsweeping in terms of the aesthetic value of cleaner streets and parking lots. For example, if half the cost of streetsweeping could be justified on the basis of aesthetic value, its cost effectiveness for water quality purposes would be .0030 rather than .0015. Thus, streetsweeping may well be competitive with the other BMPs in the set, except for shifts from continuous corn to less intensive rotations.

Implications

From the standpoint of the Occoquan Basin it appears that the initial focus of nonpoint pollution control efforts should be on land now in continuous corn. A significant acreage of land in continuous corn can be expected to remain even at the end of the 1979-2005 planning period. However, by about 1990 conversion of all land in continuous corn to a five-year rotation with two years of corn will not apparently be sufficient to attain the 208 planning goal of maintaining the 1979 level of water quality in the Occoquan Reservoir. As such, it would appear necessary to employ multipurpose modifications to sediment detention basins by that time. However, since the multipurpose modifications must be incorporated at the time of urban development,

TABLE 1. COST EFFECTIVENESS OF AGRICULTURAL AND URBAN BMPs

	Reduction in April-October average chlorophyll *a* concentration in the Occoquan Reservoir per thousand dollars of annual BMP application
Urban BMPs	
Streetsweeping	.0015
Multipurpose modification to sediment detention basins	.0046
Agricultural BMPs	
Continuous corn to CC(WH)HH	.0100
Continuous corn to (WH)HH	.0080
Continuous corn to continuous hay	.0071
C_sC(WH)HH to (WH)HH	.0034
C_sC(WH)HH to continuous hay	.0032

there might be justification for implementing a requirement for them at the present time. Though the cost of urban BMPs can likely be passed on by developers and spread broadly among many urban residents, farmers must bear the cost of BMPs, in the form of income reductions. Thus, extensive implementation of agricultural BMPs, such as a shift from continuous corn to a less intensive rotation, would almost certainly require that compensation be given to the farmers involved in order to facilitate adoption of the BMP. Since significant federal funds for this purpose are not likely to be available, raising funds for compensation from local beneficiaries of water quality improvement will be necessary.

From the standpoint of 208 areas generally, a better integration of planning for urban and agricultural nonpoint pollution control is called for. This would encourage a focus on cost efficiency on an area-wide basis rather than for urban and agricultural control separately. This point is particularly persuasive when one considers the relative cost effectiveness of agricultural BMPs even within the urbanizing Occoquan Basin. Also, development of local compensation mechanisms to insure acceptability and implementation of cost-efficient nonpoint pollution control strategies will be necessary in designated 208 areas, generally to the extent that agricultural BMPs are determined to be a part of the cost-efficient strategy.[9]

A number of future research areas can be suggested, as extensions of this study. One area would be that of assessing the complementary benefits associated with both urban and agricultural BMPs that affect the real cost of BMPs from the standpoint of water quality improvement.

Examples here include aethestic benefits of streetsweeping, flood central benefits of detention basins, and soil productivity benefits of agricultural BMPs. Another research area would be on factors which may alter the relative attractiveness of urban and agricultural BMPs such as indirect effects on urban development patterns or prices for agricultural products.

Also, to the extent that compensation should be offered to farmers who adopt BMPs there are several possible areas for research. First, should compensation to individual landowners be given as a direct cash payment, or in an indirect form such as a property tax reduction? The form in which compensation is made may affect the attitude and actions of both beneficiaries who are to provide the compensation and those who implement the BMPs. Likewise, alternative forms of mechanisms for raising revenue from local beneficiaries may be a fruitful research area.

Second, how do farm-operator objectives, other than expected net returns, affect the level of payment that would be necessary to compensate those who implement BMPs? For example, reduction of the variance in farmers' expected net returns may be of positive value to him. This reduced income variance may arise from BMPs using no tillage practices which hold spring moisture and lessen yield reductions in drought years. The significance of objectives other than net income may alter the level of compensation necessary to induce BMP adoption. Surveys of farmers aimed at eliciting realistic estimates of what level of subsidy would be required to induce adoption of various BMPs may be a fruitful research area.

Third, should BMP implementation (with compensation) be required or voluntary? Suppose for purposes of discussion that the cost of agricultural BMPs is not the same across all farms, but rather is distributed symmetrically around the level for the average farm. Requiring BMP adoption and then offering the average cost of adoption as compensation would result in some farmers receiving compensation insufficient to cover BMP costs. In such cases enforcement costs could be expected to be relatively high since some farmers would seek to avoid the regulation. This problem could be overcome by offering each farmer compensation equal to the costs he incurs from compliance with the regulation; however, the information costs of identifying each farm's compliance costs would be high.

