Nutrient Recycling : The European Experience* - Review -

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ABSTRACT : Intensive livestock production has increased dramatically in Europe since the 1960s, particularly in Northern and Central European countries, resulting in large increases in the nutrient pollution of surface and ground waters and in atmospheric emissions of ammonia. This has arisen due to inadequate management of the large amounts manure produced, particularly where there has been insufficient land area used for efficient nutrient reuse in crop production. Nutrient pollution from intensive livestock production has progressively degraded the quality of water resources in many parts of Europe, with eutrophication of many inland and coastal waters, as well as soil acidification and ecosystem degradation. These problems have been known for many years, and although there are various international agreements on transboundary pollution, it is largely left to individual countries to set and enforce standards. Consequently, a number of different approaches are employed, although the common feature of these is to encourage farmers to use the nutrients in animal manures efficiently according to crop requirements, which also reduces the potential for accumulation in soil and subsequent loss to the environment. This paper reviews nutrient production and use in Europe and some of the strategies employed to avoid and reduce nutrient pollution.
(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 667-674)

Key Words : Europe, Livestock, Manure, Nutrients, Pollution, Slurry

INTRODUCTION

Traditional mixed arable and livestock farming is the most sustainable means of food production and environmental protection, since it relies on the balance between the land growing food and the use of animal manure to fertilise the land. Throughout history, all agrarian cultures have regarded animal and human excreta as valuable commodities that should be conserved and not wasted. The concept of animal manure as waste is a recent paradox, that started in Europe and North America, due largely to the introduction of inorganic fertilisers, imported feedstuffs (concentrates), improved workforce productivity (mechanisation), which have allowed enormous increases in the production of meat and animal products to meet the growing demand from rapidly expanding and increasingly affluent urbanised populations.

Since the 1960s, livestock farming in Europe has been taking up the new technologies developed by research into animal breeding, feeding and housing. The impetus for intensification has come from the need to provide a cheap and balanced supply of food. The new technology has produced livestock which grow faster and are more efficient converters of food, but to do so they require a controlled environment. The animals diet has to be balanced and meet the needs of different growth periods. The result has been that for efficient livestock production, species such as pig and poultry need to be housed and fed constantly. The system has divorced the growing of the food source from the livestock enterprise and has provided the means for intensive livestock farming without the need for large areas of land.

The development of large intensive livestock units took place rapidly, particularly in Northern Europe, relying heavily on imported feedstuff. Initially it was considered a success due to the rapid improvement in the supply of affordable livestock products. Problems became apparent because the system had developed only the input and production side, and little had been done to develop a balanced and sustainable management system, particularly for the large quantities of wastes. Consequently, disposal systems were adopted that had minimal costs but caused considerable environmental damage, such as direct discharge to surface waters, large earthen storage lagoons, and over-application to land not as a fertiliser but as a waste.

In Europe, the recognition of the major problems, such as eutrophication of fresh water and odour nuisance from livestock units, has resulted in changes in emphasis in livestock research from food production to environmental protection. Increasingly stringent control measures have solved many of the acute problems but low level chronic and transboundary forms of pollution (such as methane, nitrous oxide and ammonia to the atmosphere, and nitrate and phosphorus to water), are now regarded as the major environmental issues of agricultural production. Economic instruments and market forces have stopped the relentless increase in animal numbers in the developed world (although not yet in developing countries), but in response, the livestock industry has tended to intensify further in order to maintain profitability with fewer farms but more animals.

In response to the need to co-ordinate and share research on the environmental and health impacts of intensive livestock production, the FAO established a

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* This paper has been presented at Pre-Conference Symposium II entitled "Management of Feed Resources and Animal Waste for Sustainable Animal Production in Asia-Pacific Region Beyond 2,000" of the 8th World Conference on Animal Production on June 28, 1998 at Seoul National University, Seoul, Korea. The paper has been reviewed and edited by Prof. J. P. Fontenot (USA) and Prof. H. L. Choi (Korea).

