MEASUREMENT OF THE CONTRIBUTION OF AGRICULTURAL PRODUCTION AND PROCESSING TO ENVIRONMENTAL POLLUTION

By

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Perhaps the last word in the title of this paper should be "quality" rather than "pollution". Certainly if one includes food and clothing as part of man's total environment, the positive effects of agriculture must outweigh the negative. But today we take all of the good things about life for granted and tend to emphasize what's bad about our way of life. We have developed a breed of self-styled "ecologists", some of whom might more accurately be labeled "enviromaniacs". Some of this group use the mantle of "science" to further their purposes but their methods are not always scientific. Nevertheless, this group has prodded many true scientists to take a closer look at what man is doing to the environment and the possibilities of alleviating this pollution. Although I'm sure that much more could and will be done in the area of research on agriculture's detrimental effect on the environment, I'm also impressed by the amount of work that has already been done in this area by scientists such as agronomists and agricultural engineers whose primary professional interest was in some other area until the environmental scare surfaced. Although a vocal group believes that society is unresponsive to what they perceive to be the real needs of society, I believe that the work already being done by agricultural researchers on pollution from agriculture is evidence that there has been a positive response to the environmental issue.

The possible adverse effects of agricultural production and processing on the environment could be characterized in several ways. I will list several potential pollutants, recognizing that others might prefer a somewhat different list and that my categories are not mutually exclusive.

1. Sediment from erosion
2. Livestock manure
3. Waste from processing plant and animal products
4. Plant nutrients
5. Pesticides
6. Air pollution, primarily odors and dusts

One possible approach to the measurement of pollution from agriculture would be to compare it with the total environmental pollution in the United States. Both of these quantities could probably be measured in units such

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as tons if we could agree on what items are pollutants but measurement would be difficult and perhaps not very useful. Comparing old car bodies with livestock manure is irrelevant. Even comparisons of livestock manure with domestic sewage can be very misleading. While comparison of agriculture with other sources of a specific pollutant may be useful as will be illustrated later, I have, in general, rejected the idea of measuring agricultural pollution relative to pollution from all other sources.

The time available does not permit a detailed analysis of each of these sources of pollution. I have selected manure, processing plant wastes and plant nutrients for more detailed analysis and will comment only briefly on the other pollutants.

Sediment from erosion of farmland is probably a smaller problem today than in the past. This may be particularly true in the Northeast where much of the steeper land is no longer farmed. From the viewpoint of my paper today, sediment is important as the carrier of phosphorus into stream water.

The detrimental effects of some pesticides are serious. Some of the worst offenders have been outlawed but the damage already done will be difficult or impossible to correct. Pollution from pesticides may be relatively easy to control compared to some other types of pollution. Use of those that are particularly bad can be made illegal. Compare this to livestock manure which would be essentially impossible to outlaw and it's difficult even to regulate spreading.

The form of air pollution from agriculture most familiar to us is unpleasant odors from livestock operations. Other examples are dust from cotton gins and alfalfa dehydrators and smoke from burning crop residues such as in the Willamette Valley of Oregon. These are usually localized problems and rather insignificant compared to industrial pollution, both in quantity and in terms of the specific pollutants released to the air.

Odors from livestock operations are a particularly perplexing problem. There is no objective test to distinguish between acceptable and unacceptable odors. Odors may be unpleasant but not likely to cause people physical harm. The odor problem intensifies as farmers enlarge livestock units to achieve size economies, particularly if they have close neighbors. In the Northeast, this means not only those producers near cities because in most areas farmers are outnumbered by rural non-farm residents by at least three or four to one. In New York the odor from livestock operations has so far probably been the largest source of conflict between farmers and environmental quality. Cornell's agricultural engineers, in response to requests from egg producers, have been studying this problem for more than 10 years. There are no complete solutions to the problem short of stopping livestock production.

Now that I have neatly disposed of those problems of environmental pollution by agriculture, let me return to the major objectives of this presentation:

1. To review some of the attempts that have been made to measure agricultural pollution
2. To point out that accurate measurement of pollution is difficult

3. To argue that some of the pollution attributed to agriculture is fictitious
4. To tell you what I think are some of the critical types of agricultural pollution, particularly in the Northeast.

It may be useful at this point to comment on a distinction between "farming" and "agriculture". Farming will be defined as the growing of crops and livestock. Agriculture is broader and could be defined to include everything from production of farm machinery (and the steel with which to build it) to retailing of food. In fact, we could include domestic sewage as part of the problem of agricultural pollution. In this paper I will conceptually include the processing of agricultural products as part of the agricultural pollution problem, but none of the pollution from farm supply activities nor from food wastes at the wholesale and retail level.

