United States
Department of
Agriculture

Economic
Research
Service

Agriculture
and Trade
Analysis
Division

Policies to Reduce Nitrate Pollution in the European Community and Possible Effects on Livestock Production

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Policies to Reduce Nitrate Pollution in the European Community and Possible Effects on Livestock Production. By Dale J. Leuck, Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture, Staff Report No. AGES 9318.

Abstract

In response to high nitrate levels in the water supply in parts of the European Community (EC), regulations to restrict farming practices have been enacted in recent years. A major EC directive, which became law in 1991 but becomes effective in 1999, attempts to restrict the amount of nitrate in the soil. This directive could reduce future livestock numbers in the EC by 12 percent. Local effects would be much higher. The projected reduction in EC livestock numbers is likely to reduce U.S. feedstuff exports and increase livestock product exports.

Keywords: Environmental policies, European Community, fertilizer, manure, nitrate, nitrate directive, pollution.

Acknowledgments

The author appreciates the helpful comments of Mary Lisa Madell, Jerry Sharples, and Steve Haley of the Agriculture and Trade Analysis Division, Stan Daberkow of the Resources and Technology Division, Doug Martinez and Bonnie Moore of the Economics Management Staff, and Dr. David Mengel, Department of Agronomy, Purdue University.

Washington, DC 20005-4788

September 1993

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Summary

The belief that agriculture is a source of pollution emerged as a political issue in the European Community (EC) as scientific evidence of farming's effects on the environment mounted throughout the 1980's. The two farming practices that most concern policymakers are the use of large amounts of fertilizer for crop growth and the disposal of livestock manure. Both materials are sources of nitrogen, which is transformed into nitrate once in the soil. Nitrate that is not used by plants or transformed back into atmospheric nitrogen leaches through the soil or runs off into water supplies. High levels of nitrate in water may adversely affect human health as well as the metabolism of livestock.

In response to high nitrate levels in water supplies, the EC passed its Nitrate Directive in 1991. Its objective is to limit the amount of nitrogen remaining in the soil as a residual after uptake by crops. The Directive limits this residual to 170 kilograms per hectare (kg/ha) in yet-to-be-defined "vulnerable zones." Other regulations on the use of nitrogen fertilizer, the numbers of livestock, and the storage and disposal of manure are to be defined and implemented over an 8-year period.

The most severe problems seem to be in Denmark, Belgium, and the Netherlands. Limiting the amount of residual nitrogen in these countries to 170 kg/ha would require decreases in livestock numbers of 9, 29, and 65 percent, respectively. Fertilizer use may have to be reduced by 2 percent in Denmark and 28 percent in the Netherlands. More effective methods of storing and disposing of manure could substitute for some of the reduction in fertilizer use and livestock production.

The aggregate nitrogen balance tables do not show the significant subnational nitrate problems that exist in many parts of northern Germany, low-lying areas of northwestern France, northern Italy, and parts of the United Kingdom. Furthermore, the aggregate coefficients used to compute the aggregate tables do not adequately account for regional differences in the inflow or outflow of nitrate from the soil. In particular, the coefficients do not account for differences related to soil structure, precipitation, the nutrient content of manure due to different feed rations, and varying rates at which nitrate may be returned to the atmosphere. These limitations illustrate the need for further physical research at the subnational level.

Policies to Reduce Nitrate Pollution in the European Community and Possible Effects on Livestock Production

Dale J. Leuck*

Introduction

Empirical evidence suggests that chemicals such as nitrate (contained in nitrogen fertilizers and livestock manure) enter water supplies in some regions of the European Community (EC) at potentially harmful levels.[1]

While some EC member countries have enacted laws to limit the adverse effect of many agricultural practices, progress at the Community level has been confined mainly to research reports, resolutions, and draft directives. A Nitrate Directive was passed by the EC Commission on June 14, 1991, in order to restrict the amount of nitrate entering water from agricultural sources (*5*).[2] The Directive is aimed at limiting nitrate from livestock manure, both by regulating its handling and by reducing livestock numbers. The Directive does recognize that any policy affecting livestock numbers may be adjusted by the addition of nitrate from nitrogen fertilizer.

A consensus is also building for structural reform of the Common Agricultural Policy (CAP), the EC's farm policy that has, at least partly, induced surplus production of agricultural products and, therefore, contributed to nitrate pollution. Although CAP reform is mainly motivated by the financial costs of disposing of surplus products, any reforms that reduce production may also reduce the amount of nitrate pollution. Some reforms to limit crop and dairy production have been enacted in recent years, while more significant reform proposals are currently pending.

Reforms affecting EC agricultural production are likely to affect world trade because the EC is a major agricultural exporter. The United States has an interest in these trade effects because it is also a major participant in world trade. The objectives of this report are therefore threefold:

- To describe the nature and magnitude of nitrate pollution in the EC, and to present the details of the Nitrate Directive. Some of the policy decisions that have led up to this Directive are also discussed.

- To calculate any reductions in livestock numbers and crop production that may be necessary to meet the requirements of the Nitrate Directive. These calculations serve as primary assumptions in Economic Research Service (ERS) reports that compare the trade and world price effects of

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[1]This report covers only the first 10 members of the European Community (EC-10). These countries are Belgium, Denmark, Luxembourg, Germany, France, Greece, the Netherlands, Ireland, Italy, and the United Kingdom. Although agriculturally related pollution is increasing in Spain and Portugal, the problem in these countries is still relatively minor.

[2]Italicized numbers in parentheses cite sources listed in the References section.

different environmental and CAP reform policies (*10, 13, 15*). These reports use 1986 as their base.

- To compare how nitrate levels have changed in the EC between 1986 and 1991 as a result of past reforms. These reforms include national policies to reduce pollution and EC reforms to limit crop acreage and dairy production.

Agricultural Practices as Threats to the Environment

Until recently, farmers were perceived as custodians of the environment who replaced in the land, woods, and wildlife that which they took for sustenance. While always somewhat of an exaggeration, this view persisted until the middle of the 20th century because industrialization had long been viewed as the dominant threat to the environment. Only after the rapid mechanization of agriculture in Europe after World War II, many people began to understand the effect of a more production-intensive agriculture on the environment.

The growing demand for meat and dairy products after the end of World War II led to rapid intensification of both livestock and crop production. Growth in production was also facilitated by the CAP pricing policies that took effect in the 1960's. The production of dairy products, beef, and veal more than doubled between 1950 and the present, while pork and poultry production more than tripled. Egg production increased more slowly. The amounts of manure increased by similar proportions.

Grain production also increased to satisfy livestock demand and export markets. Higher-yielding grain varieties were adopted, requiring more fertilizer to supply nutrients for plant growth, as well as the use of herbicides, pesticides, fungicides, and other chemicals to minimize the influence of weeds, pests, and disease on plant development. As a result, EC grain production doubled, on a slightly smaller amount of land between 1960 and 1990.

Nitrate: Necessary for Plant Nutrition and a Source of Pollution[3]

Nitrate is the form of nitrogen that can be directly absorbed by plants. Nitrogen is essential for plant growth. It gives plants their green color and aids in photosynthesis, the process by which plants grow. Nitrogen is also a component of the organic compounds that comprise a plant, such as proteins, enzymes, etc. Unfortunately, plants cannot absorb 100 percent of the nitrate in the soil, and some nitrate eventually enters ground or surface water by leaching or runoff.

Nitrate that enters ground or surface water contributes to eutrophication, which is defined as an excess of any nutrient. Excess nutrients in surface waters precipitate algae blooms, which, in turn, take oxygen out of the water. The algae blooms smell bad and may be toxic if ingested. Moreover, the decreased oxygen content of the water destroys aquatic life. The most common sources of eutrophication in water supplies are nitrate and phosphate.

