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**Differences in the Transaction Costs of Strategies to Control Agricultural Chemical Offsite and Undersite Damages**

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## Differences in the Transaction Costs of Strategies to Control Agricultural Chemical Offsite and Undersite Damages

K. William Easter*

Pollution of our water supplies by agricultural chemicals has been an area of growing concern since the second half of the 1980's when agricultural chemicals were found in many water samples from wells and springs across the United States. This was added to previous information that identified agricultural chemicals as an important source of surface water pollution. However, most efforts to alter agricultural chemical use have not been to prevent water pollution. Regulatory efforts have focused on preventing the hazardous health effects of pesticides during application and in keeping pesticide residues out of food.

Identifying and controlling the major sources of nonpoint agricultural chemical pollution are not easy. In most cases, farmers decide what, how much, and in what manner agricultural chemicals and animal waste products will be applied to their lands. As a result they strongly influence how much may eventually reach surface or ground water supplies. Farmers' decisions are dictated by their own utility maximizing behavior and government policies and institutional arrangements that constrain or enhance their decision set (Figure 1). Soil type, topography, vegetation and climatic events all influence chemical movements towards various water sources as will farming practices. While farmers have little control over climatic events they can change farming practices and vegetative cover to alter the impacts of climatic events. Thus farmers' decisions and the policies and institutional arrangements that influence their decisions are critical in controlling agricultural chemical pollution from the use of fertilizers and pesticides.

When evaluating alternative strategies and policy instruments for controlling pollution, economists have focused on the efficient use of production resources and largely ignored transaction costs. They determine what tax or other policy instrument would be the least distorting in making producers internalize the externalities they create. However, the major costs involved in reducing water pollution in agriculture are likely to be the transaction costs of enacting and implementing alternative strategies and not distortions in production efficiency.

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This paper focuses on the differences in transaction costs of policies that change farmers' decisions concerning the use of chemicals and agricultural waste products (primarily manure). The effects of policy instruments and institutional arrangements are likely to be different on ground water than on surface water, suggesting that strategies for controlling agricultural chemical pollution must be carefully designed to account for differences in water sources as well as other physical and socioeconomic differences. One simple, nationwide strategy is not likely to be the most efficient in terms of either production or transaction costs.

## Why Undersite and Offsite Damages?

Since many water sources polluted in rural areas are used by farmers, i.e., domestic wells, one may ask why farmers pollute their own water supply or that of their neighbors. There are, at least, five answers to this question. One is that farmers lack the knowledge or information concerning the adverse impacts that their farming practices and input uses have on water quality or more specifically, "their" water supply. A second explanation is that they are not concerned about water pollution costs imposed on their neighbors or those living downstream. This is the classic spatial and temporal externality problem where upstream producers damage the water supply of downstream users, but not their own. Third, they may have decided that the use of chemicals or disposal of manure and the resulting increased income is more important than clean water. They may even be willing to buy bottled water instead of reducing chemical or manure applications. A fourth reason may involve imperfect information concerning the optimum use and application of inputs. For example, many livestock farmers in southeastern Minnesota apply 60 to 100 lbs. more nitrogen, in the form of manure, than is required for optimum crop production because of the lack of information concerning its nutrient value (Legg, 1991). The fifth reason is risk and uncertainty concerning economic and weather conditions that will affect crop production. Applying extra chemicals may help reduce weather related income losses. Thus, there is no one simple answer to the question, but a combination of answers including imperfect information, externalities, risk, farmer income requirements and waste disposal.

An added reason for water pollution is the lack of clearly specified property rights concerning water quality for either surface water or ground water. Do consumers have the right to clean water, or do producers have the right to pollute the water? If the water is polluted, who has to pay to clean it up? In many cases, farmers are not prevented from polluting water supplies, and if a clean up is required, they generally do not pay any more than other consumers or taxpayers. Holding farmers financially liable for water pollution would clearly provide an incentive to stop water pollution and help internalize the externality.

### Farmer Decisions

Farmers make long run capital decisions, such as the type of manure handling facility to install or farming system to use, that have important impacts on their chemical use and the transaction costs of changing chemical use. These decisions will depend on a number of uncertainties, including future commodity and chemical prices. Annual chemical use decisions are constrained by the capital assets that are in place. The farmer will decide on chemical use rates and timing based on crops selected, prices, weather, manure supplies, labor available, management capability and soil conditions. These decisions may change during the growing season in response to rainfall and temperature conditions. A heavy rainfall in areas with sandy soil may mean last week's fertilizer application has been lost and needs to be replaced. In contrast, dry conditions mean that less nitrogen is needed and different pest control practices may be required.

Management availability and risk play an important role in these short and long run decisions. Nitrogen in the U.S. is relatively cheap and pest control with herbicides and insecticides does not require as intense management as does mechanical and biological pest control. Furthermore, price and weather uncertainty along with the demands of part-time jobs encourage farmers to err on the side of high chemical use. A little extra nitrogen may increase crop yields in a good rainfall year by 10 to 20 percent. Also, if farmers do not control weeds early in the season with heavy use of herbicides, wet weather may prevent them from getting into their fields and applying the needed weed control. Failure to control the weeds can result in as much as a 25 percent reduction in crop yields.

Differences between Surface and Ground Water

Externalities appear to be the most important explanation of surface water pollution since much of the damage occurs offsite or downstream. This explanation does not hold in all cases since local fish kills and lake pollution may directly impact the farmers that cause the pollution. Still, a major reason for surface water pollution is the external nature of the costs imposed by the pollution, while lack of information and income requirements are more important for ground water. Many externalities associated with ground water are localized while for surface water, they may occur in the next county or state.

The transaction costs of monitoring and enforcement would be quite different for surface and ground water. For surface water the problem is its mobility and the numerous sources of agricultural nonpoint pollution. Whose pesticides caused the fish kill? While it may be difficult to identify the polluters of surface water, the most likely suspects are upstream farmers. Yet the mobility of surface water means that transaction costs of ex-post measure of contamination are likely to be high (frequent monitoring). For ground water pollution, monitoring and enforcement are also likely to be expensive because of the cost of monitoring sites. In many cases the monitoring of existing wells is not enough and special monitoring wells are necessary to locate contamination and polluters so that ground water quality standards can be enforced.[1]

[1] Pesticide pollution of ground water and surface water appears to be highly related to improper use, storage or disposal of pesticides or extreme rainfall events following pesticide applications, with the exception of a few herbicides such as Atrazine. With extreme rainfall events, pesticide movement is generally accompanied by high levels of soil erosion, but not always. Ground water pollution appears to occur with normal application of nitrates and Atrazine, particularly on lighter soils. In the case of surface water, nitrate and Atrazine pollution is more closely related to high rainfall events.

Another important difference between surface and ground water pollution has to do with the values of water uses precluded by chemical pollution. There are, at least, two aspects to this difference. One is that surface water has a wider array of uses then does ground water. Irrigation, industrial, commercial and domestic water consumption are the main uses of ground water while surface water can also provide a long list of recreational opportunities. The second aspect is that the duration of pollution may be quite different between surface and ground water, particularly if the surface water is a stream or river. Many of the agricultural chemicals that contaminate water supplies are not as long lasting in the surface water as they are in the ground water. How these two aspects will influence the value of lost water uses will vary by location and water use. For example, when the ground water is, or might be, used for domestic consumption and no good alternative sources of water are available, the losses from pollution will be quite high. In contrast, if the ground water is used for irrigation and is not likely to be demanded for other uses, then the pollution losses are likely to be relatively small.