The pollutants with which this paper is concerned are those that relate primarily to water pollution. Within water pollution, we are primarily concerned with the use of water for recreation such as swimming and fishing, rather than for domestic or industrial uses. We are concerned with nutrients, particularly nitrogen and phosphorus, from plant and animal production and processing because of their relationship to eutrophication. We are also concerned with BOD (biochemical oxygen demand) from livestock manure and processing plant wastes because of its relation to dissolved oxygen in stream water and the potential for killing fish.

Five general kinds of studies in which attempts were made to measure pollution from agriculture will be reviewed:

1. Lake (watershed) Studies
2. Nutrient Balance Sheets
3. Nitrates in Stream and Ground Water
4. Livestock Manure
    a) Feedlots
    b) Spreading
5. Stream Pollution from Processing

Lake Studies

Cayuga Lake

In 1967, Gates and Riordan (10) estimated the inputs of nitrogen and phosphorus to Cayuga and Seneca Lakes from various sources. Their data for Cayuga Lake is shown in Table 1. They concluded "Despite the limitations imposed on the accuracy of the calculated nutrient input values by the necessary assumptions this study suggests very strongly that runoff from cultivated land is by far the largest contributor of nitrogen to Cayuga and Seneca Lakes. Public and institutional waste-water disposal systems and runoff from cultivated land appear to be equally important as contributors of phosphorus."

While the estimates of Gates and Riordan can be supported by coefficients found in the literature, other coefficients can be found which would make substantial changes in the relative importance of the sources of inputs of nitrogen and phosphorus. For example, phosphorus input from sewage was assumed to be 2.8 lbs. per person per year. The Canadarago Lake study reported below found the phosphorus from a village sewage plant to be 4.8 lbs. per person per year. Changing this one coefficient would increase the phosphorus from public sewage systems from 78,400 to 134,400 lbs. In addition, they apparently used a sewered population of 28,000 while Allee (2) states that sewage from 48,500 "population equivalents" enters the lake. If both population and phosphorus per capita are changed the annual phosphorus input would be 232,320 lbs. or more than double the estimated input from cultivated land rather than 71 percent as much. The estimates assumed 433 square miles of cultivated land and 193 square miles of forested land in the Cayuga Lake watershed. According to Child, Oglesby and Raymond (4), there are 349 square miles of active agriculture (not all cultivated land) and 225 square miles of forest of which more than half is described as "forest brushland and brush pasture--regenerating lands with brush cover and pole stands to 30 feet in height; 40-50 years of age". The inputs of nitrogen and phosphorus per acre were assumed to be 7.03 and .40 lbs. per acre for cultivated land and 1.30 and 0.73 lbs. for forest land. The data from the Canadarago Lake study reported below (5.63 lbs. of N per acre from a watershed that is primarily forest) would question whether the 1.30 coefficient is correct. And if the phosphorus coefficients used are correct, returning agricultural land to forest would increase the phosphorus input!

The Cayuga Lake study is cited here for two reasons: first, to illustrate the difficulty of accurate measurement of sources of pollution and second, to illustrate that the results of this attempt to measure the sources of N and P to Cayuga Lake may be very misleading.

Canadarago Lake (12, 13, 14)

Canadarago Lake is located in Otsego County in Upstate New York. The lake is about 1 mile wide and 4 miles long with a surface area of 2.94 square miles, a maximum depth of 42 feet and average depth of 22 feet. The watershed of the lake covers 67 square miles at elevations of 1,300 to 1,900 feet.

The village of Richfield Springs, with a population of 1,500 located near the head of the lake is the only significant permanent population center in the watershed. The permanent population of the watershed is about 3,500. During the summer months about 1,300 people occupy cottages around the lake shore. About 50 percent of the watershed is agricultural land, either cropland, pasture or idle, while 35 percent is forest and brush. Most of the agricultural land is used for dairy farming with about 6,000 head of cattle.

In response to concern of residents and cottagers about the deterioration in the quality of the lake water, the Environmental Research and Development Unit of the New York State Department of Environmental Conservation2/ in 1969 began an intensive study of Canadarago Lake. Gaging stations in the four major creeks that drain 78 percent of the watershed were used to measure the rate of flow and obtain samples for analysis. While many nutrients were measured, our attention is focused on nitrogen and phosphorus, particularly phosphorus. Available evidence suggests that phosphorus is the limiting element for algal growth in the lake (8), although the possibility exists that some other nutrient may be limiting.

Hetling and Sykes (12) concluded that for the April 1969 - April 1970 year 44 percent of the total annual phosphorus input to the lake was contributed by the village of Richfield Springs but during the June to September growing season the percentage rose to 68. The annual input of phosphorus from the lake shore cottages was calculated to be about 2 percent of the total. Applying the data from the gaged tributaries to the remainder of the watershed led to the conclusion that 52 percent of the annual input of phosphorus came from the land but in the June to September period this dropped to 24 percent. It was tentatively concluded that about 40 percent of the total phosphorus input to the lake could be attributed to farm operations.

