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SYMONS HALL
UNIVERSITY OF MARYLAND
COLLEGE PARK 20742

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Sequential Coordination of Agricultural and Resource Policy

by

John Horowitz
and
Kenneth McConnell

Department of Agricultural and Resource Economics
University of Maryland
College Park, Maryland 20742

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1. Introduction

This book is about policies that affect both agriculture and environmental quality. Its aims are to analyze the effects of agricultural policies on the environment and the effects of environmental and natural resource policies on agricultural practices. Various chapters consider, for example, the effects of agricultural commodity programs on pesticide use, soil runoff, or human health, or the effects of pesticide regulations on farm profits.

Our chapter examines the relationship between these agriculture-oriented policies and a second set of resource and environmental policies that often have no direct effect on agriculture. These policies, however, help determine the size of the environmental externality that agriculture generates. Thus they should be part of any discussion of the relationship between agricultural and resource policy.

An example of such a resource policy comes from commercial fishing. How the commercial fishery is managed does not affect either the profitability of agriculture or resource-use decisions made by the farm sector. It does, of course, affect the size of the rent gained from fishing. If the fishery is managed efficiently, it will provide rents as implicit payments for the fishstock as a factor of production. The reduction in benefits due to water

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We thank Tim Phipps and Kitty Reicheldorfer for help on the various agricultural and environmental policies relating to agriculture. We consulted numerous USDA publications that they recommended.

pollution from agriculture might therefore be large, since water pollution has the potential to cause a large decrease in welfare. If the fishery is open access, there is little rent accruing to it. In this case, the adverse effects of agricultural pollution will likely be small.

Our purpose in this chapter is to discuss natural resource policies of this sort, and to analyze how they affect the economic impact of agricultural policies that pollute the environment. We treat traditional agricultural policies that manipulate prices, farm income or supply, together with environmental policies that regulate agricultural practices. Together this group constitutes the set of agriculture-oriented policies that influence on-farm resource use. These policies also affect runoff water quality and quantity, including timing, temperature and volume of flow, and the levels of dissolved sediment, nutrients or pesticides. Although water pollution is the principal externality arising from farming, resources other than water are also affected. Agriculture-oriented policies can affect the levels of pesticides that persist on-farm, exist as residues on agricultural products, or are transported through the air.

Resource policies, as we use that term in this chapter, refer to policies that affect the extraction or use of natural resources or the environment but do not affect any of the resources that are used as inputs in agriculture.

The distinction between agriculture-oriented policies and natural resource policies becomes important when we discuss policy coordination. Because the level of agricultural pollution is determined primarily by agriculture-oriented policies, while the size of the externality it generates is determined by resource policies, we call the interaction between agricultural and resource policies sequential coordination.

The following section reviews the relevant agricultural and resource

policies. Section 3 discusses several examples of sequential coordination of agricultural and natural resource policies.

An alternative type of coordination might occur when one agriculture-oriented program promotes pesticide use while another restricts it. This type of coordination will not be covered in this chapter.

2. A Survey of Relevant Agricultural and Natural Resource Policies

This section gives a summary of agricultural and natural resource policies. There is, of course, no strict line dividing them. In general, agricultural policies tend to be federal policies and resource policies tend to be under state or local jurisdiction. This separation of jurisdictions is apt to make sequential coordination of policies especially difficult.

The principal agricultural policies are the commodity programs and acreage reduction programs administered by the U.S. Department of Agriculture. Resource policies such as water supply decisions or pricing rules are usually under the jurisdiction of local or regional water control boards. Commercial and recreational fishing policies for fish stocks inside three miles are made by state governments. Important resource policies do exist at the federal level; an example is the federal Clean Water Act. Even in this case, however, the nonpoint source standards required by the Act are left for the states to draw up. By the same token, there are many agricultural policies that originate at the state level, such as pesticide regulations or use-based taxation designed to keep land in agriculture.

2.1 Agricultural Policies

We first describe programs administered by the U.S. Department of Agriculture (USDA). Within the USDA, the programs that affect the largest number of farmers are those administered by the Agricultural Stabilization and Conservation Service (ASCS). The ASCS administers two types of programs. One

type attempts to influence farm income through controls on aggregate supply or the farm price of commodities. A second type attempts to conserve farm resources, principally by reducing soil erosion. The first type includes the commodity programs and acreage reduction programs. Commodity programs provide target prices or market price floors (loan rates) that producers will receive for their products. To support prices at a cheaper cost to the government (or the environment), supply controls may be implemented. For example, to be eligible to receive the target price, a producer may also have to participate in some sort of production control program, such as the acreage reduction program (explained below). Often the target price will be received by producers only for crops grown on particular "base acres". Export enhancement and payment-in-kind may also be used to reduce quantity supplied to the domestic market. For some commodities, domestic supply is controlled through import restrictions (beef, sugar, dairy) or domestic restrictions on production in the form of allotments (peanuts, tobacco). Domestic supply controls may be in effect for commodities for which a target (domestic) price or loan rate is not specified. The extent of market intervention and the nature of supply controls differs among commodities.

Supply control has primarily been accomplished through a voluntary set-aside program called the Acreage Reduction Program (ARP). This program provides producers with an incentive to retire land planted to particular crops by making retirement a requirement for eligibility for some commodity programs. The Paid Land Diversion Program acts in a similar way.