Nitrate may also adversely affect both livestock and human health. High levels of nitrate interfere with the metabolism of livestock, leading to reduced feeding efficiency. The main human health concern with nitrate is its possible link to stomach cancer. In very large concentrations, exceeding 100 parts per million (ppm), nitrate has been found to cause respiratory failure in infants under 3 months of age.[4] While extremely rare, this may occur when the blood takes up nitrate rather than oxygen.

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[3]A discussion of the role of the nitrogen cycle in producing and reducing nitrate in the soil may be found in (*9*).

[4]The measure, ppm, is sometimes given as milligrams per liter (mg/liter). The two measures are equivalent, however.

The Role of Nitrate in the Environment

Nitrate is derived from elemental gaseous nitrogen, N_2, through a number of chemical reactions. Elemental nitrogen comprises approximately 78 percent of the atmosphere. In this form, nitrogen cannot be metabolized by higher forms of plants. To be used by plants, elemental nitrogen must be "fixed" into some other form and placed into the soil where it can be taken up by plant roots. The most common ways that atmospheric nitrogen is fixed are by:

- Electrical storms ---------------------------
- Automobile exhausts ------- Acid rain
- Industrial emissions ---------------------------
- Fertilizer industry
- Legumes

The first three of these methods fix atmospheric nitrogen by converting it into nitrogen oxides. These oxides then combine with oxygen to produce nitrogen dioxide, which, in turn, produces nitric acid when absorbed by water. Another industrial emission, besides nitrogen oxide, that is becoming more common is ammonia gas, which is also soluble in water. Both nitric acid and ammonia gas then enter the soil in the form of acid rain.

The fertilizer industry produces liquid and solid nitrogen fertilizers. The most important form of liquid nitrogen fertilizer is anhydrous ammonia, applied in a gaseous form. Anhydrous ammonia is also used in a process to create ammonium nitrate, the most important source of solid nitrogen fertilizer. Other types of liquid and solid types of nitrogen fertilizers are also produced.

The forms of nitrogen delivered into the ground in the preceeding ways are known as inorganic because they are not derived from organic material, such as plant or animal wastes. Ammonia can be used directly by plants, as well as transformed into other types of nitrogen for plant use. The other inorganic forms of nitrogen undergo additional chemical transformations before being taken up by plants in the form of nitrate.

Nitrogen also exists in organic sources, such as livestock manure, crop residue, sewage sludge, and legume fixation. Nitrogen from organic sources must be converted into an inorganic form through a sequence of chemical processes. The nitrogen component of organic compounds, such as proteins and amino acids, is first broken down into ammonium ions by processes known as aminization and ammonification. Some of these ions are absorbed directly by plants; others are utilized by microorganism that decompose organic matter. Most ammonium ions are converted into nitrite and then into nitrate through the process of nitrification.

Nitrogen is also fixed by symbiotic relationships that exist between legumes and certain bacteria that live in the soil. Legumes include such plants as soybeans, alfalfa, and clover. Most nitrogen fixed in this manner is directly absorbed by the plant and used for growth. However, a portion does flow into the soil, where it may leach or undergo denitrification (by which nitrate is converted back to elemental nitrogen and re-enters the atmosphere).

A large amount of nitrogen from organic sources may return to the atmosphere in the form of elemental nitrogen through the process of volatilization. Up to 50 percent of the nitrogen content of manure that is not immediately plowed into the soil may volatilize. Some volatilization may also occur with inorganic fertilizers, particularly from liquid ammonia if it is not applied carefully.

Nitrate that is not absorbed by plants either undergoes the process of denitrification or leaches through the soil, where it ends up in water supplies. The amount of nitrate that undergoes denitrification depends upon many properties of the soil.

The amount of nitrate leached into water supplies is influenced by the structure of the soil (for example, sandy), its content of organic matter, the amount of rainfall, and the density of the plants. As much as 50 percent of soil nitrate may leach into water supplies in regions having light, sandy soils, heavy rainfall, and a high water table. Leaching may occur fairly rapidly under such conditions, but may take up to several decades with heavy soils, low rainfall, and extreme depths of groundwater.

The EC Nitrate Problem

Prompted by growing concern about nitrate in water supplies, the EC Drinking Water Directive was passed in 1980. This Directive established guidelines for nitrate levels in water consistent with recommendations made by the World Health Organization. The maximum allowable concentration (MAC) of nitrate in ground water that is recommended under the Water Directive is 50 ppm. A recent report (*1*) indicates that the MAC will not be exceeded if the average application rate of nitrogen is less than 127 kg/ha.[5] Several EC countries have used the Water Directive guidelines to establish policies to limit nitrate levels in their water supplies to the MAC, or less.

The same report (*1*) describes the current regional distribution of nitrate problems as being located in the low-lying areas of Belgium, France, the Netherlands, northern Italy, part of Germany, and parts of southern England (fig. 1). Nitrate pollution in Denmark has been significantly reduced in recent years because of Danish laws. The high levels of nitrate in these regions is typically viewed as being caused by surplus manure. Because the handling costs of manure are relatively high, farmers often do not incorporate it into their fertilization scheme. Furthermore, a Minnesota study (*12*) notes that desired yields can be more accurately obtained from commercial fertilizer than from manure because the composition of the former is more certain.

The countries with nitrate pollution extending over relatively large regions have higher densities of cattle and pig production per utilized agricultural area (UAA) than other countries. For example, Belgium, the Netherlands, Denmark, and Germany have more cattle and pigs per UAA than the other countries in table 1.

Calculations show that the "annual nitrogen surplus" in the soil of Germany has increased from 10 kg/ha to more than 100 kg/ha in the past 20 years (*1*). In the former West Germany, about 5 percent of delivered drinking water exceeds the MAC, while about 2 percent of French citizens receive drinking water in excess of the MAC. And in the Netherlands, the average nitrate concentration found in ground water 30 meters below sandy soils is 106 ppm (*16*). Since it may take decades for excess nitrate in the soil to showup as nitrate in ground water, these measurements underestimate the longer term nitrate problem.

Nevertheless, measured nitrate levels are much higher in the EC than in the United States. As an example, the concentration levels of nitrate are much higher in some European rivers than in the Mississippi River in the United States (fig. 2). This is because some of the most intensive farming activities in the world exists in the EC, partly because of incentives created by the CAP.