## Benefits from Improved Water Quality

With both the amount of agricultural chemicals entering the water supplies and the demand for higher water quality increasing, the benefits from improving water quality are on the rise. The increased demand is due, in part, to the growth in U.S. incomes and population, as well as greater knowledge concerning the harmful nature of certain agricultural chemicals. The growth in demand for bottled water and water based recreation are both directly related to this increased demand for higher water quality. Of course, water for household uses requires a different level of water quality than does water for recreational uses. Yet agricultural chemicals have damaged water for both of these uses.

Recreational benefits are among the largest, if not the largest, class of potential benefits from surface water pollution control (Rogers, et. al., 1990). Currently, they exceed the health or other water treatment benefits from reduced surface water pollution. In contrast, the primary concern in ground water appears to be the potential health effects or the increased cost of water treatment. In a number of cases, chemical pollution of ground water has forced the closing of wells and caused shifts to alternative water sources.

On the supply side of pollution, there are certain geographic areas that are more susceptible to water pollution and, therefore, they offer higher returns from pollution control efforts. For ground water, these are likely to be areas with light soils and shallow aquifers, or karst aquifers. The susceptible areas are not as easy to identify for surface water. However, surface water sources surrounded by moderately or steeply sloping, intensively farmed lands are clearly susceptible to agricultural chemical pollution. Thus, the physical characteristics of land, climatic conditions, amounts and types of chemicals, and farming practices will all be important in determining the degree of chemical contamination and level of benefits from pollution control.

On the demand side of pollution abatement, growth in per capita income and in population, the availability of alternative water supplies and the cost of pollution cleanup will all be important. These factors help determine the value of protecting water quality for a range of water uses. Clearly, areas with large populations and low rainfall, such as Los Angeles, will have a high demand for good quality water and programs that prevent agricultural water pollution. However, given where Los Angeles must obtain much of its water supply, it has a very limited capacity to influence what agricultural chemicals get into "their" water supply. For example, water taken from the Colorado River to supply L.A. will contain agricultural chemicals that have come from farms as far away as Colorado and Wyoming. Thus the demand for public action or changes in property rights concerning water pollution from agricultural chemicals is growing in urban American and is likely to continue to expand. In addition, because of water's mobility the demand for clean water may come from areas outside the source of supply as is the case for L.A.

The cost of cleaning up polluted ground water is sufficiently high, in a number of aquifers, to preclude it as an efficient alternative. In contrast, we have been cleaning up polluted rivers for many years at a wide range of costs. The persistence and toxicity of the pollutants are both important in determining the cost of clean up. Finally, the benefits from preventing water pollution will be closely related to the cost of substitute water supplies and the intended uses to which they will be devoted. To illustrate, if water is used for irrigation, there will be little or no loss from nitrate contamination, but the losses could be substantial if the use shifts to human consumption. The demand for "cleaner" water will also depend on whether the pollutant causes cancer or just tastes bad during a few weeks in the spring. When the demand is for domestic water use and the clean up costs are high, with no good substitute supplies available, then the benefits from protecting the water source from agriculture pollution will be high, especially if the water source is susceptible to contamination.

Pollution control policies need to be directed at those areas and types of water uses where the highest net benefits to society can be achieved from protecting the water supplies. In addition, policies, programs and institutional arrangements need to be designed so that the cost of such protection is minimized. One of the critical costs that should be minimized is the transaction costs of alternative courses of action. These costs must be compared with the potential benefits to be achieved since different water sources and types of agricultural chemical pollution will have different control costs. For example, inducing farmers to reduce their excessive use of nitrogen is likely to be less costly than having them change weed control practices, i.e., reduce the use of herbicides.

## Transaction Costs

When designing policies, programs and policy instruments to reduce the level of water pollution by agricultural chemicals, a clear understanding is required of the transaction costs involved in implementing each alternative including search and information costs, bargaining and decision making costs, and monitoring and enforcement costs, as well as any litigation costs (Williamson, 1985). The distribution of costs and benefits involved with each alternative approach will determine, to a large extent, their political support and the level of transaction costs. Ways to reduce such transaction costs need to be explored across alternative control policies and policy instruments.

The fundamental unit of analysis will be the transaction which Williamson (1985) defines as something that "occurs when ... one stage of activity terminates and another begins." In the case of water pollution, transactions occur whenever water is treated, or has wastes dumped in it, or when new agricultural policies or institutional arrangements are developed. Transactions also include changes in farming enterprises or farming practices. The farm plan that SCS develops for farmers is a transaction that involves a contract with farmers that is difficult to enforce and costly to develop.

The transaction costs of principal concern in developing alternative policies, institutional arrangements, and policy instruments for reducing water pollution in agriculture include, 1) the costs of enacting policies and programs, and 2) the costs of their implementation with specific policy instruments and institutional arrangements. The latter involves governance costs (monitoring and enforcement costs and administrative and information costs) and must consider compliance costs imposed on farmers and the chemical industry. There will be a feedback between the compliance costs imposed on farmers and the chemical industry and the transaction costs of enacting policies and programs. For example, the transaction cost of promulgating improved water quality (through less use of agricultural chemicals) as a specific objective in the farm bill is likely to be high. Farm groups and the chemical industry strongly oppose the idea because of their expected loss in income. In contrast, it will probably be more difficult to build continued support among environmental groups to offset these increases in transaction costs because their gains are smaller per individual and less clear cut. However, environmental groups have used ideology as a means to reduce the transaction costs of organizing to promote such restrictions (Nabli and Nugent, 1989).

The size of these transaction costs will depend on a number of factors including: — asset specificity, — information availability and use, — opportunism, — frequency of transactions, — credible commitments, — uncertainty, and — the characteristics of land and water resources involved.

Information and Opportunism

The assumptions of bounded rationality and opportunism will be particularly important since the benefits and costs of water pollution control will not be uniform across the landscape. "Transaction cost economics pairs the assumption of bounded rationality with a self-interest seeking assumption that makes allowance for guile (opportunism). Specifically economic agents are permitted to disclose information in a selective and distorted manner. Calculated efforts to mislead, disguise, obfuscate and confuse are thus admitted." Transactions must be organized "to economize on bounded rationality (limits on information and ability to process it) while simultaneously safeguarding transactions against the hazards of opportunism" (Williamson, 1989, p. 12-13).[2] Clearly, changes in the availability of information, the way it is presented and the ability of farmers and government agencies to process it will affect the transaction cost.

[2] Underline added by author.

Information is made more imperfect by the existence of opportunism and the incentives for farmers and/or chemical dealers not to cooperate. For example, what monitoring and enforcement costs of restrictions on chemical use would be required to assure that farmers do not under-report chemical use?

Asset Specificity

The differences in asset specificity across farm types mean that the transaction costs of responding to changes in policies or institutional arrangements will be quite different among farms, e.g. dairy farms as compared to wheat farms. "Asset specificity has reference to the degree to which an asset can be redeployed to alternative uses and by alternative users without sacrifice of productive value ... It is asset specificity in conjunction with bounded rationality, opportunism and uncertainty that poses the contractional/organizational strains" (Williamson, 1989, pp. 13-14). In the case of water quality, they will cause different levels of strain depending on which alternative control strategy is implemented and the type of water resource.