The ASCS also administers programs aimed at reducing soil erosion. The principal programs are the Agricultural Conservation Program (ACP), the Forest Incentives Program, and the Conservation Reserve Program (CRP).

The ACP is a cost-sharing program. Its aim is to induce farmers to adopt soil-conserving practices by sharing some of the construction costs of these practices. A wide variety of practices is eligible for cost sharing. Construction of terraces to reduce a field's slope, for example, can be partly paid for by the ACP. The Forest Incentives Program, Great Plains Conservation Program (now discontinued), and Small Watershed Program also provide cost sharing and technical assistance. These programs have not been designed with the externalities of soil erosion in mind.

The CRP was introduced in the 1985 Food Security Act. This program is aimed at reducing soil erosion, although reducing the externalities caused by erosion was not a primary goal of the program. CRP pays farmers to plant certain acres in grass or trees or to use less erosive practices. USDA rules have recently made filter strips along water bodies eligible for enrollment in the CRP. This move suggests that there is increased recognition of the external benefits of reducing soil erosion.

In addition to these programs which directly subsidize conservation practices, agencies of the USDA operate a variety of programs (such as Conservation Technical Assistance) that provide technical advice and research for farming practices that enhance farm productivity, including the reduction of soil erosion. The Soil Conservation Service and the Cooperative Extension Service are two agencies that administer these kinds of programs. Many of the research projects carried out by the state agricultural experiment stations and the USDA itself provide input to the technical assistance which is extended to farmers.

The commodity support policies and soil conservation policies are the principal means for influencing agriculture's use of the environment by the USDA. The USDA administers many other programs that enhance the profitability of farming. These include programs that loan funds or provide insurance. The

Farmers Home Administation and the Federal Crop Insurance Commission are two of the agencies that administer these kinds of programs.

There is a tendency in discussing the environmental externalities of agriculture to restrict attention to crops and to ignore livestock. Price support and supply controls are administered by ASCS for livestock. Livestock production is also affected by grazing policies that are the jurisdiction of the U.S. Forest Service (USFS), which is part of USDA, and the U.S. Bureau of Land Management (BLM), which is part of the Department of the Interior. These two agencies determine grazing fees for federal land and the portions of federal land on which cattle and sheep will be permitted to graze. The availability of federal lands to graze livestock on is an important input to the livestock production process. Throughout this paper we will often lump livestock together with crops.

Outside the laws administered by USDA, the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) is one of the most important laws constraining agriculture. This law has been administered by the U.S. Environmental Progection Agency (EPA) since shortly after the EPA's creation in 1971. Pesticide regulation, authorized by the act, is carried out through the rules governing pesticide registration. Registration requirements spell out the types of crops, conditions, and application rates for each pesticide's use. FIFRA requires the EPA, in developing the regulations, to balance the expected health and environmental effects against the economic value of the pesticide as an input in agriculture. Monitoring and enforcement of the registration requirements are left to states.

Another set of policies that affects resource use in agriculture is the irrigation construction and water pricing decisions made by numerous state agencies and, at the federal level, by the Bureau of Reclamation (in the

Department of the Interior) and the Army Corps of Engineers. In general, the Bureau of Reclamation determines which water-providing projects to build and what prices to charge the water districts that are responsible for allocating the water. Who actually uses the water is determined by a complex set of state laws, although federal decisions may be important here if the water is deemed to be essential to interstate commerce (see the article by Harrison and Cummings in this volume). Because there has been little construction recently, most of the current work done by the Bureau of Reclamation is in setting water prices. Other federal agencies such as the Bonneville Power Administration also make water allocation decisions.

Of the programs and laws considered so far, only FIFRA was explicitly designed with the environmental quality effects of agriculture in mind. Other agriculture-oriented rules and programs may have substantial impacts on environmental quality, but these impacts received little consideration in the design of the policy. Laws directed specifically at environmental quality have more often taken account of the role of agriculture. For example, the principal federal legislation concerning water quality is the Clean Water Act. The original law concentrated on point sources, but the 1987 revision recognized the importance of nonpoint sources of pollution and named agriculture as one of the origins of such pollution. It requires states to develop plans to meet water quality goals. In their plans, states must deal explicitly with agriculture. There is, however, no relationship between USDA financial support or technical assistance for conservation on farms and the Clean Water Act.

The Safe Water Drinking Act sets standards for drinking water that apply primarily to groundwater. Agriculture is a primary source of groundwater contamination. States are responsible for implementing the standards.

State agricultural and resource policies include pesticide regulation (see the article in this volume by Wise and Johnson), soil erosion, cost sharing and technical assistance, water pricing, burning laws, and property taxation. As mentioned above, the role of state agricultural policies is small compared to the federal role. State resource policies do have a substantial effect on the size of the externality imposed by agriculture. These policies are described in the next section.

2.2 Natural Resource Policies

States and local governments play a much more direct role in regulating the use of the environment and natural resources than they do in regulating agriculture. Not only do the states have their own legislation concerning the environment, but also they are responsible for implementing substantial portions of the federal Clean Air Act and the Clean Water Act. This delegation of responsibilities makes good economic sense because the economic benefits from the environment have great local and regional variation and, unlike agriculture, cannot typically be traded across regions to equalize marginal benefits.

Non-federal government agencies regulate the use of a wide variety of natural resources through regulations encompassing activities from solid waste disposal to utility pricing. Our interest is in policies for those resources that are affected by agricultural externalities. Because agricultural externalities are largely waterborne, we will naturally be most interested in policies which regulate the use of water and related resources. These include non-federal policies over groundwater, surface water and related resources such as fish and game.