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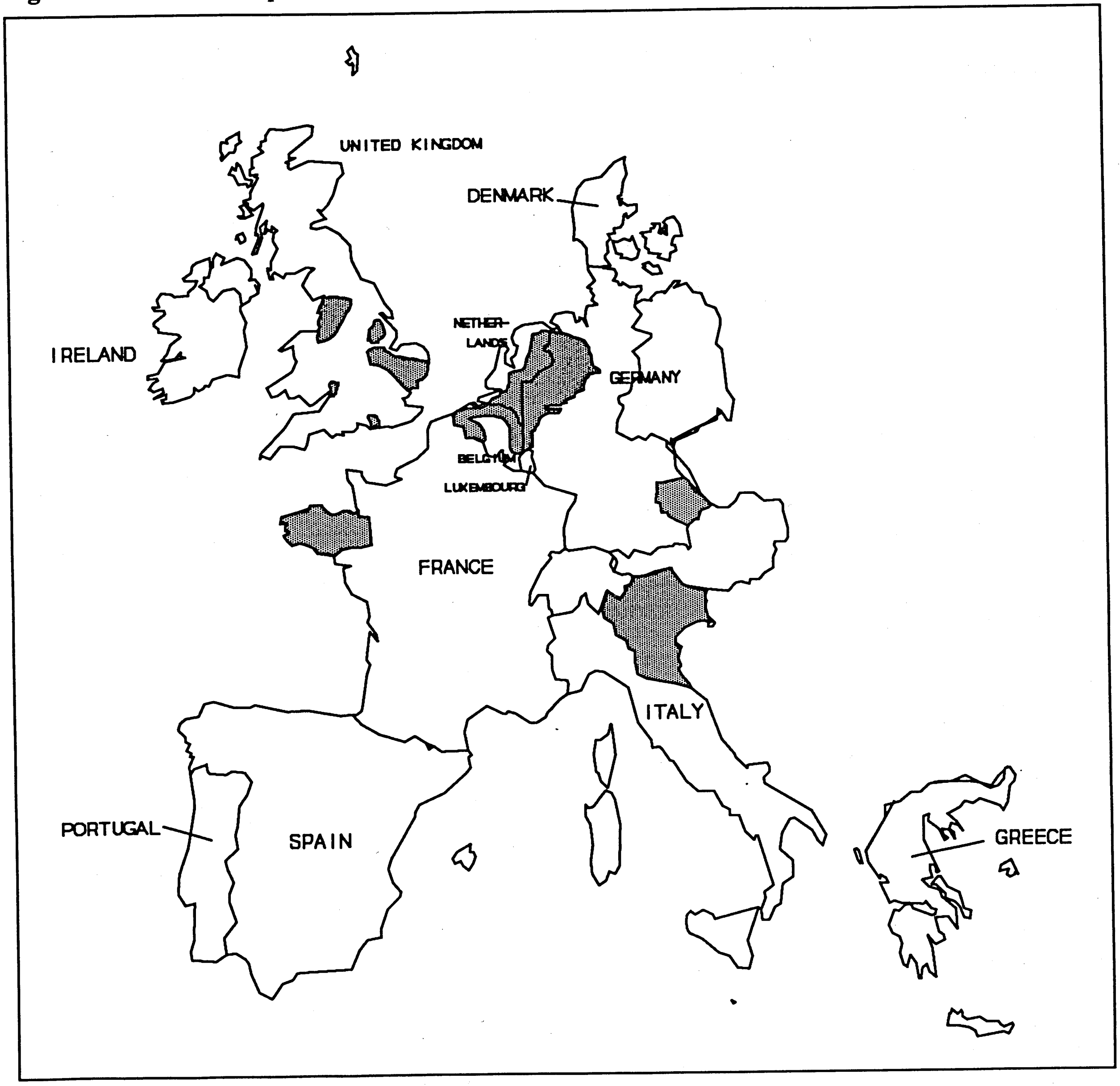
[5]No reference is quoted in (*1*) to indicate clearly whether this level refers to the amount of nitrogen applied or to the residual after plant uptake. In comparison, maximum recommended amounts of nitrogen quoted in (*1*), also without a reference, range from 125 kg/ha for spring barley in the United Kingdom to 400 kg/ha for silage in the Netherlands.

Figure 1. Areas of surplus animal manure



EC Environmental Policies

The regionality of environmental pollution makes it both a greater source of concern and more manageable at the national level, as opposed to the EC-wide level. Several national policies have been enacted in order to meet the Water Directive. However, many environmental problems show up outside the region or country of their origin and require international solutions. EC policies tend to be based upon the more restrictive national policies.

National Policies

Denmark and the Netherlands have the most stringent national legislation in the EC, and the policies of both countries are being used as models for EC-wide legislation.

Table 1—Cattle and pigs per UAA for selected EC countries, 1989

Item	Belgium	Netherlands	Denmark	Germany	France	Italy	United Kingdom
				Head per UAA			
Cattle	2.29	2.36	0.79	1.23	0.70	0.51	0.65
Pigs	4.75	6.80	3.27	1.90	.45	.54	.40

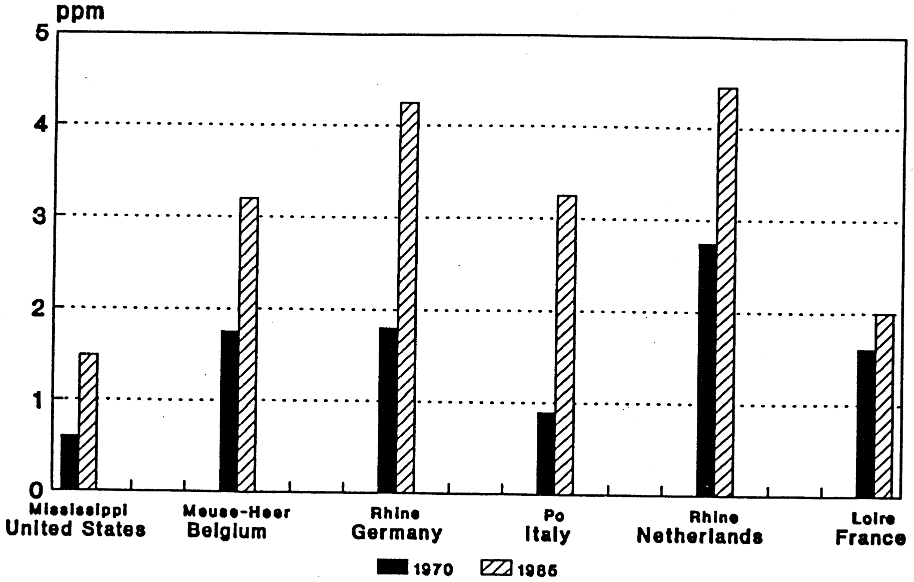
Source: (*6*).

Denmark enacted the Aquatic Environment Programme in 1987 to reduce nitrogen leaching by 50 percent and eliminating runoff from silage and livestock. This legislation requires that at least 65 percent of land be sown to green cover in the fall for all farms. A limit of two livestock (that is, cow) units per hectare exists except for licensed intensive livestock farms. All farms exceeding 30 livestock units must have 9 months' storage for manure. Farmers were to abide by a schedule for reducing nitrogen and phosphorus seepage. Finally, farms larger than 10 hectares must adhere to fertilizer management plans that include restrictions on manure spreading and incorporation into the soil. Subsidies are paid to offset some of the costs to farmers of complying with these rules.

The Netherlands faces especially severe problems of both high population and livestock densities in a small area and a high water table. By the mid-1980's, it was feared that nitrate leaching would eventually exceed the MAC under two-thirds of the grassland and 100 percent of the cropland in sandy regions. Because much of the Netherlands is sandy, the National Environmental Policy Plan (NEPP) was adopted to cover the years up to 2010. The NEPP proposes that nitrate and phosphate seepage into rivers be reduced by 90 percent by 2010 and that the use of nitrogen and phosphorus be brought into balance with crop uptake by 2000.

These requirements are to be achieved through physical limitations and levies on fertilizers. Quotas on the number of pigs and cattle already exist, but will have to be made much more restrictive if the goals of the NEPP are to be achieved (*1*). The NEPP also sets targets for ammonia emissions and pesticide use, and requires the establishment of facilities able to process and dispose of 200 million tons of manure by the year 2000.

Figure 2. Nitrate concentration in selected rivers, 1970 and 1985



Source: (1).

Germany has the most extensive system of environmental management plans, both at the national and state levels. Because Germany is a more heterogeneous country than either Denmark or the Netherlands, the plans vary from state to state. In general, though, both the national and state governments operate financial and quantitative programs to limit residual nitrate. Agricultural activities are regulated not only to protect humans, but plant, bird, and animal species.

The United Kingdom (UK) is much less densely populated in terms of people and livestock than Germany, Denmark, or the Netherlands. Nevertheless, significant levels of nitrates and phosphates are found in the rivers and some ground water supplies of the UK. Although the UK has little actual legislation directed at environmental problems, it pursues policies to balance environmental and rural development goals. Some limited legislation includes the Nitrate Sensitive Areas policy, the Sites of Special Scientific Interest, and Areas of Outstanding Natural Beauty designations.