Uncertainty and Frequency of Transactions

Along with asset specificity, Williamson (1985) identifies two additional dimensions which make transaction cost economics important in addressing problems of agricultural water pollution: 1) uncertainty and 2) frequency of transactions. Uncertainty is critical in both the farming operation and in the control of water pollution because of bounded rationality and opportunism. As uncertainty increases, more information must be processed in making decisions and in implementing decisions which adds to the transaction costs. In response to this uncertainty, investments may have to be made in information systems or in organizational changes at the farm or regulatory agency level (Galbraith, 1973).

The frequency of transactions is important because of the benefits from specialized governance structures or organizational arrangements. "Specialized governance structures are more sensitively attuned to the governance needs of nonstandard transactions than are unspecialized structures, ceteris paribus. But specialized structures come at a great cost, and the question is whether the costs can be justified. ... The cost of specialized governance structures will be easier to recover for large transactions of a recurring kind" (Williamson, 1985, p.61). For agricultural chemical pollution of water supplies the key question is whether or not it is possible to use existing agencies like Soil Conservation Service (SCS), Agricultural Stabilization and Conservation Service (ASCS) and the Extension Service to implement the necessary transactions to reduce water pollution. If they cannot or do not have the will to regulate pollution, and EPA or a new specialized agency must do the job, then the transaction cost of controlling water pollution will be substantially higher.

Another important aspect of governance structures or organizational arrangements is that they provide different levels of safeguards, incentives and adaptability. These differences would occur across policy instruments and institutional arrangements since they require different types of governance structures. For example, taxes on agricultural chemicals depend on market governance while regulations are based on some form of direct government intervention. Taxes provide monetary incentives to reduce chemical use, but regulations do not. Yet well enforced regulations offer better safeguards against exceeding specified levels of pollution than do taxes, although a combination of taxes and pollution standards offer both good safeguards and incentives.

### Credible Commitments

A final aspect of transaction costs that is likely to be important in the control of agricultural chemical pollution of water is the idea of credible commitments or assurance concerning the action of others. For example, what assurance or commitment does society have that farmers will use pesticides according to the directions on the label?

Williamson (1989) finds that legal sanctions are severely limited and that credible commitments are needed because of these limitations. For agricultural chemicals this can be important in, at least, three levels. First, what credible commitments need to be established for farmers, that the public sector will implement an effective program to reduce agricultural chemical pollution? Second, other sectors of the economy have to make credible commitments to reduce chemical water pollution so that farmers feel others are doing their fair share, i.e., urban residential and golf course users of chemicals. Third, credible commitments have to exist among farmers so that they will abide by the rules and limit chemical use. If most other farmers are thought to be cheating, why should they follow the rules? Finally, the same types of credible commitments need to be established with pesticide and fertilizer dealers. This is particularly important when they apply chemicals and/or are used as the point of regulation or taxation.

## Policy Options

To significantly reduce the level of water pollution by agricultural chemicals will require changes in the farming sector. Figure 1 indicates many of the important linkages in the farming sector, and shows where government policies and programs have an impact on the agricultural sector. These many linkages suggest that to significantly change chemical use in agriculture will require a broad-based approach, starting with trade and agricultural policies and working all the way down to technical assistance provided to farmers.

We need to be concerned with how trade and agricultural policies influence input use in agriculture. Do they encourage intensive farming and the substitution of agricultural chemicals for land and labor? If so, what changes can be made to reduce or eliminate such incentives? One starting point would be to make reduced agricultural chemical levels in water supplies a specific objective of agricultural policy, and include it in all legislation related to agricultural production.

Another step would be to develop specific policy instruments and institutional arrangements to help achieve this objective. An important aspect of selecting the policy instruments or institutional arrangements is that they are likely to have different degrees of effectiveness depending on whether they are used to reduce surface water or ground water pollution. Since surface water pollution is much more of an externality problem than is ground water pollution, the methods for improving surface water quality should be focused on internalizing the externalities. In contrast, ground water pollution appears to be more an information problem where educational and technical assistance programs should be more effective. Furthermore, there may be some important differences in the spatial variability of chemical pollutants that must be taken into account. For example, is Atrazine contamination more localized than that from nitrates?

Some of the alternative policy instruments and institutional arrangements that should be considered for managing water quality include the following: (1) subsidies, technical assistance and education (the traditional approaches), (2) bans on chemical use, (3) taxes and user permits, (4) land retirement, restrictions on chemical use and direct payments and (5) pollution rights and liability. The transaction costs of these alternatives will vary widely because of the institutional and organizational arrangements that already exist in the agricultural sector. Differences in information, uncertainty, and asset specificity across regions and farm types, along with the possibility of opportunistic behavior by farmers, credible commitments and the frequency of transactions, will all have a major affect on the level of transaction costs.

Subsidies, Technical Assistance and Education (traditional approaches)

A review of policy instruments suggests some wide differences in transaction costs, particularly in terms of support from the farming sector. Cost-sharing (subsidies), education and technical assistance, to encourage the adoption of best management practices, have been the traditional public sector approaches used in the U.S. to control soil erosion and to reduce nonpoint pollution of surface water (Easter and Cotner, 1982). This is not an accident. These approaches are the most acceptable to farmers because they are free to participate or not and the programs also reduce the farmer's costs of adapting conservation practices. The U.S. also has existing agencies that have experience in providing conservation and pollution control services, i.e., SCS, ASCS and the Extension Service. This combination of existing agencies, no enforcement costs, and farmer support lowers the transaction costs of this set of alternatives particularly in the case of surface water (Table 1). However, the same set of practices and cost-sharing arrangements are not as effective for protecting ground water quality as they have been in reducing soil erosion, although some would argue about their effectiveness in reducing soil erosion.

The current subsidy program for soil conserving practices tries to reduce pollution by changing the technology (practices) used. Another more general type would be a subsidy for meeting a set level of water quality. Farmers could then meet the standard with the lowest cost method which may or may not involve a change in technology (practices). Subsidies based on meeting a given standard would require establishing a baseline water quality and a system for monitoring water quality which is usually very dependent on rainfall events. Both requirements would substantially raise the transaction cost of reducing agricultural water pollution. Again, this helps explain why the traditional approach is being tried.

If SCS continues to have a major role in helping to reduce water pollution, serious questions need to be asked concerning their basic approach. For example, is a whole farm plan a cost-effective way to control chemical pollution of surface or ground water? The dollars spent on developing farm plans might be better spent on developing new farming practices and promoting their use.[3] Since new approaches are needed, training programs for SCS, ASCS and county extension service personnel may be critical for program effectiveness. Thus the transaction cost of using the traditional approaches may not be as low as it first appears.

It is likely that best management practices and farming systems to reduce agricultural water pollution will have to be region specific, which will raise the cost of their development. Research will be needed to determine the impact of alternative farming practices and systems on ground water supplies under different resource conditions. Currently the lack of such information limits the effectiveness of cost-sharing, educational and technical assistance efforts in the protection of ground water supplies.