European co-operative research network in 1976 on Animal Waste Management. This was initially co-ordinated by the Swedish National Board of Agriculture but has been managed by WRc since 1990. This network has produced a number of guidelines and proceedings of technical meetings published by the FAO (e.g. Hall 1991, 1995). The principal focus in recent years has been the measurement and control of emissions of ammonia and odour from livestock housing, manure handling and landspreading, as well as optimising nutrient efficiency of farmyard manure and slurry in crop production to reduce nutrient losses to the environment. This network has now extended its scope to include municipal and industrial wastes since these wastes are increasingly spread on land as a more economical and beneficial method of waste management, but which can also cause pollution if applied without appropriate controls.

NUTRIENT INPUTS TO AGRICULTURE IN EUROPE

The consumption of artificial fertilisers in Europe increased markedly from the 1950s, reaching a peak in the late 1980s and declining in recent years (figure 1) as a result of the development of various control measures, agricultural recession in Central and Eastern Europe, and farmers being made more aware of the environmental impacts of the overuse of fertilisers. There are large variations in fertiliser consumption throughout Europe from about 180 kg N ha^{-1} agricultural land in The Netherlands in 1991 to 30-70 kg N ha^{-1} in Southern Europe. The use of phosphorus fertiliser in Northern and Western Europe has generally declined since 1970 to 20-50 kg P ha^{-1}. In Southern Europe the consumption of P fertiliser has remained relatively stable at a level of 10-30 kg P ha^{-1}.

Estimated amounts of nutrients from livestock wastes produced annually in Europe are given in table 1. The application of livestock manure varies widely between European countries from >200 kg N ha^{-1} and >100 kg P ha^{-1} in The Netherlands to <40 kg N ha^{-1} and <20 kg P ha^{-1} in Southern Europe. From nitrogen balance studies on agricultural land in the EU12 countries, it has been shown that the surplus - the difference between input (fertiliser and manure) and output (crop production) - varies from over 200 kg N $ha^{-1}y^{-1}$ in The Netherlands to less than 10 kg N $ha^{-1}y^{-1}$ in Portugal. The amount of surplus nutrients increases with higher inputs and greater animal densities, with the concomitant increasing risk of greater losses of nitrogen and phosphorus to the environment.

Table 1. Estimated amounts nutrients from some animal wastes produced annually in Europe (tonnes $\times 10^6$)

Nutrient	Cattle	Pigs	Poultry	Total
N	8.83	1.68	0.75	10.67
P_2O_5	2.76	0.78	0.50	3.90
K_2O	8.83	0.70	0.38	9.16

Source : derived from FAO, 1993; Lee and Coulter, 1990.

Animal densities vary widely across Europe, with generally low densities in the Southern European countries to much higher densities in the north (table 2).

Table 2. Livestock density in Europe Union Member States (EU 12) in 1991 (livestock per hectare Utilised Agricultural Area-UAA)

Country	UAA	Livestock per ha UAA		
	($\times 10^6$ ha)	Cattle	Pigs	Poultry
Belgium	1.4	2.23	4.68	25.10
Denmark	2.8	0.80	3.51	5.39
France	30.5	0.69	0.40	6.52
Germany	16.9	1.01	1.54	6.27
Greece	5.7	0.11	0.17	4.70
Ireland	5.7	1.08	0.24	1.58
Italy	17.3	0.47	0.49	27.8
Luxemburg	0.1	1.63	0.51	-
The Netherlands	2.0	2.42	6.80	51.2
Portugal	4.5	0.30	0.56	3.97
Spain	27.1	0.19	0.64	1.88
United Kingdom	18.4	0.63	0.41	6.63
EU 12	128.1	0.61	0.79	6.42

Source : Eurostat, 1993; FAO, 1993.