EC Policies

The main principles of the EC's environmental policies evolved from the United Nations Conference on the Human Environment held in Stockholm in 1972. The theme of this conference was a call for global action toward environmental issues. The EC's first action program on the environment was adopted by the Council of Ministers in November 1973, putting in place the main principles by which further programs and legislative proposals were adopted. Among the principles was the resolution that environmental threats should be prevented at their source.

A second action program was proposed in 1977 and a third in 1983. In 1986, environmental policy became a major thrust of the so-called "Single Market Act" that laid the groundwork for a more fully integrated EC. A fourth action program was adopted in 1987, and further emphasis was placed on environmental issues related to agriculture in the Commission's 1988 paper "Environment and Agriculture" (*2*). Finally, a Commission publication in 1990, *Environmental Policy in the European Community*, described its intentions in greater detail (*3*). About 120 directives, regulations, and decisions have been adopted by the Council of Ministers as a result of these policy initiatives.

EC decisionmaking generally proceeds slowly in order to build consensus among various bureauacracies and interest groups. Within the EC Commission, where proposals to be placed before the Council of Ministers are made, differences of opinion exist on environmental policy. The Commission's Environmental Directorate General would like to see rather stringent controls on applications of fertilizer, manure, and pesticide to land. The Agricultural Directorate General is much more moderate in its views. The European Environment Agency was established to provide scientific evaluation of environmental issues and to issue policy recommendations, thus resolving some of the inherent conflict between the two directorates.

The Commission attempted to bridge this agriculture-vs.-environment gap in its 1988 report by providing guidelines for specific proposals at a later date. The Commission's objective is to influence the direction but not the speed or outcome of the environmental debate. Rather, the Commission hopes that an EC-wide consensus will ensue from the various national legislations. In its paper on CAP reform (*7*), the Commission indicated that preserving rural communities by means of promoting an extensive agriculture will be expensive.

While not focusing primarily on the pollution problem, the so-called "rural world" document published in 1988 (*8*) identified the need for social and structural policies to maintain a viable rural environment.

The "MacSharry Plan" for reform of the CAP is an outgrowth of the above philosophy. Its basic framework is contained in the "Reflections" paper of 1991 (*7*). The plan calls for reducing commodity surpluses by switching agricultural policy away from market price supports and toward social and environmental measures. Although short on specifics, the plan further laid a foundation for consensus building on the rebalancing of EC policy away from production and income support and toward social and environmental goals.

The EC Nitrate Directive

While the Commission prefers to move slowly but deliberately on environmental issues, other EC institutions are inclined to more immediate and significant action. In response to pressure from the EC Parliament, environmental groups, and some member governments, the Commission proposed legislation intended to reduce the amount of nitrate accumulation in ground and surface water. After 2 years of arduous debate, the Nitrates Directive was passed by the Council of Environmental Ministers on June 14, 1991.

In its advisory role during the consultative reading, the Council of Agricultural Ministers suggested that compliance with the directive be made voluntary. However, the Environmental Ministers decided that compliance would be mandatory. Therefore, further debate may be expected between these two legislative groups as the details of the directive are worked out.

While many important details are yet to be finalized, the general intention of the Nitrate Directive is to keep the nitrate levels in water from exceeding the MAC. Regions having excessive amounts of nitrates, known as "vulnerable" zones, are to be designated by the member countries by the end of 2 years. The member countries must also draw up "codes of good practice," which are required in the vulnerable zones but voluntary elsewhere. The minimum requirements for these codes are in the regulation, but member countries may legislate stricter codes if they desire. Records of nitrogen application in these zones must be maintained by the member governments, but the mechanism for the enforcement of these codes is yet to be determined.

After the vulnerable zones are designated, member countries have an additional 2 years in which to design specific programs to reduce nitrate levels to the MAC. These programs are to be implemented over an additional 4-year period. Thus, it will be 8 years before the requirements of the Nitrate Directive are fully implemented. The vulnerable zones will be reviewed every 3 years to take account of any changes that may affect their designation, such as a change in livestock density.

The directive is mainly directed at reducing nitrate pollution from manure because (as has been discussed) that is considered the major source of pollution. The directive has several provisions intended to reduce the leaching and runoff of nitrate from manure. Although these will have to be further clarified, they include periods when manure may be applied; regulation of manure application to sloping, waterlogged, flooded, frozen, or snow covered ground; consideration of rainfall; and provisions for manure storage facilities.

The directive also states that the amount of manure disposal must account for the use of nitrogen by crops, the amount of nitrogen from chemical fertilizer and other sources, and the amount of nitrogen in the soil. Furthermore, the directive limits the amount of livestock manure that may be applied after the 8-year transition period to 170 kg/ha, nitrogen equivalent. Although the directive does not provide detail on this crucial limitation, reference by the directive to the use of fertilizer and uptake by crops suggests that the 170 kg/ha may be interpreted as a maximum annual residual (MAR) of nitrogen inclusive of nitrogen from both manure and inorganic fertilizer, less uptake by crops. Further refinement of the directive appears necessary to more explicitly define the limits to nitrogen application in a way that takes account of various factors that influence the inflow and outflow of nitrogen to and from the soil.

The Role of Inorganic Fertilizer and Manure in EC Agriculture

While both fertilizer and manure may satisfy the nitrogen requirements of crops, fertilizer is a more practical source of nitrogen because it can be economically pelleted, transported, and applied at optimum times during the growing season. Most nitrogen fertilizer is therefore applied to cropland that is sown to grain. Most of the remainder of the UAA is pasture, which obtains much of its nitrogen from livestock manure. Other crops (such as sugarbeets, oilseeds, and vineyards) do not account for a significant proportion of total nitrogen used.

Increased grain yields in the EC were facilitated by an increase in the use of nitrogen fertilizer (fig. 3) applied to new crop varieties that were more responsive to nitrogen. Nitrogen use per UAA more than tripled, from about 30 kg/ha to about 100 kg/ha, while grain yields doubled to about 6 tons per hectare. However, it is impossible to apply nitrogen closely enough to every plant for a 100-percent absorption rate. Absorption is further reduced by soil structure, the amount of organic matter in the soil, and rainfall. Runoff and leaching can exceed 50 percent of total nitrogen applied under the most adverse soil and weather conditions (*1, 9*). Therefore, leaching and runoff increase when more nitrogen is applied.

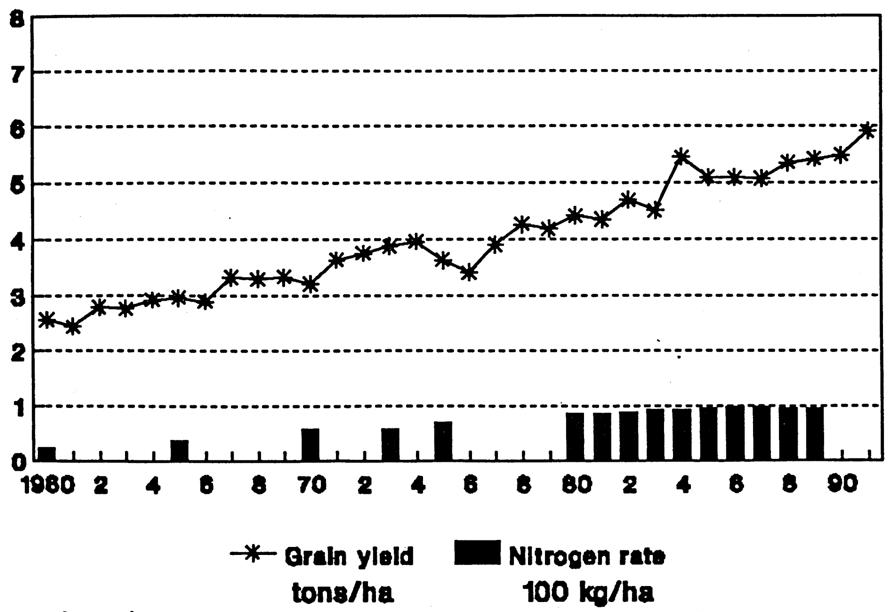
Not all countries had the same growth rate in grain yields or nitrogen use as the EC-10. France (fig. 5) and the United Kingdom (fig. 9) began the period with below average yields and had higher than average yield increases over the time period. Germany, the Netherlands, and Belgium (figs. 4, 6, and 8) had above average yields at the beginning of the period and below average increases throughout. In Denmark (fig. 7), grain yields were close to the EC average.