States have principal responsibility for regulating the exploitation of groundwater. Exploitation includes the use of both water quality (through fertilizer and pesticide pollution) and quantity. States have adopted numerous regulations over contamination of groundwater. Current proposed legislation calls for bringing the contamination of groundwater by pesticides under FIFRA. State laws also control the extraction of groundwater through prices or volume restrictions. In general, even in western states, groundwater has been available as an open-access resource.

In the Clean Water Act, states are responsible for implementing plans to attain given levels of surface-water quality. But more important, states and other non-federal jurisdictions make many rules governing the use of surface water. State water laws govern the consumption of water from streams and lakes. These laws are notorious for varying by state. Non-federal agencies, especially local governments and utility boards, determine water rates and water-supply facilities.

Many natural resources rely on surface water for habitat. Recreational and commercial uses of these resources are most frequently regulated by non-federal agencies. Recreational use of surface water is governed by many state rules and regulations. Freshwater recreational fishing requires a license in all states, and catches are frequently subject to size or quantity restrictions. Many fish species are stocked. Boating is subject to state laws. Except for nominal license or entrance fees, most other recreational activities are available for open access. Commercial fishing within three miles of the marine coast and in freshwater is regulated by the states or by regional compacts. These regulations typically entail nominal registration fees and occasional gear and season restrictions.

There are federal policies for resource exploitation. They include regulation of migratory bird hunting for a variety of species of waterfowl by the Fish and Wildlife Service of the Department of Interior. Waterfowl are affected not only by water quality but also by farming decisions such as draining swamps. In the case of saline irrigation water, the USDA directly governs both the polluter and the pollutee.

3. Three Examples of Sequential Coordination

3.1 The Property Rights for Fisheries Influence the Benefits of Water Quality

One of the biggest impacts of agricultural pollution is the reduction of biological capacity of water bodies (see Clark et al. (1985) for arguments). There are several reasons for this effect. One is the increased turbidity of water and the scouring of stream beds from extra sediments which come from soil erosion. Another is the loading of nutrients from excess fertilizer. A third is the impact of herbicides on subaquatic vegetation. These effects are present in estuaries, inland lakes and rivers, streams and ponds.

The economic costs of the reduction in biological capacity are diverse. For the sake of argument, let us categorize them in two ways: 1) the costs that result when a directly exploited species is less productive; 2) the indirect costs that are incurred when there are ecological effects that do not involve directly exploited species. The latter costs, call them ecological costs, are incurred for diverse reasons. Basically, the public, with knowledge of the decline in the productivity of an ecological system, would be willing to pay to prevent the decline. We concentrate on the more apparent effect: the productivity of commercially and recreationally sought fish stocks.

The benefits to recreational and commercial fishermen loom large in discussions of water pollution in general and the impact of agricultural pollution in particular. For example, in a synopsis of the benefits of water pollution control, Freeman (1982) cites estimates of the enhanced benefits to recreational fishing which range from $300 million to $10 billion (1978 dollars). In the campaign to enlist public support for improving water quality in the Chesapeake Bay, the potential returns to commercial fishermen have played an important role.

In this section we investigate the impact of the arrangements of property rights for fish stocks on the public's ability to benefit from improvements in water quality. We argue that when the fish stocks are allocated by open access, the benefits to fisheries from pollution control are less than when the harvest is managed optimally. Coordination of agricultural policy and resource policy might thus entail a better allocation of property rights to the fishery as an alternative to reductions in pollution to improve the biological productivity of fish stocks.

The arguments concerning the benefits to fisheries from improvements in water quality follow directly from the inefficiency of open access as found in basic fisheries models. Results for the basic fishery model may be found in Anderson (1977), while McConnell and Strand (forthcoming) analyze the impact of water quality on commercial fisheries. The basic argument is simple. In an open-access fishery, economic agents harvest fish without regard for the impact of their harvests on other agents. This external cost implies that competitive equilibria provide less benefits than social optima, where the optima require agents to account for their externalities, via some implicit or explicit assignment of property rights. When improvements in water quality increase fish stock productivity, open-access agents pursue the extra fish without regard for the social costs of their activity. In extreme cases improvements in water quality can result in no additional social benefits to the public. In all cases, better coordination in the form of assignment of property rights to fish stocks can enhance the benefits from improvements in water quality and increase the returns to reducing agricultural pollution.

Consider the recreational fishery. This fishery is characterized by anglers who take trips based in part on the rate at which they catch fish. An optimal fisheries policy is one which maximizes the anglers' surplus. A reduction in pollution ought to increase this surplus. The more efficient the fisheries policy, the more the increase in surplus. Suppose that the n anglers are homogeneous and that each angler chooses trips per season based on the cost per trip (denoted c) and the rate of catching fish per trip h. The trips per angler is given by x and the angler's inverse demand formation is p(h,x). The density of fish stocks is given by s. The catch rate, h, is an increasing function of stock density:

$$h = h(s).$$

The more fish there are, the more caught by trip: $h'(s) > 0$. Assume a concave growth function

$$\dot{s} = g(s)$$

which becomes

$$\dot{s} = g(s) - nxh(s)$$

when exploitation occurs. For simplicity, let us examine a static steady state, realizing that an optimal steady state involves considerations of discount rates, time paths, etc. (For the optimal steady state, see McConnell and Sutinen.) The fishery manager would maximize

$$(1) \qquad B(x,s,\lambda) = \int_0^x [p(h(s),t) - c]dt + \lambda[g(s) - xnh(s)]$$

which yields the conditions

$$(2) \qquad p(h,x) - c = \lambda h$$

(3) $$\lambda = \frac{\int_0^x p_h(h,t)dth'(s)}{xnh'(s) - g'(s)}$$

(4) $$g(s) = xnh(s).$$

The shadow value of the fish stock, λ, is positive for growth functions when $g'(s)$ is not "too" positive. λ can be likened to a fee which is imposed on fish caught. The equilibrium condition for trips entails a payment of λh per trip. This is the fee that internalizes the external cost of each angler's fishing.