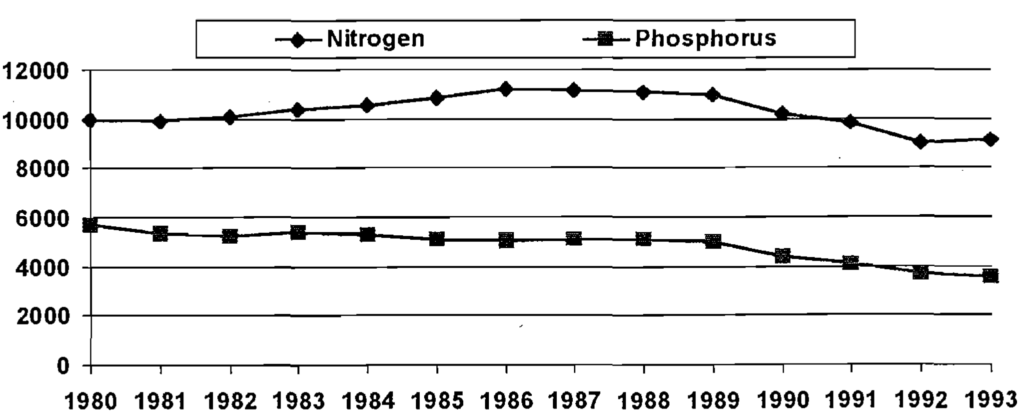

Figure 1. Nitrogen and phosphorus (as P_2O_5) fertiliser consumption in the European Union (EU 15) ('000 t y^{-1})

For pigs, the density in Northern Europe is about ten times greater than that in the southern countries. Thus countries which have high animal densities, particularly The Netherlands, have a national problem of large nutrient surpluses and high emissions to water and air, whereas in countries with lower densities, acute problems of pollution from livestock production tend to be more localised, but nevertheless contribute to diffuse nutrient pollution of rivers, lakes and seas.

Further sources of nutrients available locally to farmers are municipal and industrial wastes, for which landspreading offers a low cost and beneficial method of disposal. Sewage sludge is probably the most widely known of these wastes of which about 2.5 million tonnes of dry solids are applied to land annually within the EU. Sludge contributes only a small amount of the total nutrients applied to agriculture in Europe, about 200,000 t NPK per year or 1% of the amount applied in animal wastes or fertiliser, but its application to land is far more rigorously controlled by legislation than livestock wastes.

MANURIAL VALUE OF LIVESTOCK MANURES

The agronomic value of livestock manures applied to land for crop production depends on the content of nutrients, organic matter and trace elements. The water content of slurry and dirty water may also be of value for irrigation. The major plant nutrients (nitrogen, phosphorus and potassium) are imported to livestock units in animal feed, but animals utilise only a small proportion of these nutrients and the rest is excreted in forms that are usable directly or indirectly by crops. If livestock manure is not utilised, then the farmer is not recovering the full value of the imported feed, and because the nutrients are environmentally active, pollution occurs unless waste is conserved and managed efficiently as a fertiliser.

The nutrient contents of manures are highly variable, depending on species, breed and age of the livestock, diet and type of production and storage systems. The dry matter and nutrient contents can also vary considerably from one batch to another. Typical ranges for nutrient contents of farmyard manures and slurries in Europe are given in table 3.

Table 3. Typical dry matter (%) and nutrient content (kg^{-1}) of farmyard manure and slurry

	DM (%)	Nitrogen (kg N t^{-1})	Phosphorus (kg P_2O_5 t^{-1})	Potassium (kg K_2O t^{-1})
Farmyard manure				
Cattle	20-50	4- 9	1- 8	4-12
Pigs	25	5- 6	1- 6	4
Sheep	35-44	10-14	2- 3	1-10
Slurry				
Cattle	1-18	2-18	1-12	2-15
Pigs	1-18	2-16	1-12	2- 9
Sheep	25-46	14-17	4-21	3-15

In order to make the best use of the nutrients in animal manures for crop production and to avoid pollution, the farmer has to calculate the appropriate application rate based on nutrient content and their plant availability, and the nutrient requirements of the crop to be grown. Ideally, samples of the manure should be analysed prior to landspreading, but few farmers do this. The estimate of nutrient availability is usually as a simple percentage (table 4), although some advisory schemes in Europe also attempt to predict likely losses due to season of application (extent of nitrification and leaching of nitrate) according to soil type, climate, method of application (potential for ammonia volatilisation), crop type, growth period and potential crop yield (nutrient recovery). Increasingly, farmers are required to prepare farm management plans which take into account and balance the nutrients available in livestock wastes and the nutrient demand of crops in order to minimise losses and nutrient pollution.