The type of research and education effort that is needed is being conducted in the karst area of southeastern Minnesota. Nitrates were identified as the major agricultural chemical polluting the ground water in this porous soil with numerous sinkholes. Research conducted by Legg, et. al., (1989) showed that excessive applications of nitrogen were being applied mostly by livestock farmers that failed to give adequate credit for manure. Further research now suggests that even recommended rates of nitrogen fertilizer application are too high. The research also shows the nitrate levels in soil water below the root zone (five feet) increases rapidly as nitrogen applications increase (Figure 2). Educational material showing these relationships are now being used by the Minnesota Extension Service to moderate farmers' use of nitrogen fertilizer and manure.

<u>Bans on Selected Chemicals</u>

The U.S. experience with policy instruments includes bans on selected chemicals that have been identified as particularly damaging, such as DDT. Chemical bans have been quite effective, but it takes time to lower the transaction costs of this alternative by building up political support for enactment of a specific ban. We are now at the point where bans on herbicides are being enacted because of herbicide pollution of ground water. Current discussions about bans are focused on Alachlor and Atrazine, both widely used herbicides in the U.S.

An important transaction cost that must be considered when enacting bans or imposing chemical use restrictions is monitoring and enforcement costs. When bans or

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[3] "In a dynamic setting where technology can change, there will be transaction costs involved in gaining access to that technology and inducing the relevant agents to adapt their routines so as to accommodate these changes. Hence, in such a setting the distinction between production and transaction costs is likely to be blurred." (Nablo and Nugent, 1989, p. 69.)

restrictions on chemical use are imposed, there is a trade-off between farmer compliance and the government's monitoring and enforcement costs. Farmers will tend to exceed chemical bans or use restrictions as long as their expected gains from illegal chemical use exceed their expected losses from government imposed penalties. These expected losses, OL, will be directly related to government monitoring and enforcement expenditures and the level of fines imposed (Figure 3). The marginal loss curve, OL, is constructed based on a particular level of monitoring and evaluation expenditures. An increase in monitoring and enforcement expenditures will shift the farmers' marginal loss curve from using illegal chemicals to the right to OL″ while a reduction will shift it to the left to OL′. Farmers will apply illegal chemicals up to the point the marginal gains, GO, equal the marginal losses from the expected government imposed penalties. If the farmers' marginal loss curve is OL then they will use OU chemicals (the point where the slope of OL is equal to the slope of GO. The optimum level of monitoring and enforcement is OQ at a cost of OI given the pollution cost curve AFP (the minimum point on the total cost curve AFP and the point where the marginal cost of monitoring and enforcement equals the marginal pollution cost). The pollution cost curve is constructed from the locus of equilibrium levels of chemical use given by OCDEN which is constructed from different OL curves.

The curve ART shows the total cost to society from pollution and its control. It is a combination of monitoring and enforcement costs and pollution costs. Thus the higher the level of pollution costs, the greater the monitoring and enforcement costs that would be economical to use. More monitoring and enforcement would be justified if the pollution cost curve AFP shifts up and less if it shifts down. Improved monitoring and enforcement technology could also change the minimum cost level. This same relationship would exist between monitoring and enforcement and chemical sales if chemical and fertilizer dealers were regulated. In this case, both dealers and farmers would consider the potential gains and losses from selling and applying excessive chemicals.

If an individual state or nation bans selected herbicides, what might be the impacts on farmers, the input industry and rural communities? One likely possibility is that the impact of a ban on a few selected herbicides would be minor, particularly if there are good substitutes that are less likely to reach the ground water, i.e., they are less water soluble or break down more quickly. Enforcement would also be less costly because the farmer's gain, GO, would be less from using the illegal chemical. The curve OCDEN would be lower as would the pollution cost curve AFP.

In the case of a ban on Atrazine, the impact on net returns to farmers and gains from noncompliance depends on the weather conditions for weed control (Cox and Easter, 1990). If the weather is good for weed control, substitutes for Atrazine provide satisfactory weed control with only a small decrease in net returns. When the weather is unfavorable for weed control, the decline in weed control and resulting drop in yields can be substantial. The drop in estimated farm net returns for southeastern Minnesota would be around $20 per acre with unfavorable weather (Table 2). Thus the impact of bans and enforcement costs will depend on weather conditions and how much risk farmers are willing to accept when selecting weed control methods.

Bans on Alachlor should have a smaller economic impact on farmers and probably involve lower enforcement costs than those for Atrazine, since there are a number of good substitute herbicides. However, when Alachlor was banned in Canada, the chemical firms raised the price of the substitutes by over 15%, which significantly increased the cost of weed control. If both Atrazine and Alachlor are banned, the drop in net returns would be somewhat greater than for just Atrazine or Alachlor alone, because of limited substitutes. The loss in net returns to farmers would be even higher if cropping system changes are required to improve weed control, particularly when substantial new capital investments are required and existing capital assets have few alternative uses (high asset specificity and low salvage values). Farm asset fixity or specificity raises the transaction costs of making major changes in farming systems. Thus enforcement costs for a ban on both Atrazine and Alachlor could be high, particularly if it was a state or regional ban.

The ban could also have a differential impact regionally. For example, southeastern Minnesota generally has weather conditions better suited for a wider range of herbicides than does western Minnesota. This means that a ban on selected herbicides could cause a greater increase in weed control costs for western Minnesota then it does for the southeast. Because of the drier conditions in western Minnesota, farmers might have to shift mostly to mechanical weed control. Thus bans on selected herbicides may put certain regions, such as western Minnesota, at a competitive disadvantage and farmers would have greater incentives not to comply, which could raise enforcement costs.

Government bans on chemical use may take place at an even lower level than a state. Just as individual counties have raised their standards for domestic drinking water, they could also take direct action to ban farming practices that contribute to chemical water pollution. A county might ban certain manure handling practices or the sale or use of Atrazine. In conjunction with such restrictions, the county could help farmers install manure storage facilities or develop markets for their excess manure. Subsidies for alternative, less polluting herbicides might also be used so the county's farmers are not at a competitive disadvantage to other regions. Such combined actions would help keep the negative financial impacts for farmers to a minimum and help reduce their opposition and the transactions cost of implementing such environmental restrictions. However, with outright herbicide bans, what is to prevent opportunistic farmers from taking their business across the border? This, of course, will not please local businesses and will raise the transaction costs of implementing an effective targeted ban. The opportunistic behavior of farmers and input suppliers along with high asset fixity of farmers could lead to high transaction costs for a targeted herbicide ban, particularly if it alters farming systems.

An additional problem arises if the ban is targeted just on areas susceptible to water pollution. The susceptible areas have to be identified, which will increase information costs and raise difficult questions concerning what farms to include in the targeted area. Should everyone with land over an aquifer or near a stream be included, or should it be everyone in the county or watershed? Again, opportunistic behavior can be expected from farmers who do not want to be included in the targeted area. Combining this with the information costs suggests high transaction costs.

A final issue involves the impact on consumers of reduced agricultural chemicals. Likely, chemical bans will mean reduced U.S. agricultural production and more food imports. For the consumers' budgets, it would mean higher food prices. Since many agricultural commodities have price inelastic demands, producers will benefit and consumers will lose from higher prices. However, not all producers will benefit, and some will benefit more than the others. This will make the support for drastic restrictions on chemicals somewhat uncertain. Because of the uncertainty over who benefits and who loses, the agricultural sector will, in general, oppose the change, raising transaction costs. Those urban people with moderate to high incomes will probably support restrictions and will be willing to pay somewhat higher food prices for cleaner water. With low income people, the support is less clear cut because of the likely impact of higher food prices on their limited incomes.