Without assignment of property rights, when the fishery is in equilibrium, the conditions which determine the equilibrium level of trips and fish density are

(5) $$p(h(s),x) = c$$

(6) $$g(s) = xnh(s).$$

Compared with open access, the optimal system will have more fish stock (s higher) and fewer trips per angler (x lower). Naturally in open access, consumers' surplus will be less. As long as the fishery is operating on the increasing portion of g(s) ($g'(s) > 0$) catch will be greater in the optimal system. For most fisheries, it is reasonable to suppose that in open access, the fish stocks are thin enough so that increases, rather than decreases, in fish stock bring increases in yield.

When agricultural pollution is reduced, more vigorous fish stocks can result (with especially more vigor in the highly sought species). The increased productivity of the stock means that a given standing stock has greater productivity because natural mortality in each age class is likely to decline. In our simple model, improvements in water quality result in an upward shift in g(s). Let $g(s,\alpha)$ be the growth function which includes water quality, where α is an index for water quality, and higher α means better water quality. Improvements in water quality increase productivity, so

$$\partial \dot{s}/\partial\alpha = \partial g/\partial\alpha > 0.$$

A family of growth functions appears in Figure 1.

(INSERT FIGURE 1 HERE)

What happens to the surplus of the anglers when water quality improves the productivity of fish stocks? For incremental changes in fish stocks, the fishery with property rights gains more than the open access fishery. We analyze the movement from one long-run equilibrium to another. This ignores differences in short-run surpluses, but concentrates on the likely results after the improved water quality. In the long-run steady state, catch equals productivity:

$$g(s) = xnh.$$

An improvement in productivity can be taken partly as an increase in catch and partly as investment in denser fish stocks. Letting water quality increase by $\Delta\alpha$ gives an increase in productivity of $g_\alpha\Delta\alpha$. When part of the enhanced productivity is reinvested, it produces extra catch at the rate g_w. The final increase in fish stocks depends on the amount of the initial dividend consumed as catch and the amount invested in growth.

The value of the pollution reduction program can be assessed by the shadow value of the fish stock. For the system with property rights, the value of an additional unit of fish stock is λ. In open access, where external costs are ignored and fish are regarded as free, the value of extra fish is zero. Consequently, starting from equilibrium in each system, marginal increments of fish stock are more highly valued when resource policy ensures that fishery behavior is consistent with well defined property rights. Hence, when the resource is optimally managed, the social returns from enhancing fish stocks are higher.

The results for a commercial sector are more precise. In the commercial fishery, efficient allocation of property rights tends to maximize consumers' plus producers' surplus. The criterion reflects the public interest in the resource. When output price is constant, this becomes the well known problem of maximizing rents to the fishery. (Price might be constant, for example, if this fishery's contribution to the market supply of this type of fish were small.) The open access equilibrium is characterized by zero rents. In the long run, the biological sector tends toward equilibrium, in that harvests equal growth. Hence in the constant-price open-access commercial fishery, improvements in fish stocks brought about by improvements in water quality do not change the economic rents to the resource. They remain at zero. When the commercial fishery is optimally managed, water quality improvements which enhance the productivity of the fishery also increase the rents to the fishery. Thus, when the price of fish is constant, the returns to reducing agricultural pollution are greater when the property rights to the commercial fishery are well defined. The returns are zero when the property rights are not defined. When increases in the supply of fish reduce market price, the extra fish production brought about by less agricultural pollution will bring increases in consumers' surplus, even when rents remain at zero. However, the increase of producers' plus consumers' surplus from enhanced fish stocks is still greater when property rights are defined.

3.2 Agricultural Water Pollution: The Case of Downstream Markets

In this section, we consider the case in which the "downstream" uses of water are regulated by a water control board. The board maintains reservoirs and water-treatment facilities and then allocates water through its pricing schemes and rules for priority use in drought years. This central-planning format has the potential to avoid some of the open-access problems associated with the fishing case. But, as we shall show below, the ability to capture the benefits of improved water quality may be limited if there exist legal or institutional constraints on water pricing rules.

Water management by a water control board is usually accompanied by prices different from marginal cost. This divergence may occur because there are fixed costs or increasing returns to scale in procurement or treatment, or because legal and institutional restrictions impose average-cost pricing. We discuss these situations below. For now we note that if average cost is upward sloping, then the average cost of water is below marginal cost. In this case, if price is set equal to average cost, water is "underpriced" and there is higher water consumption than is socially optimal.