If only soluble rather than total phosphorus is considered, sewage contributes 72 percent of the annual and 89 percent of the growing season phosphorus input due to the fact that the sewage phosphorus was 87 percent soluble while the stream phosphorus was 28 percent soluble.

It was estimated that the village plus cottages contributed 6 percent, the land runoff 91 percent and rainfall 3 percent of the nitrogen (nitrate, nitrite, ammonia and organic) input to the lake.

The relevant question at this point is "How much of the nutrient input to the lake actually comes from farming?" or perhaps "How much of the nutrients from the land runoff actually comes from farming?" The available data do not allow a conclusive answer to either of these questions but can at least shed some light on them.

The four major watersheds are drained by Ocquionis, Mink, Hyder and Herkimer Creeks, located to the north and west of the lake and in that order in a counterclockwise direction. The two northern watersheds have limestone-derived soils, gentle slopes, broad, marshy valleys and are largely devoted to farming. The two southerly watersheds have acid shale and sandstone-derived soils, steep slopes, few marshes, and more pasture and forest land. Actually, the intensity of farming diminishes as one moves southwesterly over

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2/ In 1969 the Unit was part of the New York State Department of Health.

the four watersheds and the Herkimer watershed is predominately forest covered. The number of non-agricultural residences, a potential source of nutrients from septic tanks, diminishes as one moves south and west (2).

If farming operations are major contributors of nitrogen and phosphorus to stream waters, we should expect a decrease in the runoff of these nutrients as we move southwesterly. In fact, the concentrations of both soluble and particulate phosphorus are greater in the streams from the limestone soil, more intensively farmed areas. For example, soluble phosphorus was about 15 ppb. (parts per billion) in Ocquionis, 12 in Mink and 10 in Hyder and Herkimer. Whether this additional phosphorus is due to crops, livestock, septic tanks or geomorphology is unknown.

When the phosphorus input is calculated in terms of land area we find a quite different picture. The watershed with the most farming contributed the least total phosphorus while the forested watershed contributed the most phosphorus per acre (Table 2). There was some decline in soluble phosphorus per acre from Ocquionis to Mink to Hyder but Herkimer contributed more than any of the other three.

The nitrogen data tell a similar story. The pounds of nitrogen (N) per acre from the most agricultural and the forested watershed were about equal while the intermediate watersheds each contributed appreciably more nitrogen.

What conclusions about nutrient pollution can be drawn from the Canadarago Lake study? Any conclusions must be tentative because of the differing geomorphology of the farmed and forested watersheds and because neither is entirely forest or cropland. But it appears that this type of agricultural watershed is contributing less of the limiting nutrient for algal growth, phosphorus, than is the forested watershed.

Assuming that phosphorus is the limiting element for algal growth in the lake, how can the lake be cleaned up? My calculations indicate that about 28 percent of the phosphorus input came from farmland and about 24 percent from non-farm land. Hetling and Sykes estimated that 44 percent came from the village and two percent from cottages. Because the largest source of phosphorus is the village sewage system and because there is known technology for removing this phosphorus, the obvious solution (to a layman like myself with little knowledge of the problem) is to dephosphate the sewage. Somehow, those with more control over the situation than I came to the same conclusion. Richfield Springs has been required by the Department of Environmental Conservation to install a new sewage plant because the existing one does not properly handle the organic matter. Because the village is small, the state does not require removal of phosphorus. The village is now constructing a new sewage plant and is voluntarily installing equipment that is designed to remove 90 percent of the phosphorus. If removal of this large amount of phosphorus does not improve the quality of the lake, what next? Farming or forested land? Reduction of phosphorus input from either will be difficult. Some phosphorus may be entering streams directly from manure in barnyards. Phosphorus from land gets into stream water almost entirely on eroded soil particles. There is probably less erosion of farmland than in the past because some of the steeper land is no longer farmed and because of better practices. Much of the soil in streams comes from stream-bank erosion. Erosion from construction sites probably contributes a significant amount of soil particles. Converting cropland to idle land or forest won't reduce phosphorus input to streams to zero.

At this point we just don't know how to significantly reduce phosphorus input from a farming area such as that surrounding Canadarago Lake. Since we are dealing primarily with diffuse rather than point sources of pollution we aren't even very sure of the relative importance of the sources of phosphorus. Cornell's agronomy department has a graduate student making a detailed study of land use in the watershed. Perhaps this will provide more data about the relationship between farming activities and phosphorus input to stream water.

Nutrient Balance Sheets

There have been several attempts to estimate pollution from farming activities by preparing budgets describing the inputs and outputs of a particular system. Any nutrients put into the system not accounted for by output are then assumed to be pollutants.

A Connecticut Dairy Farm

Three such budgets will be described here. The first was prepared by Frink using a dairy farm as the unit of analysis (7). Output of the farm in terms of nutrients in milk and meat (plus volitalization) was subtracted from inputs as concentrate, fertilizer, fixation and rainfall (Table 3). The difference or net loss indicates that a large portion of the nutrients are lost--that is, they cannot be accounted for in measured outputs. Frink concluded that a large part of the nitrogen ultimately reached waterways but the P and K were largely fixed in the soil.