Taxes and Permits

The U.S. has had limited experience in using taxes or permits as a means for reducing chemical use. In contrast, Europe has had some success in reducing nitrogen applications through the use of taxes. The problem is that the demand for nitrogen fertilizer may be highly inelastic below certain levels, i.e., 50 to 150 lbs. per acre depending on the soil type, water availability and other factors. A similar situation may exist for certain pesticides. The advantage of taxes is that they can be implemented through fertilizer and pesticide dealers and provide farmers with market incentives to reduce chemical use. This means lower transaction costs in terms of tax collection as well as monitoring and enforcement costs. Dealing directly with each farmer, as would be required with application limits, would greatly increase these costs.

Permits could be used if we knew how much of a chemical is safe to use in a given area. Permits could then be sold or allocated up to the maximum acceptable level of use for an area or region. One difficulty is that the permitted levels would have to be varied by area, depending on an area's physical characteristics (i.e., soil texture, vegetation and slope) and its location relative to water sources. Information and monitoring (location specific) requirements would substantially raise the transaction costs of a permit system. On the positive side, tradeable permits would put a value on the assimilative capacity of agricultural land, and encourage farmers to conserve it. They would also provide an incentive to limit the chemicals used because they could sell unused permits to other farmers. In fact, nonfarmers concerned about water quality could be allowed to buy up permits and reduce the quantity of chemicals applied in an area.

With taxes and tradeable permits farmers may have less incentives for opportunistic behavior and noncompliance than they would with an outright ban since they could legally obtain the chemicals but at a higher price. This should hold down the transaction cost involved with enforcement and those related to fixed assets since there would likely be fewer changes in farming systems than with outright bans.

Land Retirement, Restrictions on Chemical Use and Direct Payments

The U.S., through its farm commodity programs, has made extensive use of land retirement and direct payments to reduce agricultural production and support farm income. Land retirement could be used in the farm program, since it was part of a package which included commodity payments to participating farmers. Would it be possible to include chemical use restrictions as a requirement for participation in the farm programs and what would be the transaction costs of doing so? One major cost would be to get such a provision included as part of the farm bill. Clearly there is a precedent for restrictions on participation in the farm programs with the current requirements concerning soil conservation and wetlands. However, promulgating chemical restrictions, as part of the farm bill, is only one of the transaction costs involved.

The task of implementing a program to retire land or restrict chemical use would probably fall on either ASCS or EPA. In terms of being the most effective (highest will to regulate) in reducing pollution levels, EPA would be the clear choice. On the other hand, ASCS, with the help of SCS, may be the only agency in a position to implement the program since they have a presence in most U.S. counties. The problem is that implementation would require close monitoring and policing, particularly in areas where farmers apply their own chemicals. This, along with the idea that they will be more lenient and sympathetic to farmers, is why ASCS and SCS might be the first choice. Where chemicals are mostly applied by contractors, the control and monitoring could be done through them and transaction costs reduced.

The high transaction costs support the idea that use standards or direct control on the amounts of chemicals applied would work better in controlling agricultural chemical pollution than performance standards (Braden and Lovejoy, 1990). Since chemical use, particularly pesticides use, could be controlled mostly through dealers, the monitoring, enforcement and information costs would be relatively lower. In contrast, performance standards would require monitoring and enforcement at a more micro level which would substantially raise transaction costs. Thus, based just on transaction cost considerations, performance standards are not likely to be a desirable policy instrument (Table 1).

The level of penalties for not complying with chemical restrictions will also have an impact on compliance. If the penalty is a small fine, then compliance is likely to be low without intense monitoring. The farmer's loss, OL, would be low (Figure 3). In contrast, a loss of all farm program benefits because of the illegal use of agricultural chemicals would likely result in higher compliance levels, even without much monitoring. How neighbors respond to the program may also be quite important in determining what an individual farmer will do. If your neighbors support the idea of chemical restrictions and abide by them, then it will likely be more difficult for you to cheat (social or community pressures). There is also the fear and possibility that your neighbors will turn you in if they see you misusing agricultural chemicals or animal waste.[4]

A land retirement program and/or easements might be used to protect areas with highly valued water supplies. Programs such as Minnesota's RIM have been used to buy easements for restoring wildlife habitats. Similar programs could be designed to protect valuable ground and surface water supplies. The transaction costs could be high for such a program since the task of determining which water supplies to protect could be highly political. It will also require a lot more information concerning the susceptibility of ground water supplies to chemical pollution and their potential future use.

Land retirement and easements would also be costly in terms of direct payments to landowners. Yet easements would be lower in cost than land retirements if farmers could continue to use the lands as long as they did not apply herbicides. Still, someone would have to enforce such restrictions on herbicide use which, of course, raises the transaction costs. In addition, increasing mechanical weed control could increase soil erosion and augment surface water pollution particularly in steeply sloping areas.

Lovejoy (1990) suggests that SCS and ASCS buy the rights to certain types of erosive land use practices to control soil erosion in erosion prone areas. He further suggests an innovative method for reducing the transaction costs of enforcement, where the property rights are assigned to some group or organization interested in protecting water quality. Organizations interested in protecting the environment such as the Nature Conservancy or Izaak Walton League would be given the partial property rights and if these contractual obligations were violated by farmers, the environmental organization could take judicial action. This, however, is just a transfer of costs and not a reduction in costs for society since the organizations would do the enforcement instead of the government and could cause over protection.

Since the practices that might be prohibited for soil erosion would have a fairly visible impact on the landscape, monitoring should not be costly. However, if the same approach was tried for agricultural chemicals, more intensive monitoring would be necessary. For example, how do you know that a farmer applied two pounds of Atrazine per acre on a given field, rather than three or four pounds? (Two pounds per acre is the limit on Atrazine use in Wisconsin.)

Pollution Rights and Liability

Implementing changes in property rights regarding water quality is a much broader issue than just agricultural chemicals. It also must include point source water pollution as well as water pollution by soil particles since rights to clean water should

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[4] The freedom and ability to organize and protest against unwanted externalities is one way to prevent excessive pollution. The lack of such freedom may explain why pollution got so bad in Eastern Europe. This same freedom and ability to organize locally in many areas of the U.S. could be used as a means to reduce the transaction costs of controlling agricultural pollution through bans or regulations.

involve all sources of contamination. The idea that the citizens of the U.S. have the right to clean water has been legislated in the U.S. clean water act. The problem is putting such objectives into practice. There are limits on the amounts of pollutants that point sources are allowed to deposit in lakes, rivers and streams, however, the rights to "clean" water do not exist de jure. This is particularly true in terms of nonpoint sources and a number of point sources. The transaction costs of implementing such a major change in water quality rights is high, particularly in the short run (Table 1). In fact, in the short run, it is almost impossible to implement because of the chemicals already in the soil or stream beds that will eventually enter our water supplies without any additional discharges or applications of chemicals.

Transaction costs are important for property rights considerations at two levels. First, there are the transaction costs involved with establishing or making major changes in property rights. For example, what are the transaction costs of establishing the rights to no chemical pollution of ground water from nonpoint sources? My guess is that the costs would be very high. At the second level, the transaction costs arise from implementing the existing property rights. These costs will be high if the judicial system is not well developed and effective.