Both France and the United Kingdom started the period with slightly less than the average amount of nitrogen fertilizer per hectare of UAA. By the end of the period, both countries were using nitrogen at nearly the same rate as the EC average. Germany, Belgium, the Netherlands, and Denmark started out the period with application rates that were considerably above average and ended the period with application rates that were also above average. However, the rate of increase in fertilizer application was less than average for these countries.

The significantly larger amount of nitrogen fertilizer applied per hectare in Germany, Belgium, the Netherlands, and Denmark suggests that more fertilizer nitrogen may be leached or lost through runoff in these countries. Indeed, nitrate pollution tends to be greater in these countries.

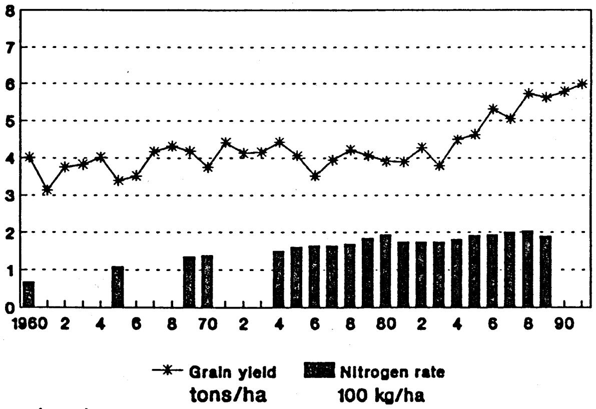
Application rates close to the maximum recommended levels point to the possibility of applying fertilizer

Figure 3. EC-10: Fertilizer nitrogen rate and grain yield



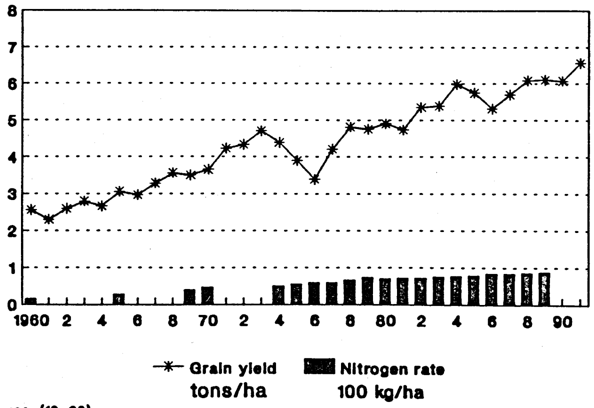
Source: (19, 20).

Figure 4. Germany: Fertilizer nitrogen rate and grain yield



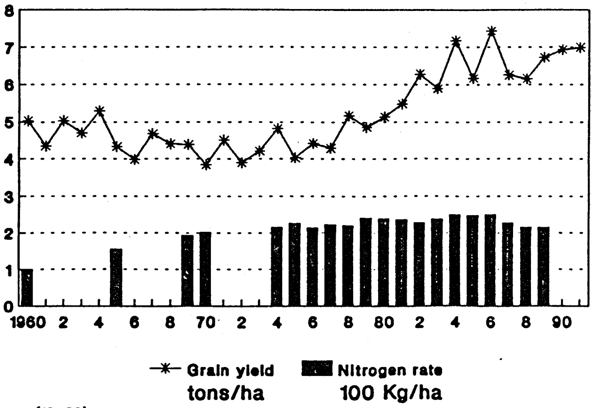
Source: (19, 20).

Figure 5. France: Fertilizer nitrogen rate and grain yield



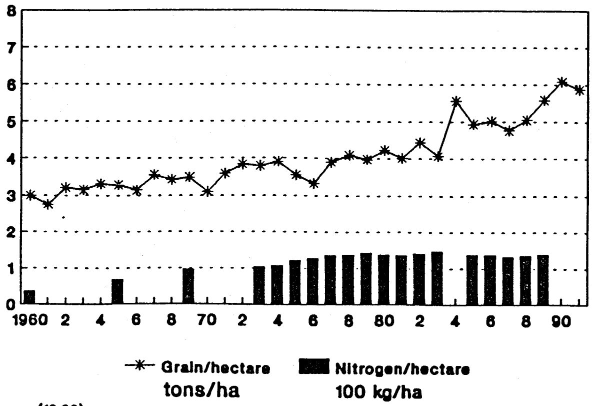
Source: (19, 20).

Figure 6. Netherlands: Fertilizer nitrogen rate and grain yield



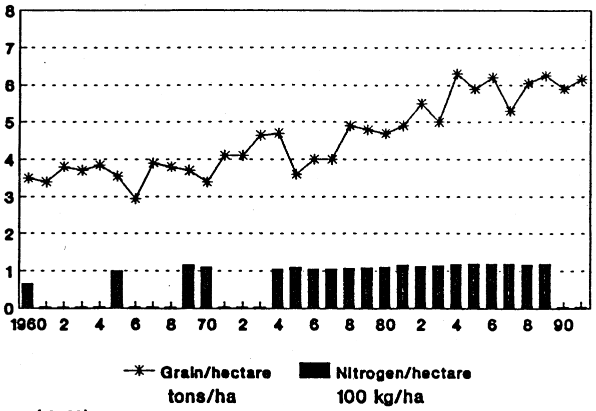
Source: (19, 20).

Figure 7. Denmark: Fertilizer nitrogen rate and grain yield



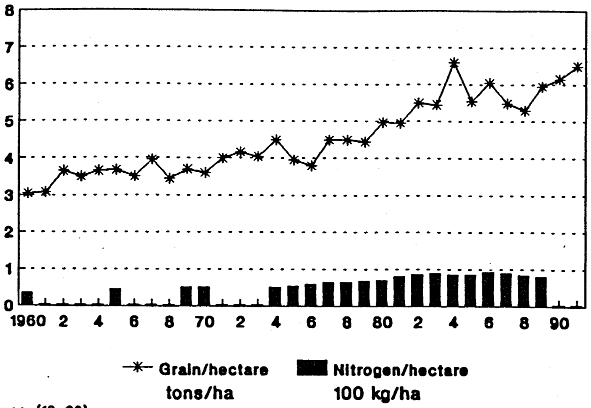
Source: (19,20).

Figure 8. Belgium: Fertilizer nitrogen rate and grain yield



Source: (19, 20).

Figure 9. United Kingdom: Fertilizer nitrogen rate and grain yield



Source: (19, 20).

more efficiently without reducing yields in Denmark, Germany, and the Netherlands. While recommendations vary according to different institutions and from region to region, some aggregate data from (*9*) are reproduced in table 2. Weighting these by crop composition provides measures with which to compare actual nitrogen applications (fig. 10). In all cases, the actual applicaton of nitrogen is less than the maximum recommended amounts. However, the difference varies from almost negligible in the case of Denmark to about 30 percent and 50 percent, respectively, for the United Kingdom and France.

Any residual nitrate from inorganic fertilizer is further increased by the disposal of livestock manure. Livestock manure is often not applied with the same goal of efficiency as fertilizer. That's because manure is generally viewed as a costly waste in need of being disposed of, rather than an economic source of nutrients for crops. This perception stems from the relatively high costs involved in handling and processing manure to economically maximize its contribution to soil fertility.