Table 4. Guide to the nutrients available in animal manure and slurry

Source	Nitrogen	Phosphorus	Potassium
Farmyard manure (kg t^{-1})			
Cattle	1.5	2.0	4.0
Poultry-broiler litter	14.5	13.0	10.5
Poultry-battery deep pit	25.0	17.0	14.0
Undiluted slurry (kg m^{-3})[1]			
Cattle (10% DM)	1.5[2]	1.0	4.5
Pigs (10% DM)	4.0	2.0	2.7

[1] Adjusted values if diluted.
[2] Value should be increased to 2.5 kg m^{-3} where slurry is direct injected or incorporated into soil soon after application

An approach to optimising the nutrient efficiency of livestock wastes adopted by several European countries is based on animal density and the land area available for manure spreading. This is usually based on the fertiliser equivalence of manure from different species in relation to a common basis of animal or dung units per hectare. An example developed for a region of Northern Germany is shown in table 5, in which maximum fertilisation for optimum crop production and minimal pollution potential could be achieved by manure from the equivalent of 2.25 cows, 7 pigs or 250 hens per hectare. This approach forms the basis of control measures in which farmers have to demonstrate that they have access to sufficient land area (their own or neighbours who have a deficit in livestock manure) to spread the manure from their livestock.

Trace elements added to feed for animal nutrition and efficient feed conversion are also essential for plant nutrition, particularly copper and zinc. While a few soils in Europe are deficient in these elements and so may benefit from manure application, the long-term application of livestock wastes to most soils will result in their permanent accumulation in soil, potentially to levels which in the long-term may lead to toxicity to crops or animals. It has been estimated that animal wastes apply 95,500 t Zn y^{-1} and 23,900 t Cu y^{-1} to land in the EU, compared to sewage sludge, which is normally credited as being the largest source of heavy metals, contributes only 2,400 t Zn y^{-1} and 910 t Cu y^{-1}.

Table 5. Maximum fertilisation[1] expressed as: number of animals per ha; dung units[2] per ha; and number of animals per dung unit

Livestock species	Max. No. of animals per ha		Max. dung units per ha		No. of animals per dung unit
	Arable	Grassland	Arable	Grassland	
Cattle					
>2 yr old	2.25	3.0			1.0
1-2 yrs	3.7	5.0	2.25	3.0	1.65
0.5-1 yr	11	15			5.0
<0.5 yr	16	21			7.0
Pigs					
Breeding sow with piglets	7	7	2.25	2.25	3.0
Fattening pig >20 kg	19	19			8.5
Hens					
Laying hen	250	250			110
Pullets	625	625	2.25	2.25	280
Broilers	780	780			350

Source : Vetter et al., 1989.

[1] Maximum fertilisation for the region :
Arable 180 kg N; or 125 P_2O_5; or 225 K_2O.
Grassland 230 kg N; or 125 P_2O_5; or 300 K_2O.

[2] 1 dung unit = 80 kg N or 55 kg P_2O_5 or 100 kg K_2O.

NUTRIENT POLLUTION IN EUROPE

Nitrogen pollution is usually dominated by diffuse sources, particularly from agriculture. In the river systems draining catchments in Central and Western Europe, 46-87% of the nitrogen load to inland waters is related to agriculture. In some catchments, point sources of nitrogen predominantly from municipal wastewater treatment plants also play an important role accounting for 35-43% of the total discharge. Nitrate contamination of surface and groundwaters, resulting from the over-application of livestock wastes and fertilisers, is a major concern in Europe, particularly for potable water sources. Ammonia concentrations in water may also be excessive in areas with high livestock densities.