One means of moving towards a policy of giving the U.S. citizens the property right to clean water would be to change the liability rules for water pollution. Polluters could be made liable for any damages or loss in uses caused by their pollution of water. For example, in Connecticut, liability has been imposed on individuals (including farmers) shown to have contaminated drinking water sources. This shifts enforcement to the court systems and, if strictly enforced, could produce some major changes in farming behavior. The major problem is being able to show or prove a farmer has polluted a particular water source while others have not.

The liability for water pollution could also be placed on agricultural chemical manufacturers or dealers. This would act as a tax on farmers because the manufacturers would have to charge a high enough price to cover the liability costs.[5] Manufacturer liability would work just as well as farmer liability except where nonpurchased inputs (manure) are used or where the methods and timing of application by farmers affect pollution rates (Braden and Lovejoy, 1990, p. 50-53). Thus, in areas where livestock production is important and/or farmers apply their own pesticides, a farmer-based liability may be necessary.

Thus, an important first step in making such a rule change effective would be to collect adequate information so that the polluters could be identified and the damages estimated. This would be a major monitoring cost for some types of pollutants because of the temporal and spatial nature of their damages. Another transaction cost is the litigation costs that would be imposed on an already overburdened court system which is

[5] Negligence is like a regulatory standard where the firm has no incentive to do better than the safety standard. For the liability rule, there is always some incentive to do better since this will further reduce the exposure to liability from pollution.

not a small cost. For example, Kopp, et. al.,(1990) point out that as much as "30 to 70 percent of all current expenditures related to Superfund take the form of legal fees, as opposed to expenditures for actual removal or stabilization of hazardous substances at waste disposal sites" (p. 13). Possibly court costs could be reduced or eliminated through bargaining to obtain out of court settlements which could benefit all participants. In fact, clearly established liabilities should encourage bargaining solutions if only a few parties are involved. However, the threat of court battles will not guarantee that the negotiated outcome is economically efficient (Porter, 1988.)

An alternative approach would be to take action at the county government level through county commissions and land use planning efforts. For example, in Fillmore County Minnesota, a farmer with excess soil erosion can be required to implement a soil erosion control program approved by SCS and enforced at the township level. Similar restrictions could be used by counties to protect their water supplies against chemical pollution. Enforcing restrictions or liabilities at the local level would reduce the transaction costs because farmers tend to know what their neighbors are or are not doing, which could reduce information costs. These local efforts would be most effective where the pollution affects a substantial number of county residents other than the individual farmer, i.e., there is a large negative externality. Highly visible erosion and pollution such as gully erosion, muddy streams and murky lakes are good targets for local action. People can see the damages and are willing to put pressure on county commissioners to take action.

Enforcement and monitoring costs may also be lower because of the social closeness of people in the rural community. When those causing the water pollution are well known in the community, social pressures, obligations and respect for neighbors will influence farming decisions (Robinson and Schmid, 1989). The greater this sense of social closeness the less likely a farmer is, knowingly, going to create a negative water pollution externality.[6] In fact, social closeness can be sufficient to maintain negative production externalities at social optimal levels. Such a level would be reached when the cost to the polluter of reducing the negative externality would equal the increased utility received by the pollutee. Community education concerning the impacts of farming on water quality could be an important policy instrument that would complement local attempts to reduce water pollution. As Braden (1990) suggests "a sense of obligation may be transferred with the knowledge that one's action substantially affect other people" (p. 27). This sense of obligation will even be stronger with social closeness.

Difficulties arise with county-specific regulations because of the fear that they may put the county's farmers at a competitive disadvantage and also because chemical water pollution is not visible and crosses county and state boundaries. This is why state or

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[6] The lack of social closeness had a lot to do with the soil erosion restriction imposed in Fillmore County. An increased number of absentee landowners who employed outside management to run their farms was a major concern of Fillmore County Officials. They felt that these "outsiders" were operating with very short time horizons and that excessive soil erosion was taking place. Since these people were outsiders, social pressures were not effective in inducing them to reduce their erosion externalities. Thus more formal means where found to limit the erosion.

national standards and pollution control efforts that focus on the watershed or aquifer are important. Such approaches can internalize many of the externalities that cross political boundaries.

## Strategy to Reduce Agricultural Chemicals in Water Supplies

Because of past levels of agricultural pollution, implementing an effective clean water policy for agriculture requires a long run point of view. It means cutting back on chemical use in agriculture, a much greater use of alternative farming practices, and reductions in lawn chemical use in cities and towns. Farmers will not cooperate if they feel others are, essentially, free riding and not making "credible commitments" to reduce their chemical use (Williamson, 1985). In addition, the effect of such cutbacks may be limited at first because of the chemicals that already exist in our soil and water resources. A first step would be technical assistance and education, with demonstrations concerning what can be achieved with fewer chemicals applied more often, but in smaller amounts. Use of fewer chemicals in smaller quantities will require more labor and better management skills to maintain production levels. Moderate sized farms may have an advantage over large or corporate farms because of the importance of timing in areas dependent on rainfall. Irrigated areas not dependent on rainfall during the crop season may also have an advantage over nonirrigated areas because control over water reduces the uncertainty involved in weed control and fertilizer use.

The real question is what mix of policies and policy instruments has the best chance of reducing agricultural chemicals in our water supplies over the long run. The whole process of reducing chemical use in agriculture would be facilitated if it was a goal of U.S. farm policy. Such a national goal would lower the transaction costs of taking action at the state and county levels. As a start, local variation should be allowed because of the wide differences amongst regions in terms of physical and climatic conditions, crops grown and inputs used. Experimentation should be allowed, since we still have a great deal to learn about the effects of reduced chemical use and how the chemicals can best be kept out of water supplies. Experimentation is also needed with rule making for monitoring and enforcing agricultural pollution control. If rules are flexible, innovative ways can be developed that reduce transaction costs.

A strategy involving technical assistance, education and cost-sharing for best management practices is favored by the existence of agencies which provide these services. Currently this strategy is being tried on a limited scale for ground water protection and should be evaluated for its cost-effectiveness. Other alternatives should be tested, including bans, use permits and easements in sensitive areas. The education effort should not be limited just to farmers, but should involve the broader population so that they have a better understanding of the problem. This has at least two possible benefits: first, an informed population will be more willing to pay higher food prices resulting from reduced chemical use and second, the nonfarm population can apply political and community pressure on farmers to limit their chemical uses.

## Conclusion

Although the extent of agricultural chemicals in U.S. water resources is still a matter of debate, most individuals would agree that it is a problem for many areas with intensive crop and/or livestock agriculture. The question is, what can and should be done about it? First we should quickly expand our research effort so that we have a better information and knowledge base from which to design our strategies for reducing agricultural chemical water pollution and reduce the transaction costs of implementing different strategies. Second, we need to improve the information available to farmers, and its transmission to farmers, concerning how "best" to use agricultural chemicals and animal wastes while minimizing their negative impacts on water supplies. As part of this, demonstrations of different low input agricultural strategies should be developed throughout the U.S. Cost-sharing arrangements should be tried for system changes that involve high asset fixity and, therefore, high transaction costs. Third, if education and technical assistance along with cost-sharing are not effective then more coercive instruments will have to be used. For example, the liability rule could be changed so that farmers are liable for their water pollution damages. User permits and taxes should also be tried.