3.2.1 Inefficient Water Prices Induce Non-optimal Water Quality

A second, less frequently cited consequence of low prices is that they induce higher demand for complementary goods. Both water quality and reliability of service, for example, are likely to be complementary to water quantity. If so, then water pricing policies will also affect the value of water quality. We show in this section that an average-cost pricing economy will likely attribute a lower value to improvements in incoming (runoff) water quality than a marginal-cost pricing economy. This result is modeled in detail below, but the general conclusions can be developed without a formal model. With average cost pricing, the water authority does not capture all of the benefits of providing improved water quality to its customers. It therefore chooses to provide a lower water quality than under marginal cost pricing. This usually means that improvements in incoming water quality also have a lower value. Agricultural policies that reduce erosion and improve the quality of runoff water will thus yield lower benefits than they would if other water pricing schemes were used.

The model includes a value function for water quantity and quality and cost functions for agricultural water quality and municipal water treatment. The value of water quantity and quality comes from its use by residential, commercial, and industrial customers. Since the problems of optimal water pricing and treatment are similar for each of these sectors, we will analyze water use by the industrial sector. Downstream uses by agriculture can also be analyzed in this framework.

For industrial users, we assume that the value of water comes from its use in a production process. Let $F(w,\alpha,x)$ be a production function with water quantity and quality as inputs. Let w be quantity of water, let α be a measure of water quality, and let x be another input. The price of output is normalized to one. Water quality is exogenous to the firm. The firm's problem is to

$$(7) \qquad \max_{(w,x)} F(w,\alpha,x) - p_w w - p_x x.$$

A solution gives the demand for water, $w(p_w, p_x, \alpha)$.

The cost to the water control board of providing an amount of water w of quality α when untreated water is of quality α_f is $G(w,\alpha,\alpha_f)$. The variable α represents water quality as experienced by its consumers and α_f is the quality of incoming (untreated) water. We assume that the quality of incoming water, α_f, is determined by practices in the agricultural sector which bears increasing, convex costs.

Average-cost pricing of water quantity implies $p_w = G(w,\alpha,\alpha_f)/w$. The first-order conditions for maximizing (7) with respect to w are: $F_w(w,\alpha,x) = p_w = G(w,\alpha,\alpha_f)/w$, where $F_w(w,\alpha,x) = \partial F(w,\alpha,x)/\partial w$.

For a given α_f the water authority chooses to treat water up to level α to maximize "social value", which is profit (excluding water costs) minus true water costs,

$$(8) \qquad V(\alpha,\alpha_f) = F(w,\alpha,x) - p_x x - G(w,\alpha,\alpha_f),$$

where w and x solve equation (7). The solution solves:

$$\begin{aligned}(9) \qquad & \{F_w(w,\alpha,x) - G_w(w,\alpha,\alpha_f)\}(dw/d\alpha + dw/dp_w \cdot dp_w/d\alpha) \\ & + \{F_\alpha(w,\alpha,x) - G_\alpha(w,\alpha,\alpha_f)\} \\ & + \{F_x(w,\alpha,x) - p_x\}(dx/d\alpha + dx/dp_x \cdot dp_x/d\alpha) = 0.\end{aligned}$$

For the moment, we assume that water price is set equal to average cost because of regulatory constraints. When $G_w(w,\alpha,\alpha) > G(w,\alpha,\alpha_f)/w$, the pricing rule implies $F_w(w,\alpha,x) - G_w(w,\alpha,\alpha_f) < 0$; in other words, there is overconsumption of water with average cost pricing.

If water quantity and quality are complements, $dw/d\alpha$ is greater than zero, and if dw/dp_w or $dp_w/d\alpha$ is small, then the second part of the first term is positive, making the overall sign of the first term negative. The last term is equal to zero by the Envelope Theorem. Together, these imply that $F_\alpha(w,\alpha,x) - G_\alpha(w,\alpha,\alpha_f)$, is greater than 0. Because $F_\alpha - G_\alpha$ is decreasing in α

and $F_\alpha - G_\alpha = 0$ at a pareto optimum, the level of α chosen by the control board is too low.

Totally differentiate $V(\alpha,\alpha_f)$ with respect to α_f, evaluate at the optimal α, and use the Envelope Theorem to get:

$$dV(\alpha,\alpha_f)/d\alpha_f = -\partial G(w,\alpha,\alpha_f)/\partial\alpha_f .$$

Although it is α, not α_f, that ultimately affects output, measures of $F_\alpha(w,\alpha)$ or $F_\alpha(w,\alpha) - G_\alpha(w,\alpha,\alpha_f)$ are not explicitly the determinants of the value of changes in α_f. The value to this economy of a marginal increase in α_f is the reduction in the costs of water treatment.

To evaluate the value of changes in α_f under different pricing rules by the water authority, we compare $-\partial G(w,\alpha,\alpha_f)/\partial\alpha_f$ evaluated at $(w_{MC},\alpha_{MC},\alpha_f)$ and $(w_{AC},\alpha_{AC},\alpha_f)$, where an MC subscript indicates the value observed under marginal cost pricing, and AC the value observed under average cost pricing. If $G(w,\alpha,\alpha_f)$ is separable in w and $(\alpha - \alpha_f)$, then $-\partial G(w_{MC},\alpha_{MC},\alpha_f)/\partial\alpha_f$ is likely to be greater than $-\partial G(w_{AC},\alpha_{AC},\alpha_f)/\partial\alpha_f$. In other words, the value of an improvement in α_f is higher when marginal cost pricing is adopted than when average cost pricing is used. When α is low, $-\partial G(w,\alpha,\alpha_f)/\partial\alpha_f$ is also low. The opposite conclusion might also be drawn, however, under different versions of the model. It could occur if $\partial^2 G(w,\alpha,\alpha_f)/\partial\alpha_f\partial w$ were large, which is a more realistic assumption than separability, or if the water control board used a different decision rule for α from (9).

