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ANALYSIS

Integrating economic, environmental and GIS modeling to target cost effective land retirement in multiple watersheds

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Abstract

An integrated framework of economic, environmental and GIS modeling is developed to study cost-effective retirement of cropland within and across multiple watersheds to achieve environmental goals. This framework is applied to 12 contiguous agricultural watersheds in the Illinois Conservation Reserve Enhancement Program region of the United States. A key goal of this program is to reduce sediment loadings in the Illinois River by 20% by retiring land from crop production. The characteristics of land parcels to be targeted for retirement within each watershed and the criteria for cost-effective allocation of abatement responsibility across watersheds are analyzed. Our analysis suggests that program costs are minimized when the abatement standard is set for the region rather than uniformly for each watershed. For both policy scenarios, the land parcels targeted for retirement should be those that are highly sloping and adjacent to a water body.

Keywords: Cost effectiveness; Land retirement; Multiple watersheds; Uniform and non-uniform standards

1. Introduction

Increasing emphasis on protecting water quality from nonpoint pollution sources has led to a shift in the policy objectives of conservation programs, such as, the Conservation Reserve Program (CRP), from on-site erosion control towards controlling off-site sediment loadings. More recently, with the development of the Conservation Reserve Enhancement Program (CREP) the focus of these programs has shifted towards achieving explicitly defined goals for water quality in locally identified environmentally sensitive river basins. The goals of the CREP in Illinois include a 20% reduction in sediment loadings, a 10% reduction in nitrogen and phosphorus loadings and an increase in aquatic and wildlife populations in the Illinois River (USDA, 1998). The program seeks to achieve these goals by retiring about 94 thousand hectares of cropland in the Illinois River Basin for at least 15 years and possibly for 35 years or

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permanently through offering rental payments to landowners based on soil productivity. Eligible land for enrollment is defined as cropland within the basin's 100-year floodplains, highly erodible cropland adjacent to riparian areas, and cropland where landowners are willing to create wetlands. A secondary program restriction requires that 85% of the land enrolled be within the basin's environmentally sensitive riparian areas defined above as 100-year floodplains. The amount of eligible land is spread out over 100 sub-watersheds[1] and is more than six times larger than the program's acreage enrollment goal of 94 thousand hectares.

This raises two program implementation issues on which the program description itself is silent. First, should land enrollment be targeted to achieve the environmental goals of the program at the sub-watershed level or in the aggregate for the river basin as a whole? Second, what types of land parcels should be selected for enrollment in each sub-watershed to achieve the environmental goals cost-effectively?

The literature in environmental economics suggests that when polluters are heterogeneous, an aggregate abatement goal can be achieved cost-effectively if each polluter undertakes pollution abatement such that the cost of the last unit of abatement is equalized throughout the river basin (Baumol and Oats, 1971). This concept implies that more abatement will occur in sub-watersheds with low abatement costs, and less abatement will occur in high abatement cost sub-watersheds; implying that a non-uniform performance standard will be more cost effective than a uniform standard. However, a social planner may prefer a uniform performance standard where the same abatement goal must be achieved in every sub-watershed, for equity reasons (Schleich et al., 1996), or to reduce transaction costs. The first objective of this paper is to estimate and compare differences in costs, hectares retired and land retirement patterns between the two performance standards on sediment loadings.

The second objective is to develop criteria for the land parcels that should be selected for enrollment to meet the sediment abatement goals of the program cost-effectively. Land parcels even within a watershed are heterogeneous in their characteristics and differ in their opportunity costs of retirement (that is the forgone profits from crop production) and in the extent to which their retirement would reduce off-site sediment loadings in the water body. Babcock et al. (1996, 1997) suggest that land with the highest abatement benefits to opportunity cost ratio should be selected to achieve abatement goals efficiently. Determining the contribution of each land parcel to off-site sediment loading requires estimation of its sediment-trapping coefficient, and those of the downslope parcels. Each parcel's coefficient depends on that parcel's site-specific characteristics (slope, soil characteristics, and distance from the water body) and land use decision (crops, trees, pasture or grass) as well as highly complex interdependencies between land use and sediment trapping efficiencies of upslope and downslope land parcels. Thus, the sediment deposition coefficient of a land parcel needs to be determined endogenously with the land use decisions upslope and downslope parcels.

To address these issues we develop an integrated economic, environmental and GIS modeling framework that includes an endogenously determined sediment transport process and incorporates the micro-economic decision by a farmer to retire land or continue crop production and the environmental impacts of such decisions. This framework extends the model development in Khanna et al. (2003) and applies it to compare cost, acreage, location and parcel differences between a non-uniform and uniform standard across twelve sub-watersheds in the Illinois River Basin.

Our research builds upon previous studies of environmental programs on land use and farming practices in several ways. A few studies have

[1] A sub-watershed is defined as an 11-digit watershed. Watersheds are delineated by USGS using a nationwide system based on surface hydrologic features. Regions are defined using a 2-digit classification, subregions are defined at the 4-digit level accounting units and cataloguing units are defined as the 6 and 8 digit levels. A watershed is defined using an 11-digit classification system and its size can vary between 16,000 and 101,000 hectares. For details, see http://www.ftw.nrcs.usda.gov/UC/ni170304.html.