Calculation of Residual Nitrate

The only systematic analysis of nitrate pollution was an EC-wide study done in 1987 by Koopmans (*11*). Koopmans calculated a nitrogen balance table that related the amount of nitrogen applied to the amount taken up by crops, with the difference representing the residual amount of nitrate available for leaching or runoff into the water supplies. This study provides coefficients that measure the level of nitrogen contained in different types of livestock manure and taken up by different kinds of crops (table 3).

Koopman's coefficients are used to calculate nitrogen balance for each EC country for 1986. The nitrogen balance is then used to identify the countries where residual nitrate exceeds the MAR, and to calculate the reduction in livestock production and fertilizer application needed to reduce residual nitrate to the MAR.

Crop Uptake of Nitrogen and Use of Inorganic Fertilizer

There were two calculations of nitrogen uptake that had to be inferred from information in the Koopmans study. First, the coefficient for the uptake of nitrogen by straw is assumed to equal 24.9

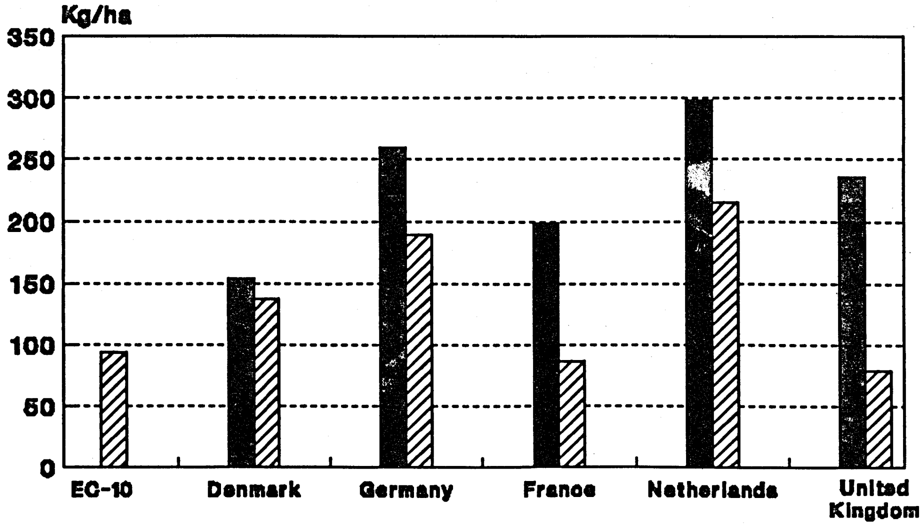
Table 2—Maximum nitrogen fertilizer recommendations, 1988

Country	Pasture	Silage	Spring barley	Winter wheat
		Kilograms per hectare		
Germany	380	300	170	210
France	NA	NA	177	208 [1]
Denmark	250	350	130	180
Netherlands	400	400	125 [1]	200
United Kingdom	275	330	125	200

[1]Author's estimate.
NA = Not available.
Source: (*1*).

percent of the nitrogen uptake by all grains. The calculation of nitrogen uptake by fodder (including hay, pasture, and silage) made by Koopmans is unclear and his data on area are much lower than that those in (*6*). The procedure used in this study was to apportion the estimate of nonmarketable forage from (*6*) to the individual countries of the EC. This was done on the basis of the number of cattle and sheep (in terms of cattle units) in each country. Although strictly defined only for grass, the nitrogen coefficient from table 3 was applied to these estimates of forage.

Figure 10. Nitrogen: maximum recommended and actual use, 1990



The estimated amounts of nitrogen from inorganic fertilizers and the estimated uptakes of nitrogen by crops and forage are presented in table 4. Several observations are worth making about those data. First of all, about 9.5 percent of the nitrogen applied in the form of fertilizer in the EC is in excess of what is needed by crops and forage. Nitrogen from fertilizer is in excess by up to 40 percent in the Netherlands, but roughly equals uptake in Belgium, Ireland, and Italy.

Aggregate data conceal much of the nitrate problem, however. Most inorganic fertilizers are not applied to forage, with the exception of a relatively small amount of corn silage. Therefore, most residual nitrogen from inorganic fertilizers is concentrated on crop acreage. Furthermore, this residual tends to be concentrated in regions of countries where relatively little forage and large amounts of crops are grown. Therefore, aggregate data understate the problem for these localized regions, with the possible exception of a small country like the Netherlands.

Table 3—Nitrogen content of selected commodities[1]

Item	Wheat	Rice	Coarse grains	Grass	Cattle	Pigs	Poultry	Sheep
	Percent				*Kilograms per animal per year*			
Nitrogen	1.9	1.3	1.5	3.0	64	13	.48	20

[1]The nitrogen composition of crops and livestock may vary, according to (*18*). The nitrogen composition of crops may vary because of variety and moisture, while the nitrogen content of manure depends upon feed composition, milk yield, and the weight to which the animal is fed.

Source: (*11*).

Table 4—Nitrogen fertilizer applied and uptake by crops, EC-10, 1986

Country	Nitrogen uptake, all sources						Nitrogen fertilizer	
	Wheat	Coarse grains	Straw[1]	Rice	Forage	Total	Applied	Residual
				1,000 metric tons				
Belgium[2]	25	16	10	0	160	211	199	-12
Denmark	41	87	32	0	127	287	381	94
Germany	195	230	106	0	783	1,314	1,578	264
Greece	49	43	23	1	287	403	432	29
France	505	346	212	1	1,342	2,406	2,568	162
Ireland	8	23	8	0	368	407	343	-64
Italy	18	131	76	14	633	1,027	1,011	-16
Netherlands	0	5	6	0	256	284	504	220
United Kingdom	263	159	105	0	995	1,521	1,671	150
Total	1,277	1,040	577	16	4,950	7,860	8,688	828

[1]It is not clear if the coefficients for straw nets out the nitrogen that is returned to the ground because of decomposition.
[2]Also contains a small amount for Luxembourg.
Sources: *(11, 19)*.

Nitrogen From Livestock Manure

Tables 4, 567

About half of the nitrate from manure comes from cattle, [illegible] a low of 10 percent in Greece, where sheep dominate, to 69 percent i[illegible]ate as the source of livestock nitrogen only in Denmark, but they a[illegible] Belgium and the Netherlands. Sheep are a significant source of nitrog[illegible]um, Denmark, Germany, and the Netherlands. Nitrogen from poultry m[illegible]ith nitrogen from cattle and is concentrated in France and the United [illegible]

The amount of nitrogen from livestock manure is nearly twice the amount of [illegible] uptake from forage, in total. Therefore, even if the uptake from forage is underestimated, the addition of manure adds an amount of nitrogen that exceeds what can be absorbed by crops for many countries. The ratio of nitrogen from livestock manure to nitrogen uptake by forage exceeds 2 in Belgium, Denmark, Germany, and the Netherlands. Since the latter three countries have residual inorganic nitrogen (and Belgium has roughly a zero balance), a residual amount of nitrogen may remain after manure is included.

Another way to view the nitrate problem is first to think of the EC as being in about 10 percent excess in nitrogen from the 8.7 million tons of fertilizer application. An additional 9.6 million tons of nitrogen from livestock manure must then be accommodated. For Denmark and the Netherlands, the amount of residual nitrogen from fertilizer alone is 25 and 44 percent, respectively. Each country must also accommodate an amount of nitrogen from livestock manure that exceeds the amount of nitrogen from fertilizer.

