CRUCIAL KNOWLEDGE GAPS IN THE RELATIONSHIP BETWEEN AGRICULTURAL PRODUCTION AND ENVIRONMENTAL QUALITY

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August 21, 1972 No. 72-19

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* Presented at the Annual Meeting of the American Agricultural Economics Association, Gainesville, Florida, August 1972.

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The purpose of this paper is to point out needs for biological, physical and economic research that are crucial to economic analysis of agricultural production systems in relation to environmental quality. The comments presented here are based largely on observations as participants over the last 18 months in an interdisciplinary research project on the management of agricultural nutrients to enhance water quality.

This paper focuses on three major points:

1. In a quantitative sense, the effect on the environment of residuals from agricultural production is largely unknown.

2. Knowledge of the relationship between farm practices and the amounts of residuals released to the environment is extremely limited. This situation severely limits empirical economic analysis.

3. This lack of knowledge renders inappropriate, in the case of most externalities from agricultural production, the concept of effluent charges which has received wide support among economists as the most efficient method to achieve improved water quality.

Residuals and Water Quality

Despite the rhetoric of environmentalists who state that Lake Erie is dead and that man's activities have greatly speeded eutrophication, serious study of research data on water quality indicates that relatively little is known quantitatively about the environmental effects and social costs of residuals deposited in water. As Boulding has pointed out, biologists don't really know the effect of DDT on the biosphere (2). Similar comments could be made about other residuals, particularly those related to nutrients used in agricultural production. The question which we are continually faced with in our interdisciplinary work is "what are the relationships between individual production practices and their residuals and water quality"?

It has been generally assumed that either phosphorus or nitrogen is the limiting element for algal growth. It has also been assumed that in most bodies of water, nitrogen is available in above-critical quantities from natural sources. Therefore, the key to the control of algal growth (and eutrophication) is control of man-made sources of phosphorus (8,9,10). More recently, several scientists have concluded that carbon (in the form of carbon dioxide) is the limiting element in many waters and thus the key to the control of algal growth (3). This suggests that the limiting element is not likely to be the same in all bodies of water and that the limiting element is not easily identified.

The important point here is that if the limiting element is assumed to be phosphorus, and measures are taken to reduce phosphorus below the critical level, eutrophication will not be arrested if, in fact, some other nutrient is the critical element. Furthermore, this action assumes the relationships between production practices, phosphorus residuals and water quality are known. If these relationships are not quantified, farmers and society may expend large amounts of resources with little or no improvement in water quality.

Agricultural Practices and Residuals

In some cases, the relationships between agricultural practices and residuals deposited in the environment are easily identificable. For example, smoke from burning the residue from grass seed production in the Williamette Valley of Oregon can be seen and traced to the field being burned. While the specific residuals released to the atmosphere and the economic value of the damages caused by the externality have not been quantified, society through the Oregon Legislature, has decreed that the practice of open field burning will stop. If all agricultural residuals were as easily identifiable, reducing such externalities would be simply a matter of legislative action. Of course, the cost to farmers and to consumers (to the extent such costs can be passed on) might be rather high in some cases. One is inclined to think of this as a classic example of an externality from agricultural production. In fact, it is a very atypical case. A more typical case is that of residuals such as nutrients, sediment and pesticides, the effects of which are largely unknown. The two major difficulties of reducing such residuals from agricultural production are: (1) the diffuse source of these residuals and (2) determining the relationship of variables including time of application, location of application, amount applied, duration of application, type of chemical applied, and land practices with the losses of these potential pollutants. Those types of relationships are essential in suggesting regulations or controls for fertilizers, chemicals and/or erosion.

Agriculture vs. Non-Agricultural Sources

Except for a few residuals which come from point rather than diffuse sources, the specific farm from which the agricultural residuals are discharged is not easily identifiable. Thus, it is not likely that we will be able to relate practices on each specific farm to the residuals from that farm deposited in the stream by the farm runoff. Perhaps, the best we can do is the development of relationships between specific practices on specific soil types and topography and stream water quality. Such data could then be used to formulate policy alternatives for farmers operating on similar land resources.