On the other hand, compensation could be offered to those who voluntarily adopt BMPs, with the rate of compensation equal to the average cost of adoption. This would be expected to result in BMP implementation on the half of the acreage with less than average cost. Information costs would be relatively low, and since no farmers would be worse off, enforcement costs would be relatively low. Increased levels of compensation could be used to induce BMP implementation on higher proportions of acreage.

The above argument would appear to favor a voluntary approach since it has lower information and enforcement costs. However, not only cost but also the effectiveness of BMPs will vary across acreages within a land-use type. To the extent that research could determine the basis for such a variance, regulations could be targeted (with compensation) to those areas where BMP cost effectiveness is highest first. This would reduce nonpoint waste loading at least BMP cost, though the information costs of targeted regulations would be high. A voluntary approach, although it has minimum information and enforcement costs, would not insure that maximum waste loading reductions per dollar of compensation were achieved unless the unlikely situation held that the acres causing the greatest waste discharges were those with the lowest cost for BMP adoption. Therefore, the choice between voluntary and required approaches will depend upon a research comparison of the expected information and enforcement cost savings of the voluntary approach with the increased cost efficiency of the targeted regulatory program.

It should be noted that if significant progress is to be made along these lines, and if research results are to be brought to bear on policy making, economists must be willing and able to work with researchers in other disciplines, regional and local planners, and public decision makers. The need for interfacing economic modeling with physical, chemical, and biological modeling on the one end and communicating efficiency and distributional implications of such modeling on the other end is apparent. Without the existence of the WQS model, the research reported in this paper would not have been possible. However, the Occoquan Basin is one of the few areas in the nation where such a model is available.

A final point which must be made is that while research on these and other related questions will be useful, there may come a point where it would be preferable to use funds to implement BMPs rather than allocate them to further research. Research can be expected to go only so far in improving our information base in the area of nonpoint pollution control, and at some time the benefits of further research in this area can be expected to fall below the costs. What may be needed are experimental programs where the response of landowners to particular levels and forms of compensation and the response of water quality to BMP implementation can be observed under real-world conditions. Based upon such experience, appropriate adjustments in existing programs, as well as new programs, could be designed.

FOOTNOTES

[1]Nonpoint pollution refers to discharges of waste which are carried off the land by storm runoff over a widely dispersed area.

[2]The term best management practices (BMPs) has gained wide use in 208 planning. These BMPs are practices of land use and land management which can effectively reduce the discharge of pollutants from nonpoint sources.

[3]Selection of the typical hydrometerological year is documented in Hydrocomp, Inc. (1978).

[4]The NVPDC staff concluded that the costs of retrofitting existing development with structural measures such as sediment detention basins would be prohibitively high.

[5]Volume controls and sediment detention basins with chemical treatment which are both substitutes for sediment detention basins, provide greater phosphorus loading reductions per acre than such a multipurpose modification to sediment detention basins, but at a significantly higher per unit control cost.

[6]The rising price of fuel relative to chemicals (i.e., herbicides and insecticides) has likely been a key impetus for this change.

[7]Due to data and time limitations, the set was limited to those which could be widely applied and for which net cost and effectiveness could be estimated with some confidence. This elminated site-specific BMPs such as livestock waste management systems; a shift to no tillage for continuous corn, since a recent study has suggested that such a shift may actually increase biologically available phosphorus loading, even though sediment loss is significantly reduced (Meta Systems, Inc.,

1979); pasture improvement, for lack of data as to its effect on phosphorus loading; and zero-cost practices such as cross-sloping and stripcropping. Contouring and terracing were excluded due to both the lack of steep slopes and difficulty posed by the large, heavy machinery currently being used.

[8]The underlying cost-effectiveness estimates for the agricultural BMPs in terms of reductions in total phosphorous or biologically available phosphorus loading are comparable to similar estimates in Casler and Jacobs (1975), Miller and Spires (1979) and Meta Systems, Inc. (1979).

[9]Other studies which have identified institutional impediments to implementation of 208 plans include Hartley and Price (1975), Allee, et. al. (1977), Castilli and Dines (1978) and Hamilton and Libby (1979).

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