The most important contributors to pollution by phosphorus are generally point sources, particularly industrial often accounting for more than 50% of P emissions. In relatively sparsely populated areas with relatively low agricultural activity such as Sweden, only about 50% of the P loading is related to human activities, the rest derived from diffuse run-off from undisturbed land. With increasing human activity, P loading from catchments increases. In more densely populated areas, 50-96% of the P load in inland waters may be derived from point sources, while agriculture accounts for 20-40%. If there was no human activity, P levels would be only 5-10% of the current levels. In densely populated catchments, municipal wastewater discharges generally account for the major part of the point source discharge.

An example of a heavily loaded catchment from multiple sources is the Po in Italy which has a high animal density. Table 6 shows the apportionment between different sources of N and P loadings.

Table 6. Apportionment of N and P budget for the Po catchment, Italy

Source	% N budget	% P budget
Domestic	21	44
Industry	10	6
Livestock	23	13
Fertiliser use	27	24
Atmospheric deposition	19	-
Natural P load	-	13

Ammonia emissions to atmosphere in Europe exceed 6 million t y^{-1} and livestock production accounts for about 80% of this. While ammonia can have significant local environmental impacts around livestock units and contribute to odour problems, the major concern is due to its contribution to global atmospheric pollution. Wet and dry deposition of ammonia and ammonium compounds causes soil acidification through nitrification, enhanced leaching of nutrients, and eutrophication. Ammonia has been implicated in forest die-back in Central Europe and damage to oligotrophic ecosystems, particularly loss of biodiversity, through nutrient enrichment.

The major sources of ammonia from livestock production are from animal housing and waste handling, storage and landspreading. Estimates for ammonia emissions in The Netherlands in 1986 showed that more than half of the emissions arose from spreading slurry on the land (table 7), and this was giving rise to annual depositions of 60 kg N ha^{-1}. Legislation was subsequently introduced in The Netherlands to control these problems which required all slurries to be incorporated directly into the soil. Since then, there has been a dramatic increase in many Northern European countries in the use and diversity of soil injection equipment to overcome problems of ammonia and odour emissions.

Table 7. Ammonia emission (t y^{-1}) in The Netherlands in 1986 from livestock

Animal	Source			Total	
	Houses/storage	Grazing	Spreading	Tonnes	%
Cattle	43,000	25,000	76,000	144,000	60
Pigs	26,000	-	43,000	69,000	29
Poultry	17,000	-	11,000	28,000	11
Total	86,000	25,000	130,000	241,000	100

Source : Oudendag and Wijnands, 1989.

STRATEGIC GOALS FOR REDUCING NUTRIENT LOADINGS IN EUROPE

Concern about elevated nutrient concentrations and adverse eutrophication effects in Europe has prompted the introduction of many reduction strategies at international, national and local levels. An important element of the strategies are the goals set, particularly where these are numerical targets, since these allow progress to be measured and the success of the policies adopted to be assessed. These are summarised in table 8.