The Genesee River

Schultz (8) developed a balance sheet for a farming area along a portion of the Genesee River (Table 4). He used a different approach in which the land in the drainage area was the unit of analysis. Inputs of N, P, and K came from fertilizer, manure, precipitation and fixation. Output was contained in crop production and percolation, which was assumed to go to ground water rather than stream water. His data indicate a loss of about 18 pounds of N and 4.8 pounds of phosphorus per acre per year.

New York State

Rezelman (17) prepared a balance sheet for nutrients for crop production in the state of New York (Table 5). He used three levels of volitalization of nitrogen applied as fertilizer and two levels of fixation by legumes.

Removal in crops was the sole output. His unaccounted for residuals of nitrogen at all combinations of volitalization and fixation were greater than the input of N as fertilizer. The residual of phosphorus was also greater than the input from fertilizer while for potassium it was 80 percent as much.

Usefulness of Balance Sheets

While balance sheets such as those illustrated here may point out some critical areas for further research, they don't necessarily tell us much about nutrient pollution from farming. One problem is defining the relevant balance sheet. Frink used the inputs and outputs for the entire farm while Schultz and Rezelman considered inputs and outputs for the land being cropped. Schultz calculated percolation losses as an output; his residual is "net loss to surface waters" although he recognizes that some part of the nutrients in percolation returns to stream water. While the problem of proper definition of the balance sheet probably could be solved, there are more serious problems that raise difficult questions about the usefulness of balance sheets. The nitrogen cycle, while well understood qualitatively, is not quantitatively well defined. There is non-symbiotic fixation as well as denitrification. Rezelman assumed these to be equal which may not be true. The amount of nitrogen from fertilizer and manure that is volitalized cannot be estimated accurately. Fixation varies tremendously with the percentage of legumes in the stand. The soil itself is a reservoir that can soak up or release nutrients. Phosphorus added to soil is quickly adsorbed to soil particles and is lost to stream water almost entirely as erosion, which has not been considered in the balance sheets. Also, the phosphorus content of soils can be substantially increased by fertilization. And finally, should we be concerned only with the nutrients that are released to stream and ground water or should we worry about nitrogen released to the atmosphere? There have been reports that increased nitrogen in rainfall downwind from cattle feedlots has eutrophied lakes (3).

The most striking result of these balance sheets is the apparently very large amount of excess nitrogen. Frink puts it at 265 lbs. of N for every dairy cow, Schultz at 18 lbs. of N for every acre of land in the region and Rezelman at 63,000 to 97,000 tons for New York State. Exactly where this nitrogen goes is unknown but other data indicates that at least part of it goes to stream and ground water. Estimates of nitrogen released to stream water of 18 lbs. per acre of total land in the watershed (Schultz) or 11 to 17 lbs. per acre of total land in farms (Rezelman) are far higher than the nitrogen found in the streams around Canadarago Lake (5 to 8 lbs. per acre) and may indicate that the balance sheet estimates are not very accurate.

Nitrate in Midwest Stream and Well Water

In 1968, Barry Commoner (5) at the A.A.A.S. meeting in Dallas said "It is evident from Figure 1 that the nitrate level of the Kaskaskia River has increased about threefold between 1946-50 and 1956-68. In contrast, there has been no significant change in the nitrate load of the Skillet Fork River in that period. The only known difference in the nitrogen inputs between these two drainage areas is the sharp increase, during this period, in the use of nitrogen fertilizer in the Kaskaskia area as compared with the Skillet Fork area. Hence it is likely that the increased nitrogen load of the Kaskaskia is due to the increased use of nitrogen fertilizer in its drainage area." In 1970, Sam Aldrich (1), et al at the A.A.A.S. meeting in Chicago, referring to Commoner's first sentence above, said "Data collected by Harmeson and Larson (1957, 1969) from several rivers in and around Illinois indicate no close relationship between nitrate concentration and nitrogen fertilizer tonnage, figure 3.

"Except for 1965, nitrate has not increased in the lower Kaskaskia River at New Athens since 1946. Nitrates one hundred miles upstream at Shelbyville, on the other hand, increased abruptly in 1965 and then remained at about the 1965 level through 1969 though fertilizer nitrogen in the watershed nearly doubled in this 5-year period. This river was the subject of an unfortunate error which is widely scattered through environmental literature concerning the nitrate status of Illinois rivers. At the AAAS meeting two years ago, Commoner (1968) stated, 'It is evident that the nitrate level of the Kaskaskia River has increased threefold between 1946-50 and 1956-68'. This erroneous conclusion was based upon the use of data from the New Athens location in the first period but from Shelbyville in the latter period."