Reductions in Fertilizer Use and Livestock Production

Of the total nitrogen applied in the EC, 57 percent is in excess (table 6). The residual amount of nitrogen varies from 52 percent in France to 77 percent in the Netherlands. Nearly two-thirds of the

Table 5—Nitrogen produced from livestock manure [1] [2]

Country	Dairy	Beef	Pigs	Layers	Broilers	Sheep	Total
				1,000 metric tons			
Belgium[3]	65	137	122	5	41	10	381
Denmark	58	109	224	2	40	1	435
Germany	349	651	549	25	102	42	1,717
Greece	14	36	33	8	32	332	455
France	416	1,043	275	33	299	327	2,393
Ireland	98	272	30	2	15	120	536
Italy	197	380	154	23	138	265	1,157
Netherlands	149	176	249	19	143	16	752
United Kingdom	208	604	217	25	254	511	1,819
Total	1,555	3,408	1,851	142	1,064	1,625	9,645

[1]Numbers may not sum to totals because of rounding.

[2]Livestock numbers from (*6*) are multiplied by the coefficients in table 3. Beginning inventories are used for cattle; number slaughtered are used for pigs and sheep, with 7 percent and 50 percent being added to account for the breeding herd; and the number of eggs hatched for chick placement for eggs and meat are used for layers and broilers.

[3]Also contains small amount for Luxembourg.

Table 6—Nitrogen use, uptake, and residual, EC-10, 1986

Country	Use			Uptake	Residual		
	Livestock	Inorganic	Total		Total	Kilograms per hectare	Share of total
	1,000 metric tons					Kilograms	Percent
Belgium[1]	382	199	580	211	369	240	64
Denmark	434	381	816	287	529	187	65
Germany	1,717	1,578	3,295	1,314	1,981	165	60
Greece	455	432	887	403	484	84	55
France	2,393	2,568	4,961	2,406	2,555	81	52
Ireland	536	343	879	407	473	83	54
Italy	1,157	1,011	2,167	1,027	1,140	65	53
Netherlands	752	504	1,255	284	972	480	77
United Kingdom	1,819	1,671	3,490	1,521	1,969	106	56
Total	9,645	8,688	18,333	7,860	10,473	108	57

[1]Also contains small amount for Luxembourg.

10.5 million tons of residual nitrogen that enters the soil for agricultural purposes in the EC is in Germany, France, and the United Kingdom. Only 18 percent of residual nitrogen is found in Belgium, Denmark, and the Netherlands. However, Belgium, Denmark, and the Netherlands have residual amounts of nitrogen equal to 64 percent, 65 percent, and 77 percent of total nitrogen use, respectively. Belgium, Denmark,and the Netherlands exceed the MAR of 170 kg/ha with residual amounts of nitrogen equal to 480 kg/ha, 240 kg/ha, and 187 kg/ha, respectively.

The calculations in table 6 make clear that nitrate pollution is a problem associated with inorganic fertilizer as well as manure, particularly in Belgium, Denmark, and the Netherlands. In theory, reduction of the nitrogen residual may be accomplished by reductions in either manure or fertilizer in order to avoid "excessive" financial harm to any one sector. Where necessary, manure may be processed and transported to other regions to be used as fertilizer in order to avoid excessive reductions in livestock numbers. However, such a balance between sectors is a political decision and any economic analysis related to that decision is beyond the scope of this study. The purpose of the present report, rather, is to calculate the reductions in livestock numbers that may possibly be required to achieve the purpose of the Nitrate Directive to be used as a standard by which to judge the need for other policies.

The amount of residual nitrogen in Belgium, Denmark, and the Netherlands requires significant decreases in livestock numbers (table 7). The total amount of residual nitrogen exceeding the MAR in Belgium, Denmark, and the Netherlands are 107,000 tons, 47,600 tons, and 632,000 tons, respectively. In order to achieve the MAR, the nitrogen residual would have to be reduced by 29 percent in Belgium, 9 percent in Denmark, and 65 percent in the Netherlands. The MAR could be achieved by reductions only in livestock numbers of 28 percent (Belgium), 11 percent (Denmark), and 84 percent (the Netherlands). Reductions of this magnitude may be difficult politically to implement since fertilizer is also a source of residual nitrogen. However, livestock manure is the source of residual nitrate considered most problematic (*1, 5*).

The nitrate directive does allow the MAR to be achieved by reductions in fertilizer use as well as by reductions in livestock numbers. It is also likely that political considerations will compel reduction in both livestock and fertilizer. Policy decisions in the EC are often made with a view toward fairness or "balance" between different sectors.

The balance between reductions in livestock numbers and fertilizer use will be decided politically. For the pupose of analysis, the present study adopts the rule that the percentage decline in livestock numbers be no larger than the required percentage decline in residual nitrogen. Although other rules could be adopted, this rule allows livestock to be the major source of reductions in residual nitrogen.

According to the above rule, the 29-percent reduction in residual nitrogen required for Belgium can be accomplised with a 28-percent reduction in livestock numbers and no decline in fertilizer use (see table 7). For Denmark, a decline in livestock numbers that is proportionate to the required decline of 9 percent in residual nitrogen is accompanied by a 2.2-percent decline in fertilizer use. Similarly for the

Table 7—Residual nitrogen and reductions in livestock and fertilizer use to achieve the MAR, 1986

Country	Nitrogen residual		Reductions only in livestock	Reductions in both livestock numbers and fertilizer	
	Above MAR	Reduction to MAR		Livestock	Fertilizer
	1,000 metric tons	*Percent*			
Belgium	107.0	29	28	28	0
Denmark	47.6	9	11	9	2.2
Netherlands	632.0	65	84	65	28.0

Netherlands, decrease in livestock numbers of 65 percent is accompanied by a 28-percent decline in fertilizer use.

In theory, at least, fertilizer use could be cut significantly without reducing crop yields because manure could replace fertilizer as the nitrogen source.[6] As noted in figure 10, application rates are close to the maximum amounts recommended for Denmark and the Netherlands. This may represent some inefficiency in use.

The calculations of livestock reduction are to be used in an aggregate EC model to compare the trade effects of the Nitrate Directive with other policy changes (*10, 13, 15*). Therefore, the aggregate reductions in livestock production are calculated by multiplying the country changes by the percentage of livestock in each of the three countries (table 8). The Netherlands has the largest amounts of each livestock: about 13.5 percent of the pigs, layers, and broilers; nearly 10 percent of the dairy; 5 percent of the beef; and 1 percent of the sheep.

The EC-wide reductions in livestock production from the 1986 base are moderate. Pig production is reduced the most, at 11.7 percent, followed by a 10-percent reduction in egg and broiler production. Dairy and beef production are reduced by 7.8 and 4.8 percent, respectively. Sheep production is reduced by less than 1 percent because relatively few sheep are raised in the three countries affected by the Nitrate Directive.

Recent Changes in Livestock and Nitrate Levels

A number of policy developments have occurred in the EC over the past decade that may have reduced the input of nitrogen from livestock and crops. The national policies designed to address the nitrate problem in Denmark and the Netherlands have already been discussed. Reductions in price support and intervention buying for grain have occurred since the early 1980's. More recently, an acreage set-aside program has been established for grain. In 1984, regional quotas were established for the production of milk. Milk produced beyond the quotas was charged a superlevy equal to 75 percent of the target price. This superlevy has since been increased to 115 percent of the target price.

Table 8—Reduction in livestock to achieve the MAR, 1986

Item	Dairy	Beef	Pigs	Layers	Broilers	Sheep
				Percent		
Belgium	4.2	4.0	6.6	3.7	3.9	0.60
Denmark	3.8	3.2	12.2	1.4	3.7	.07
Netherlands	9.6	5.2	13.5	13.7	13.4	.97
Total	17.6	12.4	32.3	18.8	21.0	1.64
Change in EC-9 livestock[1]	7.8	4.8	11.7	10.1	10.1	.91

[1]Total percentages may not agree because of rounding.