In addition, many residuals such as nitrogen, phosphorus and sediment are the same as those naturally present in stream water and/or the same as those produced by non-agricultural activities. Examples of the latter are sediment (from any type of earthmoving activity), phosphorus (from sewage) and pesticides (from lawns and gardens). Thus in many instances, it is not only impossible to identify the farmer who produced the residual but also impossible to decide whether the major source of the residual is agricultural production or some non-agricultural activity.

An example will illustrate this point. Canadarago Lake in upstate New York has a surface area of 2.94 square miles and drains a 67 square mile watershed, of which about 50 percent is agricultural land (cropland or pasture). A village of 1500 people located near the head of the lake discharges its sewage effluent into a tributary and in summer about 1300 people occupy cottages on the lake shore. Phosphorus has been identified as the most likely limiting element for algal growth, and farmland was assumed to be a major source of phosphorus. A study by the New York State Department of Environmental Conservation estimated that for the year April 1969 to March 1970, 44 percent of the annual and 68 percent of the growing season phosphorus was contributed by the village while drainage from the watershed contributed 52 percent of the annual and 24 percent of the growing season phosphorus (5). If soluble rather than total phsophorus is considered, the village contributed 72 percent of the annual and 80 percent of the growing season phosphorus. My calculations indicate that about 28 percent of the total phosphorus comes from farmland on an annual basis.

What is the appropriate strategy for improving the quality of the water in Canadarago Lake? The sewage phosphorus can and will be virtually eliminated by tertiary treatment. This may or may not improve the lake water to acceptable standards. Reducing the phosphorus input from farmland may be very difficult, particularly in watersheds such as that surrounding Canadarago Lake where only a small part is in cultivated crops. Furthermore, since most of this phosphorus is particulate rather than soluble, it may not be important to algal growth. One could question whether a substantial expenditure of resources to reduce phosphorous from the farmland around this lake could be justified without knowing the importance of particulate phosphorus. Many lakes in New York and other states have a similar intermingling of municipal and agricultural sources of phosphorus. Before regulations or incentives are instituted to try to reduce phosphorus from farmland, a study on the feasibility and cost of alternative methods of controlling phosphorus should be undertaken. This would provide an information base which could be compared with the cost of phosphate removal from sewage. This should improve decisions on the extent and method of controlling phosphorus in Canadarago Lake.