This exchange gives us some idea of the state of the controversy over the relationship between increased use of nitrogen fertilizer and increased levels of nitrates in Midwest streams. While part of the concern over high nitrate levels is because of eutrophication, a larger concern is that many of these streams have been found to have nitrate concentrations above U.S. Public Health Service Drinking Water Standard of 45 mg./l. High levels of nitrate have also been found in many shallow wells, probably related to percolation from feedlots.

Harmeson and Larson (11), who have been studying water quality of Illinois rivers report that before 1956, maximum nitrate concentrations equaling or exceeding 45 mg./l. were not found in any of the streams sampled but since 1956 this level has been exceeded in 9 rivers.

Evidence of increased nitrogen levels in stream water in Illinois can be found and this has occurred during a period of increasing rates and total use of nitrogen fertilizer. Whether there is a causal relationship is more difficult to determine. Garman (9) points out that during this period of increasing nitrate levels, many cities and villages have upgraded waste treatment which has reduced the organic matter and BOD of effluent. The result is less use of nitrogen by bacteria, resulting in increased levels of nitrate in the stream water.

Harmeson and Larson (11) have measured nitrate in the discharge from drainage tile serving an area of 400 acres in the upper Kaskaskia watershed and in the stream 3 miles below the tile outlet at Bondville. Nitrate concentrations from the drainage tile ranged from 20 to 60 mg./l. and from the stream samples 1 to 63 mg./l. The small watershed above the stream sampling location is almost entirely devoted to agriculture and there is no discharge from sewage treatment plants. The nitrate from the tile was 15 to 25 percent of the nitrate in the stream during July - September 1969 but only 7 to 10 percent in October and November. The 400 acres drained by the tile is about 6 percent of drainage area above the stream sampling point. They state: "Here the available data seem to point more conclusively to mineralization of basic soil humus and/or applications of commercial inorganic fertilizers as the source(s) of nitrates in the stream. But the relative contribution of each source is not revealed." Aldrich, according to Harmeson and Larson (11), has estimated that about 80 lbs. of N per acre is released from the basic soil humus in East-Central Illinois. Fertilizer N application on the 400 acre tiled watershed averaged about 75 lbs. per acre. Thus the two sources appear to be about equal in terms of the amounts of N but this doesn't necessarily mean that they contribute equal amounts of the nitrate found in the tile discharge.

The amount of nitrate N from the 400 acres, estimated from the July - October data is 9.5 lbs. per acre per year. Data for the entire year including periods when runoff is higher probably would increase this estimate. The amount of nitrate N carried by the Kaskaskia River past Shelbyville (downstream from Bondville) was estimated to be over 7,200 tons or 20.5 lbs. per acre of drainage area. The potential sources of this nitrogen and approximate contributions of each were estimated by Harmeson and Larson to be:

Soils	61.5%
Commercial Fertilizers	26.8%
Animal Wastes	7.6%
Atmospheric Source	3.8%
Domestic Wastes	0.3%

After reviewing this and other data I have concluded that increasing rates of nitrogen fertilization is at least partially responsible for increased levels of nitrate in stream water in the Midwest. The impact of reduced fertilization on items such as crop yields, farm incomes and food output are beyond the scope of this paper.

Livestock Manure

There have been several widely reported incidents of fish kills in the Southwest related to stream pollution by livestock manure. Although the Northeast does not have extremely large feedlots, there are a substantial number of barnyards located very close to streams and we do have an increasing number of dairy farms of more than 100 cows. Manure spread on land at high rates, particularly when the ground is frozen, may pollute surface waters.

A Small Feedlot in Ohio

A study by Edwards, Chichester and Harrold (6) of a small feedlot (60 steers from November through May) in which an estimated 1/3 of the manure was deposited in the outside yard may give some indication of pollution potential of dairy farms in the Northeast. Samples were taken from the runoff as it left the barnyard and after it passed a 500 meter grassed waterway. The area above the downstream sampling point included the feedlot and 75 acres of land half of which was pasture and half cropland in a contour strip four-year rotation of corn-wheat-meadow-meadow. The corn and wheat were fertilized and the meadow received 18 metric tons per hectare of manure in the winter prior to plowing for corn.

The concentrations of NO_3-N and P in the barnlot runoff were well above the nuisance threshold levels of 0.2 and 0.01 ppm. The volume of runoff at the end of the grassed waterway was about 100 times as great as the runoff from the feedlot. Dilution plus whatever else occurred in the waterway resulted in an average annual concentration of NO_3-N at the barnlot of 1.3 times that at the waterway outlet. When all forms of soluble N were considered, concentration was reduced 8.3 times by the waterway. For phosphorus, the concentration at the feedlot was 27.9 times that at the waterway outlet. BOD averaged 121 mg./l. (with a range of 5 to 359) at the barnlot but 4.0 (range 1 to 12) at the outlet. In May 1970, the barnlot runoff was diverted, stored and spray irrigated on the pasture land at a rate low enough to preclude runoff. There was no noticeable improvement in the quality of the water at the outlet during the following 8 months.