Finally, a broad based educational program is needed for the general public so that they can make "better" informed decisions concerning water pollution. For example, what chemical levels pose real risks to humans? In addition, why is it alright to have different chemical levels in the water supply, depending how the water will be used in the future and the assimilative capacity of the water resources? Nitrates in drinking water can cause adverse effects on humans and livestock, but in irrigation water, it can increase crop yields and lower fertilizer costs.

Transaction costs play a major role in determining the U.S. strategy for managing agricultural chemical use. This is why the President's Water Quality Initiative emphasizes the traditional approaches, such as technical assistance, education and cost-sharing, which are implemented by existing agencies. If these efforts are not successful, there will be increased pressure to try more coercive control measures with correspondingly higher transaction costs. This is when farmer compliance with alternative pollution control instruments will become critical and determine the level of monitoring and enforcement costs that will be necessary to achieve water quality goals. A noncooperative farm community could mean that monitoring and enforcement costs are prohibitively high. In addition, a strongly opposed rural community could raise the transaction costs so high that passage of any effective legislation to reduce agricultural chemical use would be blocked.

As economists, we need to estimate the transaction costs for alternative approaches to reduce agricultural water pollution and help design institutional and organizational arrangements that will reduce transaction costs. For example, can arrangements be designed that channel community concerns towards effective local and state based efforts to reduce agricultural chemical pollution of ground water? Farmer response and the transaction costs of reducing chemical use will not be uniform across the United States, or even across an individual state. Consequently, community based approaches might be the most cost effective approach, particularly when water pollution impacts are mostly localized, i.e. ground water pollution. However, when the problem crosses state or county boundaries, these local efforts are not likely to be enough. In addition, when other concerns such as economic development dampen local interests in reducing water pollution, then the federal government may have to step in to prevent or reduce water pollution.

Of course, decisions will have to be made before all the information we would like is available. The Canadian ban on Alachlor is an example of one such decision. Hopefully, the U.S. can approach the problems of reduced agricultural chemical water pollution in a more systematic and targeted fashion.

TABLE 1. THE TRANSACTION COSTS OF ALTERNATIVE POLICY INSTRUMENTS FOR REDUCING NONPOINT CHEMICAL WATER POLLUTION

| Policy Instruments | Transaction Costs | | | | | |
|---|---|---|---|---|---|---|
| | Search and Information | Bargaining and Decision Making | Monitoring and Enforcement | Litigation | Compliance Costs | Program Effectiveness in Controlling Pollution |
| Traditional Approach (cost-sharing, technical assistance & education | moderate | low | low | none | low | low★ |
| Chemical Bans | | | | | | |
| 1. National | moderate | high | low | low | high | high |
| 2. Local | high | moderate | high | low | high | moderate |
| Taxes | moderate | high | low | low | low | low |
| Permits | high | high | moderate | low | moderate | high |
| Land Retirement | moderate | high | moderate | low | moderate | moderate |
| Easements | moderate | high | high | low | moderate | moderate |
| Standards | | | | | | |
| 1. Performance | high | high | high | moderate | high | high |
| 2. Use or Practice | moderate | moderate | low | low | low | moderate |
| Property Rights and Liability | high | high | high | high | high | high |

★ The program effectiveness is low in terms of reducing ground water pollution but may be moderately effective in reducing surface water pollution.

Table 2. CHANGES IN NET RETURNS DUE TO HERBICIDE BANS ON SOUTHEASTERN MINNESOTA FARMS USING CONVENTIONAL TILLAGE PRACTICES

| TYPE OF BAN & DECISION RULE | TYPE OF WEATHER THAT OCCURS GOOD | BAD |
|---|---|---|
| | --------------(per acre) | ------------- |
| BAN ATRAZINE | | |
| Maximum Net Returns, Assuming Good Weather | -$0.51(0%) | -$20.50(10%) |
| Maximum Net Returns, Assuming Bad Weather | -$7.73(3%) | -$7.73(4%) |
| No Herbicide | -$11.62(4%) | -$71.76(35%) |
| BAN ALACHLOR | | |
| Maximum Net Returns, Assuming Good Weather | -$0.10(0%) | -$20.15(10%) |
| Maximum Net Returns, Assuming Bad Weather | -$2.64(1%) | -$2.64(1%) |
| BAN ATRAZINE AND ALACHLOR | | |
| Maximum Net Returns, Assuming Good Weather | -$0.51(0%) | -$20.56(10%) |
| Maximum Net Returns, Assuming Bad Weather | -$9.53(3%) | -$9.53(5%) |

Source: Craig A. Cox and K.William Easter, 1990.