Table 8. International goals for nutrient reductions

Timing	Agreement	Goal	Strategy
1985-1995	North Sea Conference	Reduce inputs of N and P into areas likely to cause pollution by around 50%	The Ministerial Conferences gave PARCOM agreements international legal status, often guiding the technical development by adding further political direction. In practice, implemented via the recommendations of PARCOM.
1995	North Sea Conference	To reach reduction targets set for 1995 as soon as possible	Suite of instruments to be developed for: • implementation of the Urban Waste Water Treatment and Nitrate Directives. In particular, to apply the measures of sensitive areas under the UWWT and for vulnerable zones under Nitrate Directive for the catchment of the North Sea, and regulations on agricultural policy • balanced fertiliser application • NOx emission reductions • NH_3 emission reductions
1985-1995	PARCOM	Reduce inputs of N and P into areas likely to cause pollution by about 50%	Monitoring programme and to follow changes in pollution load from various sources, to assess the effectiveness of measure to reduce pollution and provide information for assessment of the state of the marine environment. Co-ordinated programmes and measure designed nationally based on recommendations to tackle urban wastewater treatment plants, agriculture, fish farming, industry, combustion plants and vehicles.
1985-1995	HELCOM	50% reduction of the total load to the Baltic Sea by 1995	Similar to PARCOM but for the Baltic Sea.
1995-2005	Strategic Action Plan for Danube River Basin	To reduce the negative impact of activities in the Danube river basin and on the riverine ecosystem and the Black Sea	Recommendations for inclusion in National Action Plans. Maintenance of nutrients at 1995 levels. By 1997: emission limits for fertiliser plants, new industrial enterprises and livestock units; establishment of national load reduction targets for high priority rivers. By 2005, regulations for fertiliser storage, handling and application; environmentally sound agricultural policy reforms; best environmental practice for the use of fertilisers and pesticides; completion of demonstration projects for manure handling, storage and disposal; ban on phosphate detergents; investment in priority WWTP.
1976-	MEDPOL	To take all appropriate measures to prevent, abate and combat pollution of the Mediterranean Sea area	To establish programmes for pollution monitoring in order to assess the levels of pollution and to evaluate the effects of measures taken to reduce pollution. To co-operate in scientific and technological fields to develop new methods of treatment, reduction and elimination of pollutants. Recommendations for sewage discharges, fertiliser use, erosion control, manure spreading, industrial measures and river flow interventions.
1985-1995	Rhine Action Plan	50% reduction of total P and NH_3-N	Point sources, through BAT and tertiary treatment of municipal wastewater. Particular needs to further address agriculture and atmospheric pollution identified.
1996-2006	Strategic Action Plan for Black Sea	To enable the population of the region to enjoy a healthy environment and to attain a biologically diverse Black Sea ecosystem	To reduce nutrient loads in rivers until Black Sea water quality objectives are met; to reduce pollution form point sources by 2006; each Black Sea state to develop National Strategic Plan for point source reduction by 1997; achieve significant reduction of inputs on insufficiently treated sewage from large urban areas by 2006.
1992	Convention on Protection and Use of Transboundary Watercourses and International Lakes	To prevent, control and reduce pollution of water causing or likely to cause transboundary pollution	Limits for wastewater discharges stated in permits based on the Best Available Technology; at least biological treatment or equivalent processes are applied to municipal wastewater, where necessary in a stepwise approach; appropriate measures are taken in order to reduce nutrient inputs from industrial and municipal sources; appropriate measures and Best Environmental Practices are developed and implemented for the reduction of nutrient inputs from diffuse sources, especially from agriculture; co-operation about research and development of effective techniques for the prevention and reduction of transboundary impact.
1985-2000	EU 5th Enviromental Action Programme	NOx emissions 30% reduction; regional targets for NH_3 emissions; zero level of nitrate in groundwater	UWWT Directive; catalytic converters for vehicles; nitrates Directive; proposed inventory of NH_3 emissions, standards for new farms; regulations for set-aside and extensification; Groundwater Action Programme; proposed Water Resources Framework Directive; consideration of proposed Phosphorus Directive.

The Paris and Helsinki Conventions were signed in 1974 to prevent marine pollution from land-based sources in the North Sea and Baltic Sea, and have been administered by PARCOM and HELCOM, respectively. There are initiatives for the Mediterranean Sea (MEDPOL) and the Black Sea and Strategic Action Plans for Danube and Rhine river basins (see table 8). There is also an Environmental Action Programme for Central and Eastern Europe as well as a UN Convention on the Protection and Use of Transboundary Watercourses and International Lakes. A major consideration of all of these measures is the contribution of polluting nutrients from agricultural sources, particularly from intensive livestock production.

The European Commissions Fifth Environmental Action Programme, amongst other targets, aims for zero nitrate levels in groundwater over the period 1985-2000. Progress to these targets has not been good and nitrate levels in groundwater are continuing to rise in some EU Member States, although the Nitrates Directive, if effectively implemented, should help move towards this goal. There are also directives requiring Member States to reduce inputs from point sources, namely the Urban Waste Water Treatment Directive and the Directive on Integrated Pollution Prevention and Control.