[6]Fertilizer and manure, however, may not be perfect substitutes in crop production (*18*).

Reduced price supports and the acreage set-aside have not reduced grain production in any EC country. And there is potential for considerable yield increases from new varieties of grain and intensification on a slightly reduced area of grain planted. As indicated in figures 6-8, fertilizer use has remained about constant over the last several years in the three target countries.

The dairy quotas did have an immediate and long-term effect in reducing dairy cattle numbers and influencing the composition of cattle production between dairy and beef (table 9). Between 1986 and 1991, dairy cattle numbers declined by 12.5 percent in Belgium, 15 percent in Denmark, 17.8 percent in the Netherlands, and 13 percent in the other countries.

One of the effects of the dairy quota was to cause some shift toward beef production. This shift has been most apparent in Belgium, where beef cattle numbers increased by 16 percent between 1986 and 1991, and in the Netherlands, where beef cattle numbers increased by 6.2 percent over the same time period. Beef cattle numbers declined by 13.9 percent in Denmark and 1.75 percent for the EC-10 as a whole. While the cattle cycle has not yet fully responded to the dairy quotas, comparing the data at these two points in time reveals a tendency for beef not to decline as much as dairy. The only other livestock category to decline significantly in any of the countries was pigs in Belgium.

If other livestock numbers had declined by the same proportion as dairy, considerable progress would have been made in achieving the goals of the Nitrate Directive. This was not generally the case in

Table 9—EC-10 livestock numbers: Base, nitrate scenario, 1991[1]

Item	Dairy	Beef	Pigs	Layers	Broilers	Sheep
	1,000 head				*Million head*	
Belgium:						
1986 base	1,021	2,142	9,363	525	10.9	85.8
Nitrate limit	724	1,519	6,638	372	7.7	60.8
1991	893	2,483	9,073	560	10.9	110.8
Denmark:						
1986 base	913	1,710	17,228	60	4.0	82.8
Nitrate limit	827	1,550	15,617	54	3.6	75.1
1991	769	1,472	17,565	107	4.1	99.5
Netherlands:						
1986 base	2,333	2,743	19,158	788	40.6	297.3
Nitrate limit	826	971	6,782	279	14.4	105.2
1991	1,917	2,913	21,337	1,050	41.4	319.1
Other EC:						
1986 base	20,036	46,652	96,661	79,855	240.7	1,750.0
Nitrate limit	20,036	46,652	96,661	79,855	240.7	1,750.0
1991	17,440	45,444	96,500	88,286	225.7	2,197.0
Total:						
1986 base	24,303	53,247	142,410	81,228	296.2	2,215.9
Nitrate limit	22,415	50,696	125,720	80,489	266.4	1,991.2
1991	21,019	52,312	144,475	90,003	282.1	2,726.4

[1]The source of livestock numbers for the 1986 base year and 1991 is (*6*).

Table 10—Nitrate in manure, 1986 base and 1991 levels

Item	Belgium	Denmark	Netherlands	Other	Total EC
			Million tons		
1986 base	381	435	752	8,087	9,645
1991	402	422	781	8,209	9,815

most countries, however. Therefore, the amount of livestock manure increased slightly between 1986 and 1991 for all countries except Denmark (table 10). Nitrate from manure declined by nearly 3 percent for Denmark, perhaps largely because of the strict national programs in effect there. For Belgium and the Netherlands, nitrate levels rose by 5.5 and 3.8 percent, respectively. These increases support the notion that stricter regulations will be required in order to reduce nitrate levels by the magnitudes necessary to achieve the goals of the Nitrate Directive.

Conclusions and Limitations

Nitrate pollution is a significant and growing problem in some areas of the EC. Measurement of nitrate levels in surface water and ground water underestimates the problem because it may take decades for nitrate to reach the water. Better estimates of the amount of residual nitrogen currently being applied may be given by nitrogen balance tables. These tables subtract the nitrogen used by crops from the amounts applied in the form of fertilizer and manure.

This analysis has limitations, one of which involves the amount of nitrogen taken up by the different kinds of forage that account for about half of UAA (utilized agricultural area). Different forages vary in their use of nitrogen. Furthermore, the nitrogen content of forage and straw is treated as uptake, but straw and some forage not consumed by livestock is biodegradable, with some nitrogen exiting into the atmosphere and some returning to the soil. However (without better data), it is impossible to determine whether the uptake of nitrogen by forages is overestimated or underestimated.

Even so, the magnitude of residual nitrogen is underestimated by the use of aggregate data in general. For example, aggregate measures of residual nitrogen do not reveal problems known to exist in certain parts of the United Kingdom, France, and Germany. The use of aggregate data may not be too misleading for small countries such as Belgium, Denmark, and the Netherlands, where the problem is most severe. Nitrogen balance tables constructed along the lines of county-level tables in the United States would be a more appropriate approach.

Nevertheless, the aggregate analysis may not be too misleading in that it does capture the three most severe problem countries: Belgium, Denmark, and the Netherlands. The analysis does underestimate known significant problems in Germany. And as figure 1 indicates, the problem regions in France and the United Kingdom are quite small, suggesting that for practical purposes perhaps not too much accuracy is lost by ignoring them.

The analysis suggests a decline of less than 12 percent in livestock production is necessary to achieve nitrogen balance. Consequently, the analysis appears to support the conclusion that *large* reductions in EC livestock production, of 25 percent to 50 percent, may not be necessary. However, the analysis does support the conclusion that significant reductions in livestock and fertilizer use will be necessary in the three main problem countries. Unless other means are found to reduce manure disposal, livestock reductions of 29 percent and 65 percent are implied for Belgium and the Netherlands, respectively.

The significant possible reductions in livestock numbers in Belgium, Denmark, and the Netherlands point out the need for alternate policies to address the nitrate problem in these countries. Proposals have been made to subsidize the processing and transport of livestock manure to enhance its substitutability with fertilizer. It is also possible to reduce the nitrogen content of manure by changing the ingredients fed to livestock. Some room still exists to increase the efficiency of fertilizer uptake and thus decrease its use. However, the results of this study do underscore the need to address the issue of excess nitrogen as a problem of both too much fertilizer and too much manure.

A more extensive analysis of nitrate pollution would look at the problem on a subregional level within each country. Regions with excess nitrate problems, which are now canceled out by other regions in an aggregate analysis could be better identified. This is recognized by the EC Commission in its classification of vulnerable zones.

A regional analysis would also allow the sources of excess nitrate to be more accurately measured to design more equitable policies. For example, beef and dairy cattle that graze on pasture may be contributing relatively less to nitrate pollution than livestock from enclosed systems, such as pork and poultry. To the extent that manure from beef and dairy is expelled on pasture, it may supply the nitrogen necessary to maintain the pasture. Manure from enclosed systems is generally applied to cropland and is more likely to exceed the amount needed for crop growth.

Many factors are not accounted for in this analysis that would also be difficult to include in a micro-level analysis. Nonagricultural sources of nitrogen are not included. Although the contribution of agriculture to the nitrate problem may be brought into balance, much of the overall nitrate problem in water may have its source elsewhere, such as in acid rain or the decay of trees and vegetation. In addition, some account has to be taken of the nitrogen already accumulated in the soil and already leaching into ground water.

Lastly, calculating accurate nitrogen balance tables requires a complete matrix of coefficients describing the introduction of nitrogen onto or into the soil and the process of its removal by crop uptake, leaching, or volatilization. The process of nitrogen removal is strongly influenced by soil characteristics and precipitation and will therefore vary on a regional basis. The nutrient content of livestock manure varies according to the feed ration. Rations are much different away from seaport areas, where a lot of nongrain feed ingredients are used.

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WASHINGTON, DC 20005-4788