Space precludes full reporting of the results of this measurement attempt. However, I believe this study illustrates several important points. Measurement was difficult and interpretation possibly more difficult. Concentrations of pollutants at the feedlot were high but the total runoff compared to the watershed was low. It would be easy to become overly concerned with the quality of the runoff and forget the high dilution factor that reduces the problem. Much of the downstream nitrogen came from outside the barnlot while a high proportion of the phosphorus came from the lot. Concentrations of phosphorus at the waterway outlet were about 10 times greater than those in a nearby stream draining a 123 acre farmland watershed reported by Taylor, et al (21).

Commercial Feedlots in South Dakota and Nebraska

A study of runoff from six commercial feedlots in South Dakota by Madden and Dornbush (15) in 1969 and 1970 separated runoff from snowmelt from that caused by rainfall. Their conclusions follow:

1. "Under conditions similar to these occurring during the study, approximately 30 percent of the total annual runoff may be attributed to snowmelt.

2. "One half of the total annual runoff may be attributed to rainfall events which may not produce runoff from the general surrounding area. Minimum diversion of foreign drainage and detention of runoff would control these events and reduce the pollution potential in excess of fifty percent.

3. "In a typical feeding operation approximately 95 percent of the total waste produced is either removed by cleaning operations or decomposed on the feedlot surface. Potentially 5 percent of the total waste generated may leave the feedlot in surface runoff.

4. "Minimum detention facilities, diverting of foreign drainage, and reduction of runoff velocities will reduce the pollution potential to less than 2 percent of the total animal waste produced."

The magnitude of the livestock manure problem has often been discussed in terms of the total amount of manure produced by livestock. This approach is misleading because much of the manure is deposited on pasture and rangeland where pollution hazard, while not necessarily zero, is minimal. Manure from concentrated livestock operations that is carefully land-disposed has little effect on water quality. The part that enters streams directly and thus does effect water quality is a small proportion of the total manure production. The South Dakota data indicate that even in medium sized feedlots where manure is removed infrequently, only 2 to 5 percent of the waste (or N, BOD or P) produced by the livestock is carried in runoff. Looking at the problem in a different way, Swanson (20), in a talk at the International Symposium on Livestock Wastes at Columbus, Ohio in April 1971, stated that the total amount of runoff from feedlots in comparison to the total runoff of water in Nebraska is equal to 5 hours of runoff on one day per year.

I conclude from reviewing these and similar studies that the total magnitude of the manure problem is much less than some have led us to believe but there are spots, particularly with extremely large feedlots and heavy, infrequent rainfall, where the problem is immense. It also appears that the input of phosphorus to streams from feedlots may be more important than that from cropland runoff, particularly in view of the fact that it is mostly soluble phosphorus while most of that from land is carried on soil particles and may do little harm.

Nutrient Runoff from Manure Spread on Land

The interest and controversy related to the effects of spreading manure on stream water quality indicates that it would be appropriate to review some research on the problem. In a three-year study begun in winter of 1967 on 10 to 12 percent slopes at Lancaster, Wisconsin reported by Minshall, Witzel, et al (16), runoff was measured from plots with no manure, fresh manure applied in winter and fermented and liquid manure applied in the spring. Each summer corn was grown on all the plots.

While N and P runoff from winter manured plots was much greater than any of the other plots, the spring manured plots had less nutrient runoff than the non-manured plots (Table 6). It might be concluded that spring spread manure does not increase nutrient losses but that winter spreading should be avoided. The latter conclusion might be tempered somewhat by a rather unusual occurrence in the winter of 1967. Two hours after the manure was spread on frozen ground with no snow cover, 0.75 inches of rain in 1 hour resulted in almost 100% runoff. Seventy-two percent of the N and 42% of the P lost during the winter of 1966-67 from the winter manured plots were lost during this one rainfall. In the winter of 1967-68, with precipitation less than half that of either of the other two years' average December to March runoff from all treatments was 2% of the year's total compared to 70% for each of the other years. Nutrient loss from all treatments was extremely low and losses from the winter manured plots less than that from some of the other treatments. Another interesting result was that summer runoff from the unmanured plots exceeded the average runoff of all other treatments by 78% and this became worse over the three-year period (34, 48, and 155%) possibly due to these plots having less organic matter. For the three year period the unmanured plots lost 50% more P than the spring manured plots.

Several important conclusions and questions can be drawn from this research. It indicates that winter spreading on frozen ground may result in high nutrient losses, particularly if there is no snow cover and heavy rain. But the variability among years raises questions about how serious the nutrient losses from winter spreading really are. Does a situation like the 1966-67 winter occur once in three years or once in twenty? The winter 1966-67 precipitation was 10% above average and that in 1968-69 was average, yet runoff in each year from experimental watersheds nearby was more than double the 25-year average. This undoubtedly influenced the results of the manure study. In addition, there were variations in the amount of snow cover on the plots. While this research implicates winter spread manure as a source of N and P in stream water, it also suggests some positive effects of manure. And it points out that long term research is needed to more accurately assess winter spread manure as a stream polluter.