Other EC Directives set goals for protecting the environmental quality in the form of standards for specified uses. Thus the Surface Waters, Drinking Water, Bathing Water, and Shellfish Directives contain standards relating to N and P for different water uses, and the Air Framework Directive sets standards for levels of NOx in air. Member States are required to ensure that these environmental quality standards are achieved.

Recent proposals from the EC suggest a more holistic approach for protecting waters. The EC recently prepared an Action Programme for Groundwater Protection and Management which focuses on changing practices in agriculture. The Commission is also working on a Water Resource Framework Directive to protect surface and groundwater quality and quantity in a co-ordinated way and incorporating many of the recommendations of the Groundwater Action Programme. A Directive to reduce phosphate inputs was considered but the controls exerted by the Nitrates Directive are currently deemed adequate.

MEASURES TO REDUCE NUTRIENT INPUTS FROM AGRICULTURE

The nutrient load from agriculture represents a high proportion of the total anthropogenic load of nutrients to water, directly via run-off and leaching, and indirectly via ammonia emissions to air. However, reducing nutrient emissions from agriculture has been a difficult technical and political issue.

Technically, policy development in this area is complicated by:

- the different approaches to reduce nutrient losses from agriculture;
- the different ways of calculating the nutrient load from agriculture;
- the time lag between action and response which is an important problem when assessing the effectiveness of measures and the resulting reductions in nutrient inputs;
- policy measures which, once established, are often difficult to enforce.

Politically, agricultural policies aimed at efficient food production often conflict with environmental concerns. Despite widespread recognition of the need to integrate environmental policies and agricultural policies more closely at all levels, it has been difficult to influence the strong agricultural lobby.

A variety of policies have been used at international, national and regional levels, namely:

- legislation (e.g. establishing protection zones);
- economic instruments (e.g. incentives to adopt alternative farming practices);
- information (e.g. education programmes, codes of good agricultural practice).

Within the EU, key policies are the Common Agricultural Policy (through reform of support mechanisms and the introduction of set-aside) and the Nitrates Directive. Both policies will probably lead, directly or indirectly, to a decreased use of fertilisers and more efficient use of livestock wastes, although proportional reductions in nitrogen losses may not be achieved, due to, for instance, nitrate leaching from non-cultivated soils and the intensification of cultivated soils.

THE NITRATES DIRECTIVE

The objective of the Nitrates Directive (91/676/EEC) is to reduce or prevent the pollution of water by the application and storage of inorganic fertiliser and livestock manure on farmland where the surface or groundwater exceeds or is likely to exceed 50 mg NO_3 l^{-1}. The Directive requires Member States to:

- identify areas vulnerable to pollution by nitrate (NVZs) by December 1993;
- establish action programmes governing the time and rate of fertiliser and manure application, and conditions of storage of manure in NVZs, to be reviewed every four years, initially for the period 1995-99;
- implement monitoring programmes to assess the effectiveness of action programmes;
- establish Codes of Good Agricultural Practice, to be implemented by farmers on a voluntary basis in other areas.

As with most other Directives, the impact of the Nitrates Directive will depend upon how Member States interpret the requirements, particularly vulnerability since this will affect the extent of the territory designated and subject to mandatory requirements (see table 9). In The Netherlands for example, the whole country is designated as NVZ due to the high livestock density and surplus nutrients. In contrast is Ireland which does not intend to designate any NVZs, due to its lower animal density and higher rainfall (dilution). In addition, the success of the Directive will depend on the extent to which farmers co-operate since some of the rules will be difficult to enforce. In any case, the effects of the Directive will not be clear until after implementation in 1999, although the current progress towards implementation is unsatisfactory in most Member States.

The Commission also considered a Directive on phosphorus emissions but has decided that at this is not necessary at the present time.