Unfortunately, similar problems may arise even if the water control board is more astute about its water-pricing policies and prices water "optimally" using Ramsey prices. Ramsey pricing may no longer be optimal if the water control board cannot, for legal reasons, include in the pricing formula any costs borne outside the water-using sector. Costs of improving water quality that are incurred by the agricultural sector then cannot be part of the pricing formula, and the opportunity to coordinate α and α_f is again limited.

3.2.2 Higher Prices of Water Can Reduce the Benefits of Controlling Soil Loss

In this section we argue that policies that influence the use of water held in reservoirs can also affect the economic costs of waterborne soil erosion. In particular, when actual prices are below efficient prices, policies which impose more efficient water pricing can help reduce the costs of this erosion.

Farm practices which result in waterborne soil loss increase the load of sediments in streams and rivers. In many areas this results in increased sedimentation of lakes and rivers. (See Clark et al. (1985) for a summary of this evidence.) The increased sedimentation displaces water in reservoirs and lakes. When these water bodies serve as storage for municipal or other water distribution systems, the storage capacity has economic value. The value stems from the uses made of the water as well as the stochastic nature of the recharging of the reservoir. Typical uses of the storage include water for municipal and industrial use, irrigation water, and flood prevention. Where sedimentation from waterborne erosion reduces storage capacity, the economic value of the capacity is lost or the cost of restoring the capacity must be incurred.

Our concern is the use of storage capacity for withdrawal for water systems. The connection between water use and storage capacity depends on the distribution of recharge, which is typically random, and the pattern of use. (These relationships are discussed in Howe (1979) for example.) But basically, increased water use requires increased storage capacity. Storage capacity is typically provided at increasing marginal costs, as Figure 2 shows.

(INSERT FIGURE 2 HERE)

In Figure 2, a community with an aggregate annual water use (withdrawal rate) of x_0 would construct storage facilities with marginal cost of $c(x_0) = c_0$. Sediment is deposited on the bottom in the still reservoir and reduces the storage capacity.

A common view is that the effects of erosion may be offset by designing reservoirs with extra capacity to affect the sedimentation. Sedimentation can be handled by building a reservoir with more capacity or equivalently, a reservoir which would permit a higher uniform withdrawal rate. Let s be the cumulative sedimentation from erosion and let $x_1(s)$ be the uniform withdrawal rate that is equivalent to the storage capacity needed for the sedimentation. Then the cost of the sedimentation is the additional total cost of providing storage.

$$\text{sedimentation cost} = \int_0^{x_0+x_1(s)} c(x)dx - \int_0^{x_0} c(x)dx$$

$$= \int_{x_0}^{x_0+x_1(s)} c(x)dx$$

This cost can be viewed as the shaded area under the marginal cost curve between x_0 and $x_1(s)$ in Figure 2.

The withdrawal rate x_0 has been fixed. But a key element in the coordination of policies is the resource policy for the polluted resource. In this case the water control board influences the rate of withdrawal and hence the sedimentation costs through the pricing schedule for water. Higher prices for water withdrawal reduce the demand for water, which is the withdrawal rate, and reduce sedimentation costs. Let $x_0 = x_0(p)$ be the demand for water where p is price per unit withdrawal. The effect of changes in p on sedimentation costs is

$$\partial \text{ sedimentation costs}/\partial p = [c(x_0 + x_1) - c(x_0)]\partial x_0/\partial p.$$

A higher price reduces the uniform withdrawal rate. Note that the sedimentation costs are only reduced when the marginal costs of withdrawals is increasing. This is because we are requiring the system to build the extra capacity for sedimentation. If the cost of extra capacity for sediment storage were independent of the amount of capacity (or the withdrawal rate), then building extra capacity for sediment storage would have no impact on the cost of capacity for water provision.

A wide variety of farm practices can reduce waterborne erosion. These practices include contour plowing, no-till cultivation, terracing, and choice of crops and crop rotations. The reduction in erosion means a reduction in the sedimentation rate. In terms of the model, this is a reduction in s. Let the reduction in s be $\Delta s < 0$. The effects of this reduction on the sedimentation costs are of course negative:

$$\Delta \text{ sedimentation costs} = c(x_0 + x_1)\, x_1'(s)\Delta s < 0.$$

They equal the marginal cost of capacity times the required change in capacity due to sedimentation times the change in sedimentation. If higher (and probably more efficient) prices were charged for water withdrawal, the benefits of controlling erosion would be reduced (or the reduction in sedimentation costs, which is negative, would be closer to zero):

$$\partial[\Delta \text{ sedimentation costs}]/\partial p = c'(x_0 + x_1)x_1'(s)\Delta s x_0'(p) > 0.$$

This means that as the withdrawal rate goes down from the price increase, the reduction in sedimentation is worth less to society. This is because the extra capacity to hold sediment must be added to a smaller reservoir, and hence at a lower point on the marginal cost curve.

To summarize, policy coordination can be viewed as cooperatively choosing the level of erosion and the price of water. A higher price of water reduces the cost of sedimentation and also reduces the benefits of curtailing sedimentation. Increases in the price of water may be substituted for sediment control to achieve the same end.