**Figure 1. Agriculture Related Water Quality System**

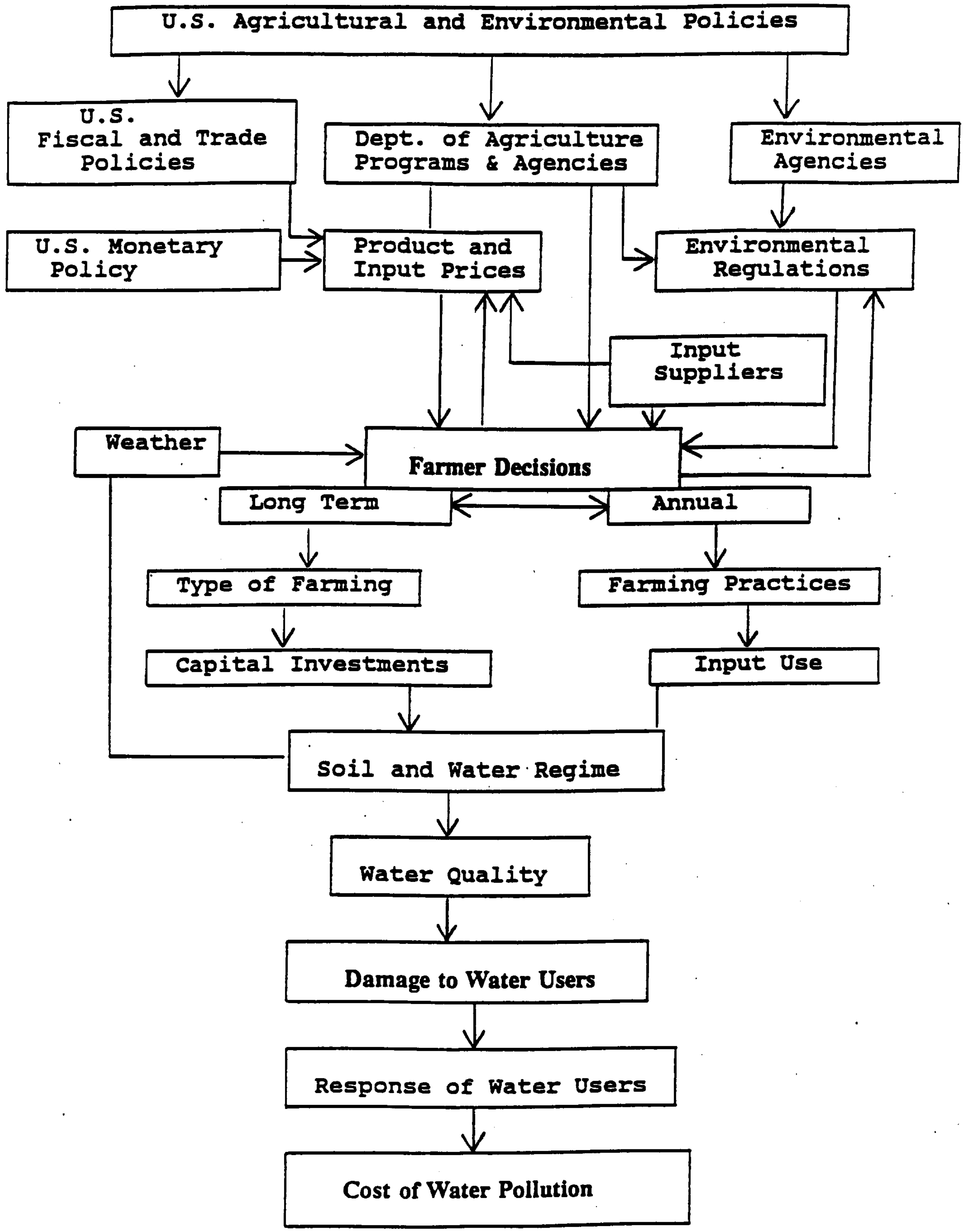
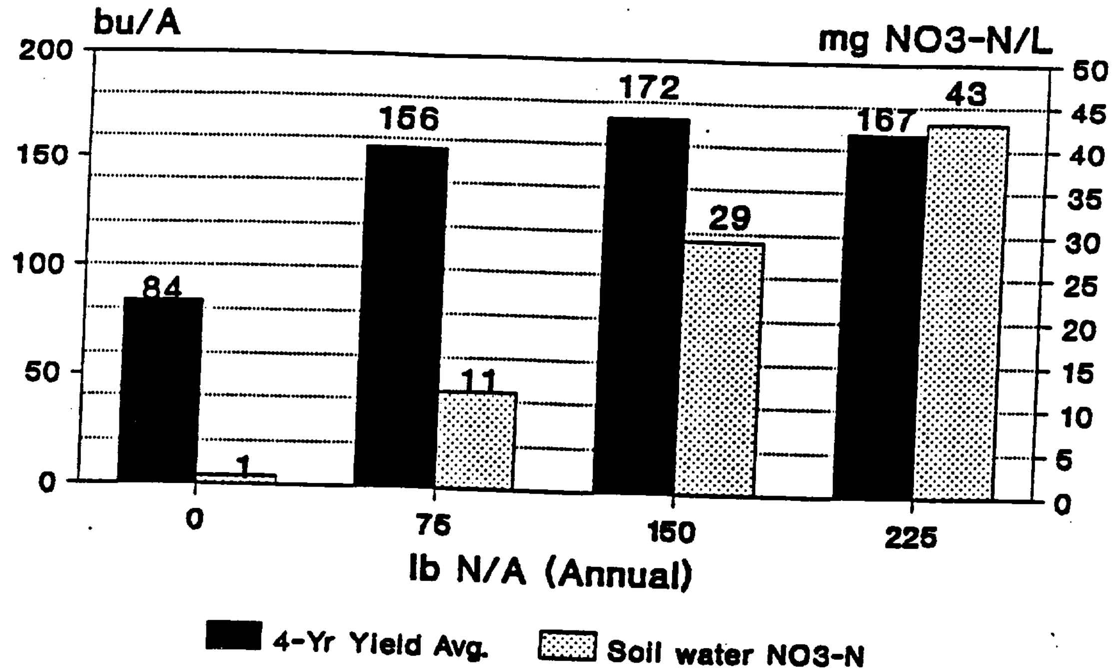


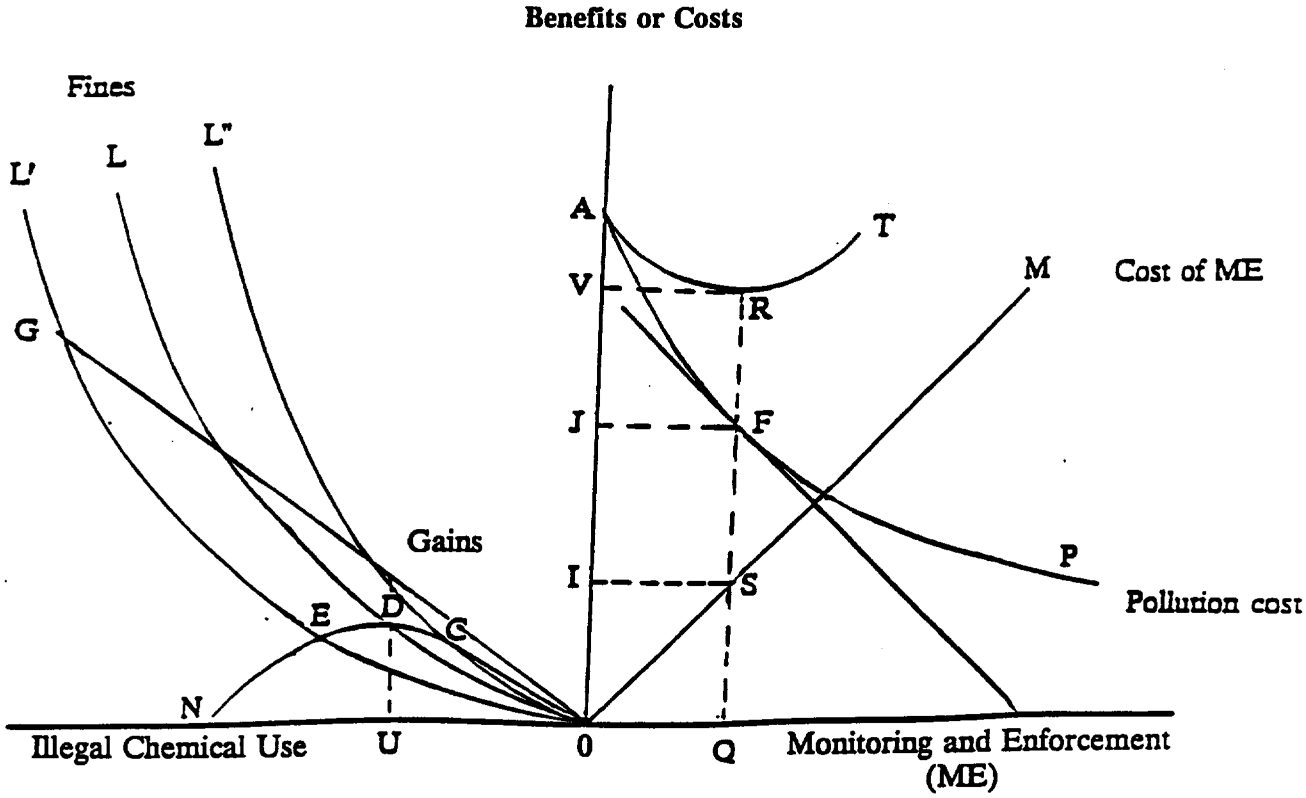
**Figure 2 Relationship between Yield and Nitrate-N in soil water at 5' in September 1990.**




Lawler Farm, Olmsted County, Minnesota.

Source: Randall, et. al., 1991.

**Figure 3 Monitoring and Enforcement Cost of Restriction on Agricultural Chemicals Used.**




**Source: Adapted from Nabli and Nugent, 1989, p. 48.**

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