Data Needs

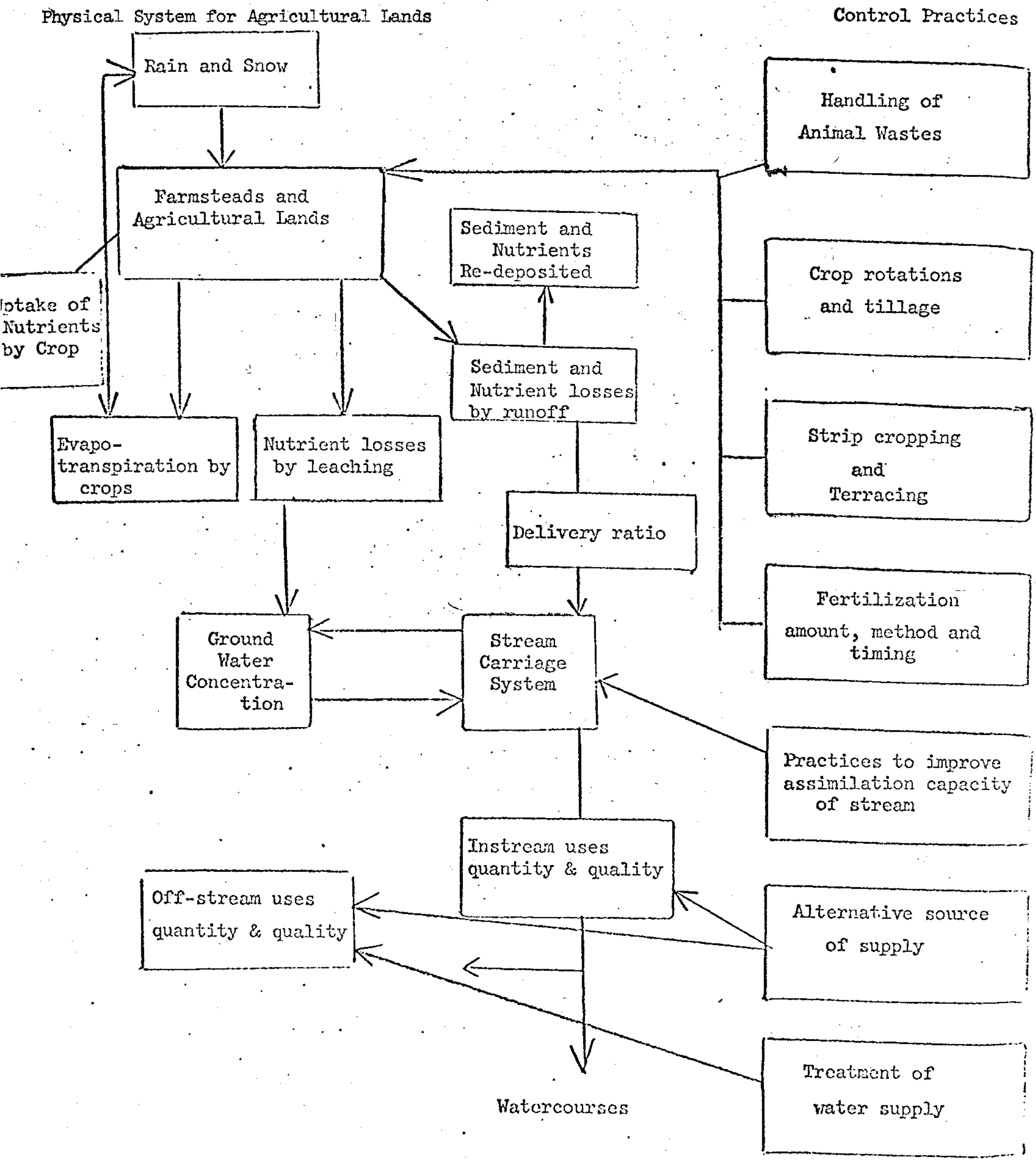
The vast and complex relationships between agricultural production and water quality indicated above necessitates communication and interaction among researchers in various disciplines. The interdisciplinary project with which we are associated includes researchers from agricultural engineering, agronomy, and conservation. The engineers are primarily interested in treatment processes for animal wastes, the agronomists in runoff at the edge of plots, and the conservationists are interested in studying lake eutrophication. No one, with the exception of a systems analyst in engineering, is attempting to research the relationship between specific agricultural practices and the residuals deposited in streams. Without such data it is very difficult to perform meaningful economic analysis. While it is easy to criticize researchers in other disciplines for not collecting needed data, one must also blame economists for not effectively communicating to such researchers the type of data needed for an economic analysis.

Langham, "in an article on pollution," stated: "As applied researchers, we have been somewhat guilty of playing down the role of observation and data collection and dwelling on techniques which assume the existence of data". (8) I would comment that dwelling on techniques in the absence of data is not particularly harmful if our research is used primarily for the edification of our colleagues. Economic research on agricultural productivity and environmental quality may be used as one of the inputs in policy decisions. If such research is based on poor or assumed data, some costly policy decisions will be made.

While communication across disciplines appears to be difficult, a discussion of the physical system illustrated in Figure 1 may be helpful. Specifically, Figure 1 indicates the physical linkage system for the potential pollutants of nitrogen, phosphorus and sediment from agricultural practices. It also suggests some alternatives for alleviating divergences between stream quality and the quality desired by subsequent uses.

The unavailability of data relating agricultural practices to residuals discharged to stream water requires the estimation of these relationships to make economic analysis possible. In a study of agricultural production and water quality in a 2000 square mile watershed in Western Iowa (6), analysis was focused on sediment and phosphorus. Because data relating agricultural practices to sediment and phosphorus was unavailable, it was necessary to estimate the technical coefficients which specify these relationships. Erosion losses from fields were estimated by using the Wischmeier-Smith soil loss equation (12); but because not all this soil reachs the river, alternative delivery ratios were employed. Phosphorus relationships were developed from the pounds of phosphorus per ton of top soil, top soil loss from erosion, an enrichment ratio (to reflect the increased concentration of phosphorus in the eroded soil), and the delivery ratios employed above. Using these two equations, estimates of sediment and phosphorus losses under alternative combinations of crop rotations, tillage methods and conservation practices were obtained. However, considering the number of estimates made because of incomplete knowledge, it is difficult to

Figure 1. A Model for Estimating and Controlling Runoff and Leaching Losses of NO_3, PO_4 and Sediment from Agricultural Lands



know how closely the estimated relationships approximate reality. While the results of this research may be good enough to allow formulation of reasonable policies, one would feel more comfortable with more complete knowledge about the relationships between farm practices and sediment and phosphorus deposited in the stream. Nitrogen was not considered because of lack of data to make guestimates of the relationship between nitrogen fertilization practices and nitrogen lost to stream water.