This argument has been stated as if capacity were the policy option. In fact, most of the reservoir sites have already been exploited. The thrust of the argument remains. We may think of the productive life of the reservoir instead of its capacity. The life of the reservoir may be increased by sediment control or by increasing the price of water. In terms of coordinating agricultural and resource policy, when a higher price is charged for water, there is a diminution in the value of the marginal extension in the life of the reservoir from a reduction in erosion.

3.3 Agriculture and Job Safety: The Case of Perfectly Competitive Downstream Markets

The final case we consider is one in which a well functioning but unregulated market exists for the agricultural "externality". We consider as an example an agricultural firm that buys labor in a competitive labor market. On-farm work entails particular health risks, as does work in most occupations that farm workers would consider as substitutes. If risks are associated with particular jobs and if workers can choose among jobs, the risk becomes a local public good. The local nature of the public good allows a market to develop (Starrett 1988). A worker may thus be compensated for the extra risks he incurs from working in the farm sector (see Thaler and Rosen (1976) for the seminal treatment of this problem). In the extreme case, when this market is well functioning and perfectly competitive, efforts to reduce the risks of farm jobs may result in no net improvement in the worker's welfare. This claim is substantiated in the remainder of this section.

The "market for safety" generates a wage-risk schedule, $L = \{(w,\alpha)\}$, where w is an hourly wage and α is a measure of the riskiness of the occupation (for simplicity, we will assume that α is single-valued). L is a set of wages and risk levels between which a worker is indifferent. A higher α will be associated with a less risky occupation, and the number of hours of labor per worker is assumed fixed. For simplicity, we assume that we can write $w(\alpha)$, with derivative $w'(\alpha) < 0$. The derivative $-w'(\alpha)$ is the wage premium for a marginally riskier job.

An individual laborer is indifferent between incurring risk α_0 and being paid wage w_0 and incurring the lower risk α_1 and being paid wage w_1 for all pairs (α_0, w_0), $(\alpha_1, w_1) \in L$. The farm sector is assumed small relative to the market so that labor supply at (α_1, w_1) is infinitely elastic. Labor demand at L (but not necessarily at $\notin L$) is also assumed to be perfectly elastic. Each individual farm is assumed to have a downward-sloping demand curve for the amount of labor it hires at wage w for each level of riskiness α. We expect that the demand curve for labor to shift in as α rises. In other words, a farm is willing to hire fewer workers at any wage if it must supply greater safety.

The wage paid by a particular farmer and the amount of labor he hires are determined by the intersection of the labor demand curve and the flat supply curve, both of which reflect the on-farm level of α. The farm manager chooses the level of α (and thus w) and n (the number of workers hired) that maximizes profit. Although we have assumed that the health risk is a local public good, the risk need not be farm-specific; for example, the primary source of risk may be exposure to pesticides sprayed on another farm's crops.

Let $(\alpha^*, w^*(\alpha^*))$ and n^* be the market equilibrium quantities. The state promulgates a regulation affecting farm operations that requires farms to provide a minimum level of safety, say $\underline{\alpha} > \alpha^*$. Regardless of the number of workers hired, the wage paid now falls to $w(\underline{\alpha})$. Workers are indifferent between (α^*, w^*) and $(\underline{\alpha}, \underline{w})$, so there is no surplus to the workers. If the farm has to incur expenses to attain a level of safety $\underline{\alpha}$, then the regulation has made the farmers worse off.

This result is not surprising. Mishan (1971) recognized it when he wrote,

> Insofar, then, as additional risks associated with the service or facility are all voluntarily assumed, there is no call for intervention in the allocative solution to which the market tends. As for project evaluations, insofar as benefits are calculated by reference to estimates of consumers' surplus, no allowance need be made for additional risk of life. For the sum each person is willing to pay for the service provided by the project is net of all the risks associated with them.

Mishan's notion of voluntariness is equivalent to our characterization of the risks as local public goods whose level the individual can (voluntarily) vary. Along the same lines, Starrett (1988) says (in speaking about including employment effects in benefit-cost analysis), "Unforgiveable sins are committed when one counts, for example, employment benefits for workers who merely switched from equally attractive alternative jobs".

Even though safety is compensated for by the market, a worker will still have positive willingness-to-pay for an increase in safety. Consider a worker who receives $(\alpha_0, w_0) \epsilon L$ and is offered an improved level of safety, $\alpha_1 > \alpha_0$. His willingness-to-pay for the change $\alpha_1 - \alpha_0$ is $d = w_0 - w(\alpha_1) > 0$. The costs of changing α, however, should include both the costs incurred by farmers to improve safety and the costs (to the workers) of lower wages. A better regulation in this situation would attempt to change both w and α, not to change α alone.

4. Conclusion

Property rights, pricing rules and other aspects of resource policy influence the benefits that come from reductions in agricultural pollution. This result suggests that natural resource policies may be more effective in decreasing the economic impacts of agricultural pollution than agricultural policies would be! Our conclusions are, first, that in some circumstances natural resource policy should be pursued instead of using agricultural policy to reduce externalities; second, when natural resource policies cannot be altered, the choice for a particular agricultural policy should consider the nature of the downstream economy.

We have concentrated on the effects of water pollution from agriculture in two cases: recreational fisheries and the use of water for municipal purposes. In each case we have shown that benefits from reduced agricultural pollution may be enhanced or reduced by the downstream natural resource policy.