Stream Pollution from Processing

Two examples from the many situations where processing of agricultural products might or does pollute stream water will be cited.

Delaware Vegetable Processing

A 1967 study of six vegetable processing plants by Stevens and Cole (19) revealed very high water use in relation to product output (Table 7) as well as high variability among plants. Recirculation varied from 39 to 93 percent. In addition to the variation in water use among plants and products, there was great variation among days in water use per case for a given product in the same plant due primarily to fluctuations in product output.

There were wide variations among plants and products in the strength of the waste, as measured by BOD per case. Low case yields of product per ton of raw product resulted in higher BOD because much of the raw product went down the drain.

BOD levels for individual samples of waste water taken in these plants ranged from 168 to 2,450 for beans and 576 to 4,880 ppm. for peas. Another study (23) found an average BOD level of 2,730 mg./l. in waste water from pea processing. These levels are well above the 200 to 300 mg./l. of BOD usually found in domestic sewage. In addition, the large volumes of water present a disposal problem because they lower stream water quality if discharged directly, require large areas if irrigation disposal is attempted and add greatly to the total sewage loads if discharged to municipal systems.

A Genesee Valley Cannery

Data from a survey of the Genesee River (22) show the probable impact on stream water of discharge from a processing plant (Table 8). The plant is located on a tribitary about 1 mile upstream from the river. Both the river and tributary drain primarily agricultural land above the plant. Water quality, as measured by BOD or coliforms was definitely lower at the sampling station below the plant than at either the river or tributary stations above the plant. There was a further drop in water quality as the river passed a village with a municipal sewage system.

Conclusions

Available measurements of the impact of agricultural production and processing on water quality are at best inadequate and sometimes very misleading. Data that I have reviewed suggest that the problem of excess phosphorus in lake and stream water will not easily be solved through the agricultural route. Farmland probably contributes no more phosphorus per acre than forest or idle land and in both cases it is largely particulate rather than soluble. However, there may be cases where soluble phosphorus from manure enters streams directly from feedlots. Nitrogen from heavy fertilizer applications does not appear to be a problem in much of the Northeast, primarily because a rather low percentage of the land is in corn or other crops with high rates of N fertilization. But even my agricultural bias doesn't prevent me from concluding that there is probably a relationship between increasing nitrogen fertilization levels and increasing nitrate levels in Midwest stream waters.

We are sadly in need of data showing the actual relationship between farm operations and stream water quality. Data purported to show this relationship is largely circumstantial--collected by comparing stream water quality in areas that are supposedly agricultural and non-agricultural but ignoring other factors in the watersheds. Data collected by measuring runoff at the edge of plots may be misleading in either direction. Nutrient loss per acre from large fields may be much higher than from plots. When runoff from cultivated fields crosses noncultivated fields, border strips, or grass waterways, nutrient contents may be greatly reduced from levels at the edge of the field. This statement also applies to runoff from feedlots, as shown by the Ohio feedlot study.

In the Northeast there are several kinds of situations where the problem of pollution from agriculture is real, measurable, and in need of attention. Wastes from fruit, vegetable, and milk processing plants are problems of this type. Some processors appear to be handling the problem adequately through municipal systems, lagoons, or irrigation. Others because of factors such as plant location, type of waste product, or financial resources, could not meet current regulations if strictly enforced. Acid whey from cottage cheese is an immense problem because it is produced in very large quantities of dilute material prohibitively expensive to dry in relation to the value of the finished product. Accidental or intentional location of dairy barns near streams or watercourses, particularly with increasing herd sizes, sometimes presents a barnyard runoff problem with essentially no solution except relocation.

Rather large amounts of resources have been expended in attempts to measure pollution from agriculture. Sometimes data has been collected to point the finger at a particular industry as a polluter rather than to make a thorough study of the problem. For example, concentrations of N and P have been measured at times of low flow, spring runoff, etc. in streams entering Cayuga Lake. The absence of a systematic procedure for continuous monitoring of the streams to determine flow as well as concentrations, may mean that the data is almost meaningless. Even well collected data on stream-water quality may be of little help to one who wishes to analyze the economic relationship between agricultural production and water quality because the nature of all activities, including agriculture, in the watersheds has not been well specified. As an economist who is a member of an interdisciplinary team studying agriculture's relation to environmental quality, I am beginning to wonder whether I must collect data myself because there are too many gaps in that collected by the agronomists and conservationists. Much of the data problem, in my opinion, is due to the lack of a comprehensive view of the problem, even by ecologists. But perhaps we economists are primarily at fault for not defining the problem in economic terms and communicating this definition to those in other disciplines who are attempting to measure pollution.