While the physical system depicted above provides information on the extent of pollutants under various practices and possible methods of control, the question of the level and method of control remains. Since the physical system provides no criteria of choice, economic considerations must be brought into the analysis to answer these questions.

The solution to which control method and the extent of it depends on (1) level of water quality desired, (2) technical coefficients of the alternative methods, i.e., unit effectiveness of each control method with respect to a particular pollutant, and (3) the unit cost coefficients of the alternative methods. It is in estimating these coefficients and constraints needed to conduct economic analyses where the knowledge of researchers in other fields must be enlisted.

The above suggests that the following are strategic to analyzing agriculture's role in water quality management: (1) the estimation of technical and cost coefficients associated with various agricultural practices and their respective pollutants, (2) specification of desired levels of quality, and (3) quantification of the stream linkage system. Another area of concern is the appropriate institutional forms to use in reducing environmentally damaging externalities, which is discussed in the next section.

Economic Incentives

Alternative methods for reduction of environmentally damaging externalities have received substantial attention in the literature. These include effluent standards, stream standards, effluent charges, payments for reducing effluents, taxes on products causing pollution, and subsidies for constructing effluent treatment facilities. While arguments have been presented for and against each of these alternatives for pollution control, effluent charges have the widest support among economists as the economically most efficient method to achieve improved water quality (1,4,7).

Some economists insist that the effluent charge for a particular residual should be equal to the marginal or incremental damage caused by the pollutant, or conversely, the marginal benefit from the reduction of the pollutant. Stream or effluent standards would not be part of the effluent charge system.

In the case of water, calculation of the benefits of higher quality is very difficult because of the fact that esthetic and recreational uses require higher quality than municipal and industrial uses. While the value of increased water quality to municipal and industrial users may not be easy to calculate, the attempts to estimate such values for recreational and esthetic uses indicate that useful data is not likely to be generally available in the near future. This situation, plus the fact that the states are committed to the improvement of water quality through the use of stream standards, has led many economists to argue that effluent charges would be the least cost method to achieve a given level of stream water quality (1,4).

The effluent charge system can work only if the residuals emanating from a particular production site can be measured. At the very least, this implies point rather than diffuse sources of pollutants. Although there are exceptions such as agricultural processing plants and some of the concentrated livestock production units, most of the residuals from agricultural production come from diffuse rather than point of sources. Identifying the specific farm from which nitrogen, phosphorus, pesticides, sediment or other residuals in a stream were deposited would be extremely costly and in most cases impossible. Thus, for most pollutants from agricultural production, effluent charges are an irrelevant economic incentive. Agricultural economists have been remiss in not pointing out this flaw in the conclusion by economists that effluent charges are the most efficient method to increase water quality. A greater need, however, is for agricultural economists to conduct research on the most efficient incentive, economic or otherwise, for controlling residuals from agricultural production. For example, is cost sharing under the Rural Environmental Assistance Program (REAP) as efficient in reducing pollution as a legislated standard or some alternative program? Would a tax on nitrogen fertilizer be the most efficient method of reducing the level of nitrate in the rivers draining the corn belt? The most efficient method of reducing externalities from agricultural production is not likely to be the same for all residuals. Assuming that there are benefits to society from decreasing the residuals from agricultural production, agricultural economists need to research the alternative policies for achieving such a reduction.

Summary

The comments in this paper have been directed toward the following points:

1. The effect on the environment and the social cost of many of the residuals from agricultural production is unknown. Research is needed to quantify these effects.

2. The relationship between most farm practices and the quantities of residuals deposited in water is not well defined. Until

researchers in other disciplines identify such relationships, only very limited economic analysis can be accomplished.

3. Effluent charges are an inappropriate economic incentive for reduction of pollutants from most agricultural production activities. Research is needed on other types of incentives.

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