Table 9. Designation of nitrate vulnerable zones (NVZs)

Country	Area covered
Austria	Whole territory
Denmark	Whole territory
France	46% of agricultural land
Germany	Whole territory
Ireland	No zones
Luxemburg	Whole territory
The Netherlands	Whole territory
Sweden	5 NVZs
United Kingdom	69 NVZs

OTHER EUROPEAN AGREEMENTS AND MEASURES

Other agreements making recommendations for measures to reduce nutrient losses from agriculture are PARCOM (North Sea states), and MEDPOL (Mediterranean area). Although the two regions share a common problem, the approaches recommended are different reflecting regional differences in the source and nature of the main emissions. While both regions seek to control nutrient applications, the emphasis for the Mediterranean area is the control of erosion, but for the North Sea States the key concerns are the highly intensive agricultural systems and high livestock densities. The common element of both programmes is the need for improved information on nutrient levels and inputs to identify the most significant nutrient sources enabling policies appropriate to the local situation to be derived.

In the PARCOM area, the estimated reductions in nitrogen inputs for the period 1985-95 vary between 10% in France and 28% in Sweden, and the reductions in phosphorus inputs vary between 0% in The Netherlands and 40% in Norway. Despite recommendations for a comprehensive suite of measures, the overall reduction targets for PARCOM were not reached and this was attributed to:

- inadequate information and advisory services to farmers;
- ineffective control and enforcement of adopted measures;
- inadequate use and/or lack of financial instruments.

Ammonia emissions, which originate mostly from agriculture, represent about 30-50% of the total emissions of nitrogen to the atmosphere. PARCOM recommendations included measures to reduce ammonia emissions with mixed success. The Netherlands achieved a reduction of 31% over the period 1985-95 through stringent legislation which for instance controlled the method and timing of livestock slurry application to land. Over the same period, the ammonia emissions from Belgium increased by 19%.

The measures recommended by PARCOM included:

- spreading of manure and chemical fertilisers should only take place in such a way and at such time that optimal use of nutrients by plants can be achieved, whilst ensuring minimum losses to the environment;
- harmony should be established between the number of livestock and the area available for safe spreading on manure or the availability of environmentally acceptable alternatives;
- the capacity of manure storage facilities should exceed that required for the storage of manure throughout the longest period during which landspreading of manure is restricted;
- in order to reduce losses of nutrients through erosion and run-off, the application of manure and fertilisers should be more strictly regulated or possibly prohibited, for example in areas in close proximity to watercourses;
- the planting of winter cereals or catch crops should be encouraged;
- measures should be taken to reduce atmospheric emissions of ammonia when handling manure by setting rules for storage (e.g. cover) and for ploughing-in as soon as possible after spreading on arable soil;
- the establishment of mandatory manure and chemical fertiliser handling plans for individual farms should be encouraged.

The following activities were found to be very effective in reducing nutrient inputs:

- spreading manure and sludge to match nutrient requirements on a farm basis, taking account of ground conditions;
- storing manure and silage effluent in impermeable storage facilities, with requirements for storage capacity and covering;
- fertiliser advice programmes.

Some measures were found to be not very effective, these included:

- incorporation of straw into soil;
- organic farming;
- treatment of stored manure.

Individual countries in Europe have considered, tested and adopted a number of national and regional measures to reduce nutrient losses from agriculture, focusing mostly on emissions from intensive livestock production. Many countries in Northern Europe with intensive agriculture have now adopted complex strategies for controlling nutrient inputs from agriculture and have had some success in reducing emissions. Most of these measures are similar to the PARCOM recommendations, but vary according to local conditions.

In Central and Eastern Europe, the economic reforms and recession have meant that there has been a shift from large farming units to smaller private enterprises with reductions in fertiliser use and in livestock production. Unlike Western Europe which has high animal densities due to the large number of small but intensive livestock units, many of the Central and Eastern countries had a number of very large livestock units, some over 100,000 pigs. These caused considerable chronic point source pollution to many rivers in Europe due to a lack of means of treating and landspreading the wastes. Most of these units have now gone or their wastes are now being managed more appropriately as these countries bring their environmental legislation in line with EU environmental standards.

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