We have also discussed the case of farm safety and farm worker health. We have shown, in concept at least, that when the labor market reflects preferences for wages, health and safety, public intervention may not bring increases in social welfare. This result has broad implications for drawing up policies to improve health and safety as they are (rumored to be) affected by pesticides. Grocery stores have begun to advertise their products as "pesticide free." This provides an opportunity for the effects of pesticides to be captured in price differentials; that is, for the internalization of what had been considered an externality. The fewer pesticides a fruit has been treated with, the higher the price that can be charged, for example. As in the case of agricultural labor markets, if food-and-risk markets are competitive, regulations to improve safety may have no effect on consumer safety. Policies to improve safety and price, however, should be pursued.

REFERENCES

Anderson LG (1977) The economics of fisheries management. Johns Hopkins University Press, Baltimore MD

Clark EH, Haverkamp J, Chapman W (1985) Eroding soils: the off-farm impacts. The Conservation Foundation, Washington DC

Freeman AM (1982) Air and water pollution control. John Wiley and Sons, New York

Howe CW (1979) Natural resource economics. John Wiley and Sons, New York

Laffont J-J (1988) Fundamentals of public economics. MIT Press, Cambridge MA

McConnell KE, Sutinen JG (1979) Bioeconomic model of recreational fishing. J Environ Econ Manage 6:127-139

McConnell KE, Strand IE (forthcoming) The benefits of water quality for commercial fisheries. J Environ Econ Manage

Mishan EJ (1971) Evaluation of life and limb: a theoretical approach. J Polit Econ 79:687-705

Osborn CT, Shulstad RN (1983) Controlling agricultural soil loss in Arkansas' North Lake Chicot watershed: an analysis of benefits. J Soil Water Conserva 38:509-512

Ribaudo MO (1986) Consideration of offsite impacts in targeting soil conservation programs. Land Econ 62:402-411

Starrett DA (1988) Foundations of public economics. Cambridge University Press, New York

Thaler R, Rosen S (1976) The value of saving a life: evidence from the labor market. In: Terleckyj N (ed) Household production and consumption. Columbia University Press, New York, p 265

Figure 1

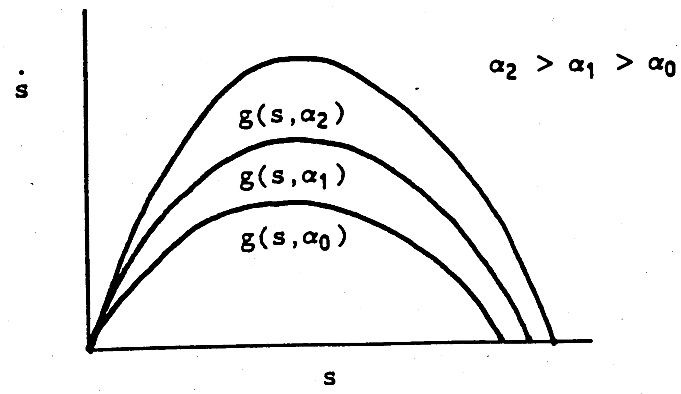
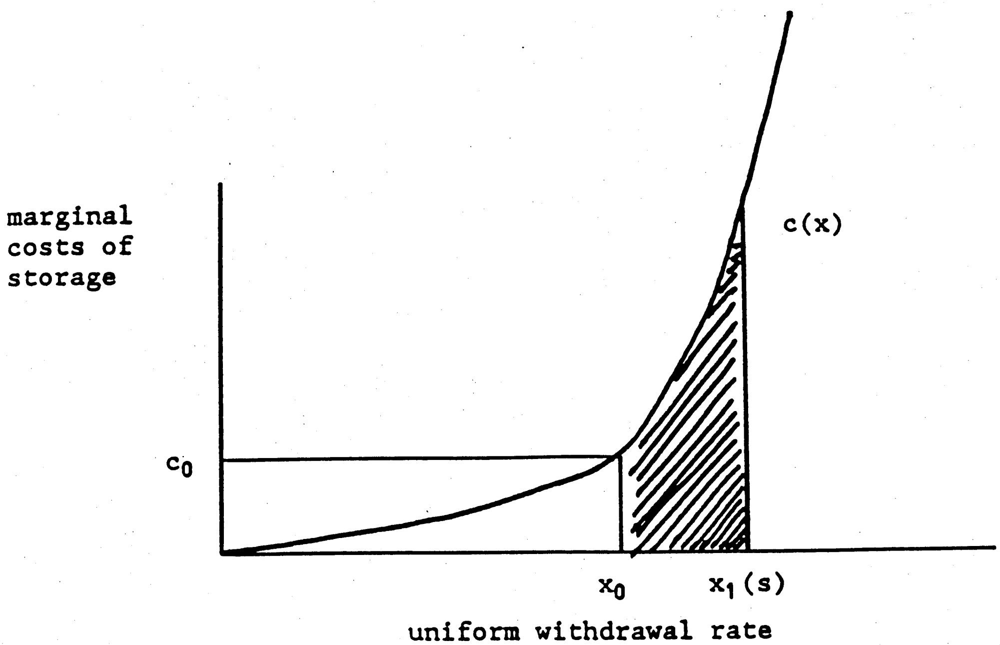


Figure 2


marginal
costs of
storage
c(x)
c_0
x_0
$x_1(s)$
uniform withdrawal rate