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Table 1. Estimated Annual Nitrogen and Phosphorus Contributions to Cayuga Lake

	Source	Total Nitrogen lbs./year	Total Phosphorus lbs./year
1.	Public and institutional waste-disposal systems	216,000	78,400
2.	Private (individual)	18,500	5,900
3.	Lakeside cottage waste disposal systems	17,000	4,900
4.	Runoff from cultivated land	1,950,000	110,000
5.	Runoff from forested land	160,000	92,000
6.	Wastes from boat traffic	1,500	450
7.	Precipitation	246,000	---

Source: (10)

Table 2. Nutrient Losses from Canadarago Lake Watersheds, April 1969-April 1970

Watershed	Phosphorus, Lbs. per acre per year: Soluble	Particulate	Total
Ocquionis	0.051	0.093	0.144
Mink	0.041	0.116	0.157
Hyder	0.037	0.127	0.164
Herkimer	0.058	0.164	0.222

Watershed	Nitrogen, Lbs. per acre per year: $NO_3 + NO_2$	NH_4	Organic	Total
Ocquionis	3.68	0.38	1.55	5.61
Mink	5.13	0.38	2.44	7.95
Hyder	5.72	0.32	1.34	7.38
Herkimer	3.79	0.42	1.42	5.63

Source: (13) and (1)

Table 3. Nutrient Budget for a Connecticut Dairy Farm

Item	Pounds per cow per year		
INPUT	Nitrogen	Phosphorus	Potassium
Concentrate	180	40	45
Fertilizer	110	50	90
Fixation	200	--	--
Rainfall	10	--	--
Total	500	90	135
OUTPUT			
Milk	70	10	18
Meat	10	2	2
Volatilization	155	--	--
Total	235	12	20
NET LOSS	265	78	115

Source: (7); kilograms converted to pounds by Garman (9)

Table 4. Nutrient Balance Sheet for Farmland in a Portion of the Genesee River Basin

	Nitrogen	Phosphorus
Nutrients Added	million pounds	
Fertilizer	2.6	2.1
Manure	3.1	0.3
Precipitation	1.4	--
Total	7.1	2.4
Nutrients Lost		
Crop Production	2.2[a]	1.7
Percolation	.7	--
Total	2.9	1.7
Net Loss to Suface Waters	4.2	0.7
Loss per acre of total land	18.1	4.8

a) Nitrogen in crops produced 7.6 million pounds less fixation of 5.4 million pounds.

Source: (18)

Table 5. Annual Nutrient Balance Sheet, Agricultural Land, New York
(Tons of Nutrients)

ITEM	N I	N II	N III	N IV	N V	N VI	P	K
Chemical Fertilizers	-	-	-	-	-	-	26,266	42,050
0% Volatilized	35,067	-	-	35,067	-	-	-	-
25% Volatilized	-	26,300	-	-	26,300	-	-	-
50% Volatilized	-	-	17,534	-	-	17,534	-	-
Legume Fixation	112,340	112,340	112,340	95,756	95,756	95,756	-	-
Manure	74,621	74,621	74,621	74,621	74,621	74,621	23,997	101,735
Precipitation	24,106	24,106	24,106	24,106	24,106	24,106	-	-
TOTAL	246,134	237,367	228,601	229,550	220,783	212,017	50,263	143,785
Removed in crops	149,242	149,242	149,242	149,242	149,242	149,242	20,219	109,765
Residual	96,892	88,125	79,359	80,308	71,541	62,775	30,044	34,020

Source: (17)

Table 6. Nutrient Losses from Manured and Non-Manured Corn Plots, 3 year average, 1967-69, Lancaster, Wisconsin

		Manure Treatment		
Nutrient	None	Fresh Winter	Fermented Spring	Liquid Spring
Total N	3.89	11.30	3.59	3.20
Total P	1.17	2.62	0.72	0.86

Source: (16)

Table 7. Water Use and BOD in Several Delaware Vegetable Processing Plants, 1967

Plant Number	Product	Water per 303 case Gross	Intake	BOD per 303 case
		gallons		pounds
1	Green beans	591	117	0.34
2	Green beans	571	120	0.29
3	Green beans	320	73	0.97
4	Green beans	178	77	0.23
1	Peas	748	53	0.79
3	Peas	818	44	0.57
4	Peas	137	83	N.A.
1	Asparagus	2,857	203	N.A.
2	Asparagus	1,250	190	0.02

Source: (21)

Table 8. Water Quality Measurements, Genesee River, August 25, 1959

Sampling Station	Dissolved Oxygen ppm.	BOD 5-day ppm.	Coliforms per 100 ml.
Tributary above plant (1.9)	6.4	1.2	9,300
Genesee River above plant (40.3)	5.2	1.2	2,300
Genesee River below plant (34.7)	5.0	5.0	230,000
Genesee River below village (33.4)	2.4	6.6	930,000